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Clinical study

The impact of time, legislation, and geography on the epidemiology of traumatic brain injury

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Abstract

In 1991, a population-based epidemiologic traumatic brain injury (TBI) study was done in urban and rural areas of Taiwan; this was 5 years before the helmet use law was passed and 8 years before the drink driving law was passed. In order to evaluate the impact of three major determinants (time, geography, and legislation) on the epidemiology of TBI, we conducted a prospective study in 2001 and used the 1991 data to examine the differences in TBI distribution in urban and rural Taiwan a decade after these laws were passed. In 2001, 5754 TBI cases were collected from the urban area of Taipei City, and 1474 TBI cases were collected from the rural area of Hualien County. The TBI incidence rate in Taipei City in 2001 was estimated to be 218/100,000 population (285/100,000 for males and 152/100,000 for females). When compared to the 1991 data, the incidence rate in 2001 had increased by 20%. The TBI incidence rate in Hualien County in 2001 was estimated to be 417/100,000 population (516/100,000 for males and 306/100,000 for females); this was a 37% increase over the 1991 data. Our study found that the distribution of causes and age distribution had shifted significantly over the 10-year period. In 2001, the age group with the highest incidence was 20–29 years, while in 1991 it had been the over 70 years age group. While traffic-related TBI had decreased, falls and assaults had increased in 2001. We also found that legislation, such as the helmet law, affects TBI distribution by decreasing the traffic-related TBI rate, decreasing the admission severity of TBI, and reducing TBI-related mortality. Finally, geography plays a crucial role in the outcome of TBI; over the 10 year period, Taipei had an increase in moderately severe outcomes, while Hualien had an increase in more severe outcomes. Comparative studies of TBI in urban and rural areas have shown that time, legislation, and geography are crucial determinants of TBI epidemiology. Although time and legal interventions seem to have more of an impact, geography does affect TBI outcomes.

Keywords: Traumatic head injury; Rural and urban; Follow up study

1. Introduction

In both developing and developed countries, traumatic brain injury (TBI) is a difficult clinical problem and presents complex social issues. Overall, TBI incidence is reported to be about 100 to over 3000 per 100 000 population.[1–4] Treatments are costly, the death rate is high, and survivors of moderate or severe TBI often require extensive care and may never return to full employment.

In Taiwan, the motorcycle is the most common means of transportation; industrialization has resulted in a rapid increase in the use of motorcycles (9% growth in 1995).[5] Both international and national epidemiologic surveys have found that most fatal motorcycle-related injuries

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involved the head.[6–9] Given this information, compared to other nations, Taiwan should have a much higher TBI incidence and mortality rate. Thus, there is a need to study TBI epidemiology in Taiwan. The TBI mortality rate is 21/100 000 population in Taiwan, 6.6/100 000 in Japan, and 5.2/100 000 in Singapore.[10] Taiwanese health officials have successfully promoted a number of new public policies to reduce TBI casualties; these have included a helmet use law in 1997 and a drink driving law in 1999. Initial reports that the death rate was reduced by 33% were encouraging, but no follow-up was undertaken.[5]

Most TBI research has analyzed the overall population and the effect of new public policies; seldom is the effect of environmental factors studied, such as geographical remoteness.[11–13] We could not identify any studies that continuously followed up the change of TBI distribution over time, especially in remote areas, after the introduction of new policies.

A population-based epidemiologic TBI study in urban and rural areas was carried out in Taiwan in 1991,[13] half a decade before the helmet use law was introduced. To study the effect of time, geography and pertinent new legislation, we conducted a prospective study in 2001, using the 1991 model as a comparison to determine TBI distributions in urban and rural Taiwan a decade after the relevant laws were implemented.

2. Materials and methods

Taipei City has the only mass rapid transportation system in Taiwan; it has a total population of 2 633 802, and 59% (1 024 154) of the motor vehicles in 2001 were motorcycles.[14] In contrast, Hualien County is the largest county in Taiwan with a total land area of 4628 square kilometers and a population of only 353 139. Of 324 087 motor vehicles in 2001, 220 769 (68%) were motorcycles; thus, motorcycles provide the major means of transportation.[14] Hualien County is a typical rural area in Taiwan that is isolated from urban areas by mountains; thus, it was chosen for inclusion in the 1991 study.

TBI-related hospitalization did not change appreciably in both areas between 1991 and 2001. In Taipei City, most TBI patients are treated in large teaching medical centers, although some were treated in small and medium-sized hospitals before being transferred to larger centers. In Hualien County, Tzu-Chi remains the major hospital handling most TBI patients. Three hospitals (Men-Nong Hospital, Hualien County Provincial Hospital, and 805 Army Hospital) also receive TBI patients. The TBI registry data in both areas were collected prospectively from the large medical centers and the medium-sized to small medical facilities; there were 22 hospitals in Taipei City and four in Hualien County in 1991 and 2001.

A few differences in pre-hospital care between 1991 and 2001 need to be addressed. Over the 10-year period, there was a major improvement in the Emergency Medical Service (EMS) that tremendously decreased out-of-hospital deaths nationwide. EMS staff were also strongly encouraged that all out-of-hospital deaths be transferred to major health facilities so that accurate death certificate records could be maintained. Out-of-hospital deaths were not included in the 2001 study. Since the EMS system existed in both the rural and urban areas throughout the study period, pre-hospital care was assumed to be basically the same. However, the actual quality control of EMS in terms of equipment and personnel was assumed to be different due to geographic differences, including government budget support, cultural variations, and other factors.

Critical care also improved over the 10-year period, both in terms of equipment and personnel. According to the Department of Health, Taipei City had a total of 673 ICU beds in 1991, and a total of 1191 ICU beds in 2001. In Hualien County, the number of ICU beds also increased (from 44 in 1992 to 129 in 2001).[15] The Taiwan Society of Critical Care Medicine was established in 1998, and by 2001, all major health facilities were required to have at least one certified intensive care doctor in the ICU, without regard to geographic location, compared to none in 1991.[16] On the other hand, neurosurgeons were available in both rural and urban Taiwan in both 1991 and 2001.

In order to maintain consistency, TBI was coded in 2001 according to the same definition (ICD-9) as was used in 1991, despite the availability of the new ICD version.

The classification by Kraus et al.[17] based on the Glasgow Coma Scale,[18] was adapted for classifying the severity of TBI on admission. The Glasgow Outcome Scale[19] was used to categorize the outcome on discharge.

Case-ascertainment involved:

- Careful review of medical records and related investigations.
- Confirming TBI-related death based on the death certificate.

Data pertaining to the identification of possible causative factors implicated in traffic accident-related injuries, such as type of vehicle involved, time, place of occurrence, use of helmet, result of blood alcohol tests, and cause of accident, were obtained from hospital records and reports.

The medical records of the possible cases that were identified based on the ICD items and the case ascertainment criteria mentioned above were collected. Twenty TBI cases were selected randomly from each hospital and were submitted to the authors for review and evaluation of the completeness of information that was initially collected by either neurosurgical residents or nurses.

Data were assessed using SPSS software, and the gender incidence rate was age-adjusted. The age-adjusted rates were considered based on the fact that a different age distribution exists between the genders, and we wished to control for this in our analysis. On the other hand, we did not adjust for age for the overall population-based incidence, because a different age distribution during various

time periods is considered to be one of the many changes that occur over time.

3. Results

In 2001, 5754 TBI cases were identified in Taipei City; the population-based incidence was 218/100 000, with an age-adjusted incidence of 285/100 000 for males and 152/100 000 for females. In 1991 the population-based incidence was 182/100 000, with an age-adjusted incidence of 250/100 000 for males and 113/100 000 for females. Thus, over the decade, the total population-based incidence increased by 20%; the age-adjusted male incidence increased by 14% and the age-adjusted female incidence increased by 35%.

In Hualien County, 1474 TBI cases were collected in 2001; the population-based incidence was 417/100 000, with an age-adjusted incidence of 516/100 000 for males and 306/100 000 for females. In 1991, the population-based incidence was 304/100 000, with an age-adjusted incidence of 370/100 000 for males and 226/100 000 for females. Thus, Hualien County had a greater increase in the total incidence (37%), with an approximately equally distributed increase for men (40%) and women (35%).

In both 1991 and 2001, men were predominantly affected in a ratio of about 2 : 1. In 2001, the age group with the highest incidence was the 20–29 years group, while it had been the over 70 years group in 1991. Among the causes of TBI, traffic accidents were the leading cause in both 1991 and 2001, although traffic accidents had decreased in 2001, while falls and assaults had increased in both areas (Table 1). Although the population-based incidence of TBI increased in 2001, the admission severity had improved, with a lower rate of severe and moderate cases. Table 2 summarizes the TBI severity in both areas in 1991 and 2001.

The comparison of peak age by cause in both areas in 1991 and 2001 is shown in Table 3. For TBI caused by traffic accidents, the peak age declined from over 70 years of age in 1991 to 20–29 years in 2001. There was no change in age distribution for falls. However, for assaults, not only did they account for a greater percentage of TBI, but the peak age was younger in 2001. In both areas, motorcycles continued to be the predominant vehicles involved in traffic-related TBI, although there was a slight change in percentage (Table 4); motorcycles remained the major form of transportation in 2001.

With respect to length of ICU and hospital stay for TBI patients, there was a larger decline in both hospital and ICU stays in Taipei City (hospital stays dropped from 11 days in 1991 to 7.3 days in 2001; ICU stays dropped from 1.7 days in 1991 to 1.2 days in 2001) than in Hualien County (hospital stays dropped from 8 days in 1991 to 7.3 days in 2001; ICU stays dropped from 1.2 days in

Table 1
Causes of traumatic brain injury in Taipei and Hualien County in 1991 and 2001

	Taipei[a]				Hualien[b]			
	1991		2001		1991		2001	
Cause	*n*	%	*n*	%	*n*	%	*n*	%
Traffic accidents	3250	66	2588	45	857	80	808	55
Fall	1104	22	1,966	34	133	13	405	28
Assaults	373	7	632	11	42	4	190	13
Others	228	5	568	10	37	3	71	4

[a] Taipei: χ^2: 472.1; p-value < 0.001.
[b] Hualien: χ^2: 184.2; p-value < 0.001.

Table 2
Severity of traumatic brain injury in Taipei and Hualien County in 1991 and 2001

	Taipei[a]				Hualien[b]			
	1991		2001		1991		2001	
Severity	*n*	%	*N*	%	*n*	%	*N*	%
Mild	3651	78	5033	87	629	77	1219	83
Moderate	452	10	339	6	73	9	130	9
Severe	576	12	382	7	115	14	125	8

[a] Taipei: χ^2, 166.4; p-value < 0.001.
[b] Hualien: χ^2, 17.8; p-value < 0.001.

Table 3
Peak of age (years) distribution of the three major causes of traumatic brain injury in Taiwan

		Taipei		Hualien	
		1991	2001	1991	2001
Traffic accident	Peak 1	Above 70	20–29	Above 70	20–29
	Peak 2	20–29	30–39	40–47	40–49
Fall	Peak 1	Above 70	Above 70	50–59	Above 70
	Peak 2	Under 10	Under 10	–	40–49
Assault	Peak	40–49	20–29	40–49	20–29

Table 4
Motor vehicles used in traffic-related traumatic brain injury

	Taipei[a]				Hualien[b]			
	1991		2001		1991		2001	
Cause	*n*	%	*n*	%	*n*	%	*n*	%
Automobile	309	9	167	7	127	15	87	11
Motorcycle	2,253	69	1849	71	627	73	601	74
Bicycle	88	3	133	5	43	5	45	6
Pedestrian	580	18	313	12	52	6	63	8
Others	20	1	126	5	8	1	12	1

[a] Taipei: χ^2: 71.1; p-value < 0.001.
[b] Hualien: χ^2: 7.4; p-value < 0.5.

Table 5
Percentile of other factors contributing to traumatic brain injury incidence

	Taipei		Hualien	
	1991	2001	1991	2001
Alcohol intake prior to the accident	10	14.8	24	41.8
Drug abuse	0.2	0.5	0	2.5
Helmet use rate	15	87.2	7	96.5

Table 6
Outcomes comparison

	Taipei[a]				Hualien[b]			
	1991		2001		1991		2001	
GOS	*n*	%	*n*	%	*n*	%	*n*	%
In-hospital death	252	5.4	152	2.6	55	6.7	65	4.4
Vegetative	34	0.7	20	0.3	3	0.4	12	0.8
Severe disability	166	3.6	246	4.3	15	1.8	130	8.8
Moderate disability	169	3.6	345	6.0	27	3.3	44	3.0
Good recovery	4058	86.7	4991	86.7	717	87.8	1223	83.0

GOS, Glasgow Outcome Scale.
[a] Taipei: χ^2: 90.6; *p*-value < 0.001.
[b] Hualien: χ^2: 47.7; *p*-value < 0.001.

1991 to 1.1 days in 2001). In Hualien County, over the decade, the rate of helmet use increased dramatically, while alcohol intake also increased significantly. Table 5 shows helmet use, alcohol intake, and the drug abuse rate. Mortality was the highest among the elderly (⩾70 years) in both areas during both years; the outcomes based on the Glasgow Outcome Scale are summarized in Table 6.

4. Discussion

In 2001, the population-based incidence of TBI in rural Hualien County was nearly double that of urban Taipei City. The rural urban incidence ratio was much higher than that reported in South Australia,[11] where the incidence of hospitalized TBI was only 33% higher in the rural area than in the urban area. Jagger et al. reported the crude incidence of hospitalized TBI in rural north central Virginia to be 175/100 000;[20] in 2001, Hualien County had a much higher incidence of 417/100 000. Given that traffic-related TBI is much higher in Taiwan than in other countries,[21] the higher TBI incidence in Hualien County may be partially explained by the greater percentage of motorcycle use (68%);[14] the high rate of motorcycle use in Hualien County may be due to the lack of alternative transportation systems, such as the mass rapid transportation system of Taipei City.

There has been a decrease in the rate of traffic-related TBI over the decade and an increase in falls in both Taipei City (34%) and Hualien County (28%). Several possibilities may explain these findings. The drop in traffic-related TBI may be due to the efficacy of the legislative initiatives, while the increasing elderly population, which has increased by 50% over the 10-year period (from 1 302 536 in 1991 to 1 947 330 in 2001)[22] may contribute to the higher fall-related TBI rate. Assault-related TBI also increased during this period, possibly due to cultural changes.

The findings of this study are similar to those reported in the US, Canada and South Australia, all of which found a relatively high rate of TBI due to falls (20–35%).[21] However, assault-related TBI increased more significantly over the decade in rural Hualien County (from 4% in 1991 to 13% in 2001) than in urban Taipei. This is an unexpected finding, since most international studies have shown a higher rate of interpersonal violence in urban areas, such as inner city Chicago (40%) and Bronx County (34%), than in less populated areas, such as north central Virginia (11%) and Rhode Island (9%).[21] Thus, the higher increase of assault-related TBI observed in rural Taiwan in 2001 deserves further study.

Of the 7228 TBI cases in 2001, 65% were males, which is similar to the percentage of males (for example, 67% in Colorado, USA) reported in Western studies.[23] Over the decade, the age-adjusted incidence increased by 14% for males and 35% for females in Taipei City, and by 40% for males and 35% for females in Hualien County. Compared to Hualien County, Taipei City females had a relatively more dramatic increase in the incidence of TBI over the decade compared to males. Based on a report from a department of the Ministry of Transportation and Communication in Taiwan, motorcycle use among women has

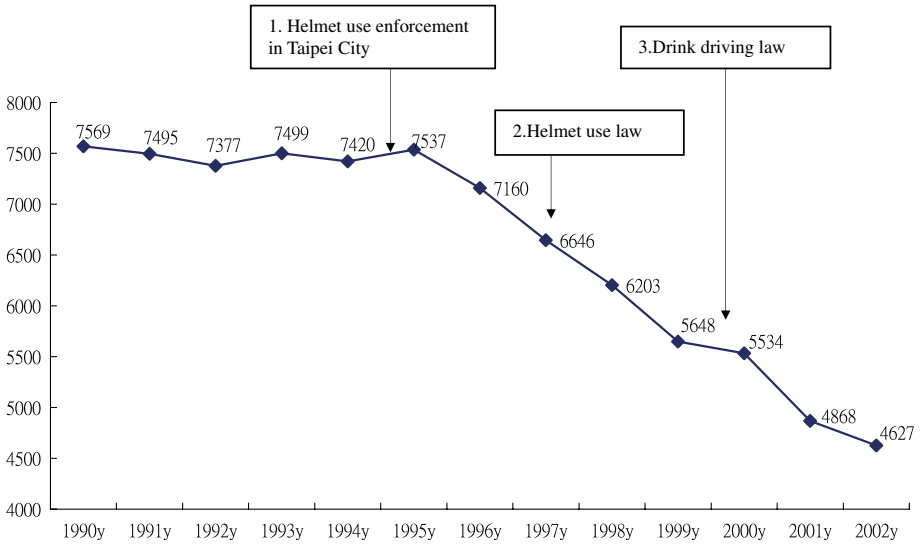

Fig. 1. Trend in traffic injury death in Taiwan, 1990–2002.

increased significantly in urban areas compared to motorcycle use among men.[24] Since motorcycle use contributes to the majority of traffic-related TBI in Taiwan, this finding may partially explain the higher increase in incidence of TBI among urban women.

Our study also indicates that the age distribution of TBI has changed over time. In the 1991 study, the highest incidence of TBI was among those aged 70 years or older; this was significantly different from Western studies in which the 20–29 year age group had the highest incidence of TBI.[13] However, by 2001, the highest incidence of TBI shifted to the 20–29 year age group in Taiwan, which may reflect the transformation of Taiwanese society into a more Western-like environment. The peak age of traffic- and assault-related TBI dropped from the 70 years and older group and the 40–49 year-old group, respectively, to the 20–29 year-old group in both areas, which is also similar to that reported in a Western study.[21] It is interesting to note that assault cases not only increased in number, but their peak age dropped to a much younger age group.

Over the 10 years, the severity of TBI (Table 2) decreased dramatically; the percentage of cases with severe injuries on admission, based on the GCS, dropped in both areas ($p < 0.001$). The motorcycle has been the major means of transportation in Taiwan, and the majority of fatal motorcycle injuries involve the head. The improvement in the severity score on admission may be partially due to the drop in the rate of traffic-related TBI (Table 1) and could be the result of the new laws. As shown in Fig. 1, according to the annual statistical report of the Department of Health, traffic-related deaths declined rapidly since 1997 after the implementation of the helmet use law (from 7160 in 1996 to 4868 in 2001).[25] Table 5 shows that there was a tremendous increase in the helmet use rate over the 10 years both in Taipei City and Hualien County. However, despite the l999 drink driving law, our study surprisingly showed that the alcohol drinking rate increased significantly from 1991 to 2001 in both areas, more especially in rural Hualien County (from 24% to 42%). The reason is still unclear; however, since our data are based on hospital records, the increasing use of blood alcohol testing in hospitals could probably explain this unusual finding.

The length of stay of TBI patients decreased over the decade, as shown by the drop in both the ICU stay and hospital stay in Taipei City and Hualien County. In both areas, the outcome also improved, as the mortality decreased (Table 6). These findings may partially be due to the improvement in severity on admission or to improved quality of care, such as the availability of intensive care staff in 2001 and the increase in the number of ICU beds, which doubled in Taipei City and tripled in Hualien County. It is interesting to note that geographic difference did affect the outcomes, but not the causes of TBI, the age distribution, or other variables. In Taipei City, the moderate disability rate increased over the decade; on the other hand, Hualien had a higher severe disability rate in 2001 despite the greater increase in the number of ICU beds in Hualien County. However, many other geographic differences other than the quality of care, such as budget support from National Health Insurance and quality control of the EMS, may be operative and may have affected the length of stay and outcomes; these potential differences deserve further study. Due to the limited scope of our study, we were unable to explore these issues, and interestingly, there have been no previously published papers that have dealt with these issues.

In summary, this comparative study of TBI in urban and rural areas found that time, legislation and geography are all crucial determinants of the epidemiology of TBI. Although time and legal initiatives appear to have more impact on the various epidemiological distributions, the outcome of TBI does vary geographically. Therefore, a follow-up study dealing with the effects of time and legislation in remote areas is warranted.

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