

Original article

## **Injury severity of the bicyclists involved in traffic accident: for the prevention of fatal bicycle injuries**

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**Abstract**

**Purpose:** To clarify the relationship between the outcome of the patients or the type of offended vehicles and the injury severity in bicyclists, retrospective analysis was performed. Furthermore, the study propose a effective measure to prevent fatal bicycle injuries.

**Methods:** Hospital records were reviewed for all patients who had rode a bicycle and involved in a traffic accident, then transferred to the Emergency Room (ER) of Dokkyo medical University Koshigaya Hospital from 2007 through 2010. Outcome of the patient, mechanism of injury and injury severity of each patient were examined.

**Results:** The 115 patients with a mean age of  $47.1 \pm 27.4$  years were included in the study. Average Injury Severity Score (ISS) of the patients was 23.9 with average maximum Abbreviated Injury Scale (MAIS) scores of 3.7. ISS, MAIS, head AIS and chest AIS were well correlated to the outcome of the patients. Head AIS is extremely and significantly higher value in death cases (mean 4.4). However, ISS, MAIS and head AIS score did not differ significantly among the type of offended vehicles. Mean head AISs were high as 2.4 to 2.9 in any offended vehicles.

**Conclusions:** This is the useful information for trauma surgeon that high occurrence of head injuries must be suspected for the bicyclists involved in any type of vehicle accidents. Effective intervention, helmet use for all bicyclists, is recommended to bicyclist's fatalities.

**KEY WORDS:** Bicyclist, Head injury, Traffic collision, Injury Severity, Safety

## Introduction

Road traffic injury is a major public health issue worldwide. According to the World Health Organization, 1.3 million people die annually in road collisions worldwide [1]. The year 2011 was marked by the launch of the UN Decade of Action for Road safety [2]. This is a very important step towards making road safety a priority in all countries and to reducing the number of persons killed and seriously injured every day on our roads. An overwhelming majority of the traffic deaths and injuries involve vulnerable road users, such as pedestrians and bicyclists. In Japan, the number of fatal and injured bicyclists in 2011 was 143738, accounting for 16.7% of all injured or died persons in traffic, increased from 10 years ago (14.9% in 2001) [3]. Also, the rate of collision involving bicyclists of all road traffic collision was 20.8%, larger than that in 2001 (18.5%). Based on this status, Japanese Government emphasized a bicyclist safety as one of the three strategic objections in the 9<sup>th</sup> fundamental Traffic Safety Program which set up the road safety strategies for 2011-2020 in Japan.

Bicycle riding is a popular activity as both recreation and transference. Bicycle-related injuries are responsible for frequent visits to emergency departments. Therefore, understanding the pattern and severity of bicyclist injuries is essential to the trauma surgeons for prompt initial assessment. Although the traffic injury severity of vehicle passengers and pedestrians has been examined, to our knowledge, few reports in the English-language literature have examined the relation between the outcome of the patients or the type of offended vehicles and the injury severity in bicyclists [4-6].

We retrospectively analyzed bicyclists' injuries with the outcome and background of the accidents. Our study can provide useful information for trauma surgeons and propose a effective intervention for the bicyclist safety which is a high priority public health issue.

## Materials and Methods

### Data collection

Hospital records were reviewed for all patients who had rode a bicycle and involved in a traffic accident, then transferred to the Emergency Room (ER) of Dokkyo medical University Koshigaya Hospital from 2007 through 2010. This hospital located in suburban area, Koshigaya city, Saitama Prefecture, serves as a high care ER which covers the 1.6 million persons living in 12 surrounding cities. The ER receives about 700 patients annually and of them 200 are trauma patients. About 100 patients visited due to road traffic accidents annually. The following data were obtained from each record in addition to the general information (age gender, and so on).

#### 1) Outcome of the patient

We investigated the outcome of the patient and classified as death, transferred or discharge. The “Death” also includes the patient who was in cardiopulmonary arrest on arrival at the hospital and subsequently pronounced dead. When the patient’s general condition improved but needed further medical care at the medical facilities, he was transferred to the other facilities from Dokkyo Medical University Koshigaya Hospital. For this case, the outcome is defined as “Transferred”. When the patient discharged from the hospital to his home and needed not continued medical care at the medical facilities, the outcome was defined as “Discharge”.

#### 2) Mechanisms of injury

We surveyed how and when the accident occurred. Furthermore, we surveyed the collided object at the accident. Then, we classified them as heavy vehicle, passenger vehicle, motor cycle, bicycle or the road. When the patient had lost control of bicycle driving and directly attacked to the road surface without contact to the other vehicles, collided object was defined as the “road”.

### 3) Injury severity

The region injured and the type of injury were examined. Then the injury severity was assessed for all patients. The Injury Severity Score (ISS) and the 1990 revision of the Abbreviated Injury Scale (AIS) were calculated for each patient [7, 8]. The AIS is used to categorize injury type and severity in each body region on a scale from 1 (minor) to 6 (clinically untreatable). The ISS, which is useful for assessing the severity of multiple injuries, is the sum of the squares of the highest AIS score in each of the three most severely injured body regions. The maximum AIS (MAIS) score denotes the most severe injury in each of six body regions.

Collisions were excluded from analysis if information regarding the type of vehicle, collided object at the accident, or detailed medical data were missing.

### **Statistical analysis**

In comparing the AIS or ISS values between three groups, the Kruskal-Wallis test was used. Differences with a *P* value of less than 0.05 were considered significant.

## Results

### Overview

A total of 115 patients (58 male and 57 female) were reviewed for this study. Ages ranged from 7 to 84, with a mean of  $47.1 \pm 27.4$ . The largest numbers of patients were aged 31 to 40 years and 41 to 50 years. All patients had not worn helmet or other protective devices. Regarding the offended vehicle of the accidents, passenger vehicle was the most common offenders (59 cases), followed by heavy vehicles (36 cases) and two wheeled vehicles (motorcycle and bicycle, 9 cases). Eleven patients had fallen down to the road with themselves. At arrival of the hospital, @ were in cardiopulmonary arrest and then pronounced dead. Another @ patients were finally died in spite of treatment (summary, 33 patient died). Forty patients were transferred to the other facilities after the medical care for the acute phase. Forty-two patients discharged after the treatment of the hospital.

### Injury severity

The ISSs in all patients ranged from 1 to 75 (average,  $23.9 \pm 22.6$ ). Forty percent of patients had an ISS of less than 10, and more than a half of patients had an ISS of less than 20 (Fig. 1). Most patients had severely injured body regions with average MAIS of  $3.7 \pm 1.5$ . In comparing injured body regions, the head had the highest AIS score ( $2.4 \pm 1.3$ ), followed by the chest ( $1.2 \pm 1.8$ ), extremities ( $1.1 \pm 1.3$ ), face ( $0.5 \pm 1.1$ ), abdomen ( $0.2 \pm 0.8$ ) and spine ( $0.2 \pm 0.8$ ).

### Difference of Injury severity by the outcome of the patient

We compared the severity of injuries by the outcome of the patient (death, transferred, or discharge). First, we compared the ISS and MAIS scores between the three groups (Fig. 2). The mean ISS and MAIS scores of the death group were  $49.6 \pm 25.1$  and  $5.2 \pm 0.9$ , respectively, those of transferred group were  $17.0 \pm 10.9$  and  $3.5 \pm 1.2$ , respectively, and those of discharge group were  $10.4 \pm 7.3$  and  $2.8 \pm 1.1$ , respectively. The overall injury

severity was well correlated to the outcome of the patient. The ISS and MAIS of death group were significantly higher than those of other groups ( $p < 0.01$ ).

We then compared the AIS scores of any body region between the three groups (Fig. 3). Because the mean AIS score of all cases were higher, the values exceeded 1.0, in the head, chest, extremities, than those of other body regions, these three body regions were selected for comparison. The AIS score of the head and chest were well correlated to the outcome of the patients (head AIS:  $4.4 \pm 2.0$ ,  $2.2 \pm 2.1$ ,  $1.2 \pm 1.7$ , respectively; chest AIS:  $2.2 \pm 2.3$ ,  $0.9 \pm 1.4$ ,  $0.6 \pm 1.2$ , respectively). In death group, the head and chest AISs were significantly higher than those of other two groups ( $p < 0.01$ ). Furthermore, we examined the rate of body region with MAIS and compare them among three groups. The rates in which MAIS was shown in the head region were 78.8% in death, 52.5% in transferred, and 31.7% in discharge group. Because severity of the head injuries was the most contributing factor for the outcome of the patients, following analysis focused on the head injury severity.

### **Difference of head injury severity by the type of offended vehicle**

Except for the patients who had not collided to the other vehicles, ISS, MAIS and AIS score of the head were compared between 3 groups (heavy vehicle, passenger vehicle, two-wheeled vehicle). The rates in which the MAIS score was shown in the head region were compared. As result, no significant differences of injury severity were found between 3 groups (Table 1). More than a half of the patients in each group, MAIS was shown in the head. Furthermore, we compared the prevalence of having skull fracture and brain contusion. Skull fracture and brain contusion were shown in 41.7% and 41.7 % of the patients collided to the heavy vehicle respectively, 27.1% and 33.9%, in those to the passenger vehicle respectively, 33.3% and 66.7%, in those to the two-wheeled vehicle respectively.

## Discussion

Recently in the world, reduction of CO<sub>2</sub> emission is widely appealed. Furthermore, in Japan the bicycle has been more popular means of transport since the terrible earthquake which hit the eastern part of Japan in March 2011, and has become a real alternative to vehicles for commuting. Although 20.8% of all traffic accidents involved a bicycle in 2011, this share may rise, given the increasing popularity of riding [3]. Previously, the changes of fatalities and injured persons were estimated when 10% of the short car trip (less than 7.5km) was substituted by bicycle trips [9]. The result suggested that increase of 1% of cyclist fatalities and of 3.5% of number of inpatients was expected. Therefore, bicyclists with fatal or severe injuries may be increased as it stands in Japan.

Our result suggested that about one-third of the bicyclists visited to the ER had become died. Because this ER is located in suburban district in Saitama prefecture, this trend is considered as representative of Japan. In death cases, mean ISS is extremely high as 49.6 with mean MAIS score of 5.2. Bicyclist is at great risk of injury than is an car occupant because the bicyclist's body is fully exposed without the protection of the car's frame and body. Therefore, bicyclists often sustain severe injuries in multiple anatomic body regions. These findings are similar to those of previous reports of autopsied persons dying in traffic accidents [10]. To prevent the death, the authors propose from present findings that decreasing the mean ISS of less than 17 with mean MAIS of less than 3.5.

The characteristics of bicyclist that suffering from multiple injuries was reflected by the values of mean AIS score. Mean AIS scores were higher in three body regions, the head (2.4), chest (1.2) and extremities (1.1). Our result is well accordance with the previously understood trend that pedestrian and bicyclists suffer from higher rate of head injuries than vehicle occupants [11]. Also, the result is compatible with the cyclist's accident database that head is the frequent injured body region in Japan and European countries [12-14]. From the biomechanical perspective, most common impact configuration for bicyclists is



considered as an impact from the side by the front of a moving vehicle [15]. Subsequently, the head directly attacked to the front structure of offended vehicle: the head attack to the windshield or roof of a sedan vehicle; the head attack to the ground by the forward projection following to the primary attack with the vehicle. At the collision, because an offended vehicle was heavy object with high velocity, bicyclists received high energy. Therefore, the head suffered from large external force and lead to high prevalence of skull fracture or brain contusion. Mean AIS scores of death cases, mean head AIS score was especially high as 4.4. AIS score is oriented towards the survivability of an injury and correlates well with the probability of death at severe or life threatening levels of AIS of 3 or more [8]. Therefore, decreasing the AIS score to less than 3 is required for preventing deaths. Even in death cases, the patients suffered from chest injuries with mean chest AIS of 2.2. However, AIS 2 revealed the moderate injury and that shows the enough possibility to save lives. Furthermore, in most of death cases, MAIS was shown in the head (78.8%). Therefore, to save the lives of bicyclists, prevention of head injuries or decrease the severity of head injuries is the priority.

In the current study, injury severity was compared between the type of offended vehicles. It is interesting that scores of MAIS and the head AIS showed no significant differences between the vehicle type. Furthermore, in each vehicle group MAIS of the patient was shown in the head region in more than a half of cases. This is the useful information for trauma surgeon that high occurrence of head injuries must be suspected for the bicyclists involved in any type of vehicle accidents.

For the prevention of severe head injuries, bicycle helmet is most simple and useful tool. The fact that wearing bicycle helmet can reduce fatal and non-fatal head and brain injuries seem to be evidently and confirmed by a multitude of recent studies. A recent meta-analysis of bicycle helmet efficacy revealed that when a helmet is worn, 42% of reduction of head injuries can be obtained after adjusting for publication bias [16, 17]. Furthermore, 17% of reduction for facial injuries and 15% of reduction for head, face or

neck injuries can be obtained. Generally, bicycle helmet clearly reduces the risk of head injuries.

Australia was the first country to introduce compulsory bicycle helmet legislation in the early 1990s [17]. Then, some countries, New Zealand, Finland, some jurisdictions in the United States, and so on, were followed. The legislation has led to increased helmet wearing rates and marked reductions in bicyclist's fatalities and head injuries [18]. However, in Japan, until 2008, no legislation of wearing helmet for bicyclists had been regulated. At June 2008, the Road Traffic Act was revised and that bicyclists less than 13 years-old were legally required to wear a helmet. Because this rule is decided as the effort for the parents without penalties, most of children have not corresponded to this rule. In our study, all 11 children less than 13 years-old did not wear helmet. Therefore, we strongly hope the increase of compliance of wearing a helmet by cooperation with schools and local communities.

In addition, the revised Japan Road Traffic Act restricted in 2008 that the bicyclists should use roadway with the exceptional usage of sideway. This regulation was owing to the fact that the great increase of number of accidents of pedestrian and bicycle contacts on sideway from 633 cases in 1997 to 2856 cases in 2007 [3]. Although this rule is valuable for the pedestrian protection, more bicyclists are enhanced to contact with the vehicles at roadway. Consequently, among bicycle related accidents, the rate of contact with four or two-wheeled vehicles was increased from 89.5% in 2007 to 90.4% in 2011 [3]. We worry about the increase of the chance of bicyclists to be involved in vehicle accidents. Therefore, for the prevention of fatal bicycle injuries, all bicyclists are recommended to wear a helmet. To enhance the helmet usage, comprehensive regulation might be promoted.

Present result was based on the retrospective observation of ER in a suburban area in Japan. To our knowledge, there have been few reports concerning the injury severity of bicyclists in Japan. Along with the increasing rate of bicyclists among injured persons of traffic, the increasing popularity of bicycle riding and the increasing the road way users in

bicyclists, our result suggests the need for prevention of fatal bicyclist's injuries especially for head injuries. Effective intervention might be needed as soon as possible.

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## Figure legends

Fig. 1.

Distribution of ISS.

Fig. 2.

ISS, MAIS score and the outcome of the patient.

Fig. 3.

AIS scores of the head, chest, extremities and the outcome of the patient.

Fig. 4.

Comparison of injury severities by the type of offended vehicles.