Factors influencing vehicle passenger fatality have changed over 10 years: a nationwide hospital-based study

Wataru Ishii1, Masahito Hitosugi2, Arisa Takeda1, Mineko Baba3 & Ryoji Iizuka1

Traffic injury trends have changed with safety developments. To establish effective preventive measures against traffic fatalities, the factors influencing fatalities must be understood. The present study evaluated data from a national medical database to determine the changes in these factors over time, as this has not been previously investigated. This observational study retrospectively analysed data from the Japanese Trauma Data Bank. Vehicle passengers involved in collisions from 2004–2008 and 2016–2017 were included. Data were compared between the two study periods, and between fatal and non-fatal patients within each period. Multivariate logistic regression analyses were performed to determine the factors influencing fatalities. In 2016–2017, patients were older and had lower fatality rates. In 2004–2008, fatalities were more likely to involve older male front-seat passengers with low d-BP, BT, and GCS values, and high AIS of the neck and abdomen. However, in 2016–2017, fatalities were more likely to involve older males with low GCS, high AIS of the abdomen, and positive focused assessment with sonography for trauma results. Our study identified independent factors influencing vehicle passenger fatalities, which will likely continue to evolve with the aging of the population and changing manners of injury.

A motor vehicle collision (MVC) is defined as a collision involving at least one moving vehicle that occurred or originated on a road or street open to public traffic and resulted in one or more persons being killed or injured1. Worldwide, the number of fatalities from MVCs in 2004 was higher than those from malaria (ranked 9th and 13th, respectively)2. The number of MVCs is continuously increasing, and MVC was the cause of 1.35 million fatalities in 20163. MVCs are predicted to become the 5th most common cause of fatalities in the world by 20304. Therefore, it is recommended that all countries make greater efforts to decrease MVC fatalities. The value of setting targets to improve road safety performance was acknowledged in the Paris-based Organisation for Economic Co-operation and Development (OECD) report, Safety on the Road, in 20025. Target-setting is recommended for all countries attempting to reduce road fatalities.

Technological advancements and road improvements have been made to prevent MVCs and decrease the severity of injuries incurred by vehicle occupants; improvements in vehicle crashworthiness have increased the collision survivability of motor vehicle passengers, and the focus of recent automobile designs is to avoid crashes altogether6. Since the 1990s, vehicle safety technologies such as airbags and electronic stability control have been developed. As a result, the MVC mortality decreased to its lowest level of 1.08 fatalities per 100 million vehicle miles travelled in 20144. Recent crash avoidance technologies, such as side view assist, forward collision warning/mitigation, lane departure warning/prevention, and adaptive headlights have great potential for preventing crashes6. The motor vehicle fatality rate may be further reduced by improved road conditions, clear zone sizes and clearing of roadside vegetation, improved driver behaviour, and modified speed limits during inclement weather8,9.

The Japanese government established the Traffic Safety Measures Basic Law in 197010. With this law, the Traffic Safety Basic Plan specified goals every 5 years after 1971, and traffic safety measures were promoted.

1Kyoto Daini Red Cross Hospital, Critical Care Center, Emergency of Medicine, Haruobi, Kamazamarutamachi, Kamigy, Kyoto, 602-8026, Japan. 2Department of Legal Medicine, Shiga University of Medical Science, Tsukinowa, Seta, Otsu, Shiga, 520-2192, Japan. 3Center for Integrated Medical Research, Keio University School of Medicine, Tokyo, Japan. *email: watarauaug0804@lily.ocn.ne.jp
comprehensively and systemically. The essential goal is to achieve a society with no traffic accidents. For the period from 2011–2015, the target was fewer than 3,000 fatalities and 700,000 casualties. However, although the goal for casualties was achieved by the end of 2015 (670,140), the goal for fatalities was not (4,117). The Japanese government established a new set of objectives in 2016 to reduce the number of fatalities to fewer than 2,500 and the number of casualties to fewer than 500,000 by 2020. These goals necessitate the continuous elimination of traffic fatalities in Japan. Data from 2017 show that most motor vehicle injuries in Japan are incurred by motor vehicle drivers (64.1%), followed by bicyclists (15.9%), motorcyclists (10.3%) and pedestrians (9.5%). An evaluation of the factors that led to these injuries would be useful in establishing effective measures to prevent motor vehicle fatalities.

Many studies have investigated the circumstances under which motor vehicle passengers are more likely to be killed or severely injured in MVCs, and have evaluated the factors affecting the severity of MVC injuries. However, these studies were based on police data or crash databases that contained information regarding the type of vehicle involved, situation of the collision, major injuries incurred by the victims, and other associated factors. No studies have examined the factors influencing the occurrence of motor vehicle passenger fatalities based on nationwide medical data obtained from hospitals. The main objective of the present study was to examine the data from a nationwide trauma database to identify the factors influencing MVC fatalities; this information will aid in the establishment of effective preventive measures. In addition, as traffic injury trends have changed with traffic safety development, the present study investigated the changing factors influencing fatalities.

Methods

Study design and patient selection. This observational study was a retrospective analysis of the data from a national hospital-based database, the Japanese Trauma Data Bank (JTDB). The JTDB is a nationwide trauma registry in Japan that contains data recorded since 2003 by the Japanese Association for the Surgery of Trauma. Approximately 294,000 trauma patients were registered until 2017. Fifty-five hospitals participated in the registry in 2005, and over 272 hospitals participated in the registry in 2017; this accounted for approximately 75% of the critical care centres in Japan. The inclusion criteria for the JTDB were patients with trauma who had an Abbreviated Injury Scale (AIS) of 3 or more. The JTDB collected information on the manners and mechanisms of injuries, vital signs, anatomical and physiological injury severity, pre-hospital and in-hospital treatment, and outcome.

Date were obtained from the JTDB in December 2018. A total of 294,274 patients were registered in the JTDB from 2004–2017. Of these, 31,250 were MVC-related trauma patients. Cases were excluded if the patient arrived with cardiopulmonary arrest (n = 1,600), if they had unclear or missing data (n = 339), and if they were younger than 15 years old (n = 888). The data from 28,423 vehicle passengers (including drivers) were assessed. Among them, the cases that occurred from 2004–2008 (Period A) and 2016–2017 (Period B) were selected. Period A included data from 4,684 patients, while Period B included data from 3,690 patients (Fig. 1). As only a small number of hospitals participated in the registry in its early period, Period A comprised 5 years of data, while Period B comprised 2 years of data.

Collected data. The JTDB was created in 2003 by the Japanese Association for the Surgery and Trauma (Trauma Surgery Committee) and the Japanese Association for Acute Medicine (Committee for Clinical Care
Patient backgrounds characteristics and vital signs at the time of hospital arrival were compared between Period A (2004–2008) and Period B (2016–2017). A marked aging trend was observed in Japan between these two periods. In 2006, the average life span was 79.0 years for males and 85.8 years for females, and people aged 65 years or older accounted for 20.8% of the total population. In 2016, the average life spans had increased to 81.0 years for males and 87.1 years for females, with people aged 65 years or older comprising 27.3% of the population. Compared with Period A, the patients in Period B had a significantly older average age and a significantly greater proportion of females.

Statistical analysis. Categorial variables were summarised in the form of values with proportions or frequencies. Continuous variables were summarised mean ± standard deviation for the values that followed the normal distribution, and as the median and interquartile range (IQR) for values that were not normally distributed. Chi-square tests were used to compare prevalence between the two groups. To find the differences in values between two groups, the Student's t-test was used for values with normal distribution, while the Mann-Whitney U-test was conducted for values without normal distribution. A P value of 0.05 or less was considered statistically significant. To identify which variables were independently associated with poor outcome, a logistic regression analysis was performed. Risk factors with P values < 0.05 in univariable analysis were included in the multivariable model. The analyses were performed with SPSS Ver. 23.

Endpoint. The changes in factors influencing traffic fatalities were examined using the data from the JTDB.

Ethics. Personal identifiers had already been removed from the JTDB. This study was conducted in accordance with the Declaration of Helsinki, and was approved by the Ethical Committee of Kyoto Daini Red Cross Hospital (Sp 2019–10). Because of the anonymous and retrospective nature of this study, the need for informed consent was waived by the Ethics Committee that approved the study protocol.

Results

Comparisons between the two periods. Patient backgrounds characteristics and vital signs at the time of hospital arrival were compared between Period A (2004–2008) and Period B (2016–2017). A marked aging trend was observed in Japan between these two periods. In 2006, the average life span was 79.0 years for males and 85.8 years for females, and people aged 65 years or older accounted for 20.8% of the total population. In 2016, the average life spans had increased to 81.0 years for males and 87.1 years for females, with people aged 65 years or older comprising 27.3% of the population. Compared with Period A, the patients in Period B had a significantly older average age and a significantly greater proportion of females (Table 1). The proportion of front-seat passengers was significantly lower in Period B than in Period A, while the proportion of rear-seat passengers was significantly higher in Period B than in Period A. The proportion of front-seat passengers was significantly lower in Period B than in Period A. A marked aging trend was observed in Japan between these two periods. In 2006, the average life span was 79.0 years for males and 85.8 years for females, and people aged 65 years or older accounted for 20.8% of the total population. In 2016, the average life spans had increased to 81.0 years for males and 87.1 years for females, with people aged 65 years or older comprising 27.3% of the population. Compared with Period A, the patients in Period B had a significantly older average age and a significantly greater proportion of females (Table 1). The proportion of front-seat passengers was significantly lower in Period B than in Period A, while the proportion of rear-seat passengers was significantly higher in Period B than in Period A. The duration between the emergency call and hospital arrival was significantly shorter in Period B than in Period A. On arrival at the hospital, the average s-BP, d-BP, BT, and GCS values were significantly higher in Period B than in Period A. In contrast, the HR, RR, and proportion of FAST positivity were significantly lower in Period B than in Period A. There was also significantly lower mortality in Period B than in Period A.

| Table 1. Patient characteristics and vital signs at the time of hospital arrival in Period A versus Period B. | Period A (2004 to 2008) | Period B (2016 to 2017) | P value |
|---|---|---|---|
| Age (years) | 45.1 ± 19.2 | 52.7 ± 21.4 | <0.001 |
| Sex, n (%) | | | |<0.001 |
| Male | 69.0 | 61.6 | | |
| Female | 31.0 | 38.4 | | |
| Seating position (%) | | | 0.038 |
| Driver | 77.4 | 76.8 | | |
| Front seat passenger | 14.4 | 13.5 | | |
| Rear seat passenger | 8.2 | 9.6 | | |
| Duration between emergency call to hospital arrival(min) | 55 ± 46 | 48 ± 39 | <0.001 |
| Systolic blood pressure (mmHg) | 129.7 ± 32.4 | 134.9 ± 31.5 | <0.001 |
| Diastolic blood pressure (mmHg) | 77.1 ± 18.9 | 80.9 ± 19.9 | <0.001 |
| Heart rate (beats/min) | 88.4 ± 21.1 | 86.2 ± 18.8 | <0.001 |
| Respiration rate (breaths/min) | 22.8 ± 7.3 | 21.5 ± 6.7 | <0.001 |
| Body temperature (°C) | 36.3 ± 0.9 | 36.6 ± 0.8 | <0.001 |
| Glasgow coma scale | 13.5 ± 3.0 | 13.9 ± 2.5 | <0.001 |
| FAST positive (%) | 15.2 | 11.6 | <0.001 |
| Death (%) | 7.9 | 4.3 | <0.001 |
Injury severity was then compared between the two periods. There was no significant difference in the ISS of the patients between the two periods (Table 2). The highest AIS score was attained for the chest, followed by the head and lower extremities in both periods. The AIS scores of the head, face, abdomen, and lower extremities were significantly lower in Period B than in Period A. In contrast, the AIS scores of the chest and spine were significantly higher in Period B than in Period A.

Comparisons of patient outcome during Period A.
Of the patients in Period A, 301 (7.9%) died (fatal group) and 3,527 survived (non-fatal group). Patient background characteristics and vital signs at the time of hospital arrival were compared between the fatal and non-fatal groups. Compared with the non-fatal group, the fatal group had a significantly higher mean age and proportion of males, and a significantly lower proportion of front-seat passengers (Table 3). At the hospital, the d-BP, BT, and GCS were significantly lower in the fatal group than in the non-fatal group. Regarding injury severity, the ISS and AIS of the neck and abdomen were significantly higher in the fatal group than in the non-fatal group (Table 4).

Comparisons of patient outcome during Period B.
Of the patients in Period B, 145 (4.2%) died and 3,295 survived. Patient background characteristics and vital signs at the time of hospital arrival were compared between the fatal and non-fatal groups. The mean age and proportion of males were significantly higher in the fatal group than in the non-fatal group (Table 5). At the hospital, the fatal group had a significantly lower GCS and a significantly higher FAST positive rate than the non-fatal group. Regarding injury severity, the ISS and AIS of the chest, abdomen, and lower extremities were significantly higher in the fatal group than in the non-fatal group (Table 6).

Table 2. Injury Severity Score (ISS) and Abbreviated Injury Scale (AIS) by body region in Period A versus Period B. *Median values were significantly higher in Period A than Period B. **Median values were significantly lower in Period A than Period B.

Table 3. Patient characteristics and vital signs at the time of hospital arrival of patients who survived (non-fatal group) versus patients who died (fatal group) during Period A (2004–2008). OR: odds ratio, 95% CI: 95% confidence interval, FAST: focused assessment with sonography for trauma.

Injury severity was then compared between the two periods. There was no significant difference in the ISS of the patients between the two periods (Table 2). The highest AIS score was attained for the chest, followed by the head and lower extremities in both periods. The AIS scores of the head, face, abdomen, and lower extremities were significantly lower in Period B than in Period A. In contrast, the AIS scores of the chest and spine were significantly higher in Period B than in Period A.

Comparisons of patient outcome during Period A. Of the patients in Period A, 301 (7.9%) died (fatal group) and 3,527 survived (non-fatal group). Patient background characteristics and vital signs at the time of hospital arrival were compared between the fatal and non-fatal groups. Compared with the non-fatal group, the fatal group had a significantly higher mean age and proportion of males, and a significantly lower proportion of front-seat passengers (Table 3). At the hospital, the d-BP, BT, and GCS were significantly lower in the fatal group than in the non-fatal group. Regarding injury severity, the ISS and AIS of the neck and abdomen were significantly higher in the fatal group than in the non-fatal group (Table 4).

Comparisons of patient outcome during Period B. Of the patients in Period B, 145 (4.2%) died and 3,295 survived. Patient background characteristics and vital signs at the time of hospital arrival were compared between the fatal and non-fatal groups. The mean age and proportion of males were significantly higher in the fatal group than in the non-fatal group (Table 5). At the hospital, the fatal group had a significantly lower GCS and a significantly higher FAST positive rate than the non-fatal group. Regarding injury severity, the ISS and AIS of the chest, abdomen, and lower extremities were significantly higher in the fatal group than in the non-fatal group (Table 6).
Factors influencing the outcome. To identify variables that were independently associated with fatality, logistic regression analyses were performed based on the univariate results. In Period A, significant differences were found in univariate analyses for sex, proportion of front-seat passengers, age, d-BP, BT, GCS, and AIS scores of the neck and abdomen. These variables were included in the logistic regression analysis. Ultimately, male sex (OR: 1.95), front-seat passenger (OR: 1.99), age (OR: 1.04), d-BP (OR: 0.98), BT (OR: 0.54), GCS (OR: 0.74), and AIS of the neck (OR: 1.85) and abdomen (OR: 1.464) were identified as independent predictors of fatality in Period A (Table 7). In Period B, significant differences were found in univariate analyses for sex, age, GCS, AIS score of the abdomen, and FAST results. These variables were included in the logistic regression analysis. Ultimately, male sex (OR: 2.49), front-seat passenger (OR: 1.99), age (OR: 1.05), GCS (OR: 0.77), AIS of the abdomen (OR: 1.40), and FAST positivity (OR: 2.40) were identified as independent predictors of fatality in Period B (Table 8).

Discussion
Comparing the two study periods, there was a dramatic increase in the mean age of patients with MVC-related injuries from 45 years in Period A to 53 years in Period B. This trend likely reflects the aging population in Japan, with those aged 65 years or older increasing from 20.8% of the population in 2006 to 27.3% of the population in 2016. As the average life expectancy of Japanese women (87.1 years) was higher than that of men (81.0 years) in 2016, the proportion of males decreased from 69.0% to 61.6%.

Comparisons between the two study periods also showed a significant decrease in fatalities from 7.9% in Period A to 4.3% in Period B. Furthermore, the injury severity in most body regions significantly decreased, and other physiological parameters improved significantly. These trends are similar to those found in previous

| Table 4. Injury Severity Score (ISS) and Abbreviated Injury Scale (AIS) by body region of patients who survived (non-fatal group) versus patients who died (fatal group) during Period A (2004–2008). OR: odds ratio, 95% CI: 95% confidence interval, IQR: interquartile range. *Median values were significantly higher in the fatal group than the non-fatal group. |
| ISS, median (IQR)* | Non-fatal (n = 3,527) | Fatal (n = 301) | OR | Lower 95% CI | Upper 95% CI | P value |
|---------------------|----------------------|----------------|-----|---------------|--------------|---------|
| Head                | 13 (9.0–20.0)        | 29 (20.8–41.0) | 1.099 | 1.087         | 1.110        | <0.0001 |
| Face                | 0 (0.0–4.0)          | 0 (0.0–4.0)    | 1.080 | 0.941         | 1.240        | 0.274   |
| Neck*               | 0 (0.0–0.0)          | 0 (0.0–0.0)    | 1.850 | 1.010         | 3.389        | 0.046   |
| Chest               | 2.5 (0.0–4.0)        | 0 (0.0–0.0)    | 0.961 | 0.852         | 1.085        | 0.520   |
| Abdomen*            | 0 (0.0–0.0)          | 0 (0.0–0.0)    | 1.464 | 1.239         | 1.731        | <0.001  |
| Spine               | 0 (0.0–0.0)          | 0 (0.0–0.0)    | 0.849 | 0.698         | 1.033        | 0.102   |
| Upper extremities   | 0 (0.0–0.0)          | 0 (0.0–0.0)    | 0.819 | 0.634         | 1.059        | 0.129   |
| Lower extremities   | 0 (0.0–2.0)          | 0 (0.0–3.0)    | 1.803 | 0.855         | 1.777        | 0.967   |

| Table 5. Patient characteristics and vital signs at the time of hospital arrival of patients who survived (non-fatal group) versus patients who died (fatal group) during Period B (2016–2017). OR: odds ratio, 95% CI: 95% confidence interval, FAST: focused assessment with sonography for trauma. |
|---------------------|----------------------|----------------|-----|---------------|--------------|---------|
| Age (years)         | 52.2 ± 21.2          | 63.9 ± 22.1    | 1.050 | 1.033         | 1.068        | <0.001  |
| Sex (%)             | Male 61.3            | 69.0           | 2.493 | 1.236         | 5.031        | 0.011   |
| Female              | 38.7                 | 31.0           | Ref. | Ref.          | Ref.         |         |
| Seating position (%)| Driver 76.8          | 74.5           | Ref. | Ref.          | Ref.         |         |
| Front seat passenger| 13.7                 | 13.8           | 1.762 | 0.773         | 4.016        | 0.178   |
| Rear seat passenger | 9.5                  | 11.7           | 1.854 | 0.744         | 4.620        | 0.185   |
| Duration between emergency call to hospital arrival (min) | 55 ± 47 | 57 ± 50 | 1.001 | 0.998 | 1.001 | 0.645 |
| Systolic blood pressure (mmHg) | 136.0 ± 29.5 | 102.1 ± 51.2 | 0.995 | 0.981 | 1.009 | 0.5    |
| Diastolic blood pressure (mmHg) | 81.4 ± 19.1 | 67.0 ± 30.1 | 1.003 | 0.983 | 1.023 | 0.771 |
| Heart rate (beats/min) | 85.5 ± 18.2 | 99.9 ± 27.3 | 1.008 | 0.994 | 1.022 | 0.244 |
| Respiration rate (breaths/min) | 21.5 ± 6.5 | 21.8 ± 11.2 | 1.032 | 0.991 | 1.073 | 0.991 |
| Body temperature (°C) | 36.6 ± 0.8 | 36.0 ± 1.0 | 0.743 | 0.538 | 1.026 | 0.072 |
| Glasgow coma scale | 14.1 ± 2.1          | 8.4 ± 4.9      | 0.768 | 0.707         | 0.834        | <0.001  |
| FAST positive (%)   | 10.4                 | 44.6           | 2.395 | 1.204         | 4.765        | 0.013   |
Other studies performed using the same data-bank found that in-hospital mortality decreased over time.27,30. Because the number of serious or fatal injuries decreased, the present study found that the GCS score of the patients significantly improved, and that the FAST positivity rate significantly decreased.

It is difficult to explain reductions in in-hospital mortality with any single factor. The decrease in the MVC-related fatality rate over time may have been affected by many factors, such as education, law enforcement, and improvement of prehospital and trauma care (including the shortening of the duration between the emergency call and hospital arrival). Education on standard trauma care, such as Japan Prehospital Trauma Evaluation and Care, and Advanced Trauma Operative Management, has been widely promoted.27. In 2002, the Japanese Association for the Surgery of Trauma published the Japan Advanced Trauma Evaluation and Care (JATEC), which provides doctors with medical treatment guidance for off-the-job training.31. These educational approaches might contribute to decreased vehicle passenger fatality rates. A previous study in Japan revealed that helicopter

### Table 6. Injury Severity Score (ISS) and Abbreviated Injury Scale (AIS) by body region of patients who survived (non-fatality group) versus patients who died (fatality group) during Period B (2016–2017). OR: odds ratio, 95% CI: 95% confidence interval. *Median values were significantly higher in the fatality group than the non-fatality group.

| Body Region | NO | Fat | OR Lower 95% CI | Upper 95% CI | P-value |
|-------------|----|-----|----------------|--------------|---------|
| ISS, median (IQR)* | 12.0 (8.0–19.0) | 27.5 (18.0–43.0) | 1.102 | 1.087 | 1.116 | <0.0001 |
| AIS, median (IQR) | | | | | |
| Head | 0.0 (0.0–2.0) | 0.0 (0.0–4.0) | 1.103 | 0.924 | 1.318 | 0.278 |
| Face | 0.0 (0.0–0.0) | 0.0 (0.0–0.0) | 0.750 | 0.444 | 1.270 | 0.284 |
| Neck | 0.0 (0.0–0.0) | 0.0 (0.0–0.0) | 1.019 | 0.504 | 2.063 | 0.958 |
| Chest* | 1.0 (0.0–3.0) | 3.0 (0.0–4.0) | 1.282 | 1.080 | 1.523 | 0.005 |
| Abdomen* | 0.0 (0.0–0.0) | 1.0 (0.0–3.0) | 1.401 | 1.145 | 1.713 | 0.001 |
| Spine | 0.0 (0.0–1.0) | 0.0 (0.0–0.0) | 0.862 | 0.674 | 1.102 | 0.236 |
| Upper extremities | 0.0 (0.0–0.0) | 0.0 (0.0–0.0) | 0.873 | 0.604 | 1.262 | 0.470 |
| Lower extremities* | 0.0 (0.0–1.0) | 0.0 (0.0–2.0) | 1.266 | 1.025 | 1.564 | 0.029 |

### Table 7. Results of multivariate analyses to identify the factors associated with fatality in Period A (2004–2008). d-BP: diastolic blood pressure, BT: body temperature, GCS: Glasgow coma score, AIS: Abbreviated Injury Scale, OR: odds ratio, 95% CI: 95% confidence interval.

| Period A (n = 4,684) | OR Lower 95% CI | Upper 95% CI | P-value |
|----------------------|----------------|--------------|---------|
| Gender | | | | |
| Male | 1.948 | 1.143 | 3.321 | 0.014 |
| Seating position | | | | |
| Driver | Ref. | | | |
| Front seat passenger | 1.985 | 1.089 | 3.620 | 0.025 |
| Age | 1.036 | 1.024 | 1.047 | <0.001 |
| d-BP | 0.976 | 0.960 | 0.991 | 0.002 |
| BT | 0.539 | 0.426 | 0.681 | <0.001 |
| GCS | 0.740 | 0.696 | 0.788 | <0.001 |
| AIS of the neck | 1.850 | 1.010 | 3.389 | 0.046 |
| AIS of the abdomen | 1.464 | 1.239 | 1.731 | <0.001 |

### Table 8. Results of the multivariate analyses to identify the factors associated with fatality in Period B (2016–2017). FAST: focused assessment with sonography for trauma, GCS: Glasgow coma score, AIS: Abbreviated Injury Scale, OR: odds ratio, 95% CI: 95% confidence interval.

| Period B (n = 3,690) | OR Lower 95% CI | Upper 95% CI | P-value |
|----------------------|----------------|--------------|---------|
| Gender | | | | |
| Female | Ref. | | | |
| Male | 2.493 | 1.236 | 5.031 | P < 0.001 |
| FAST | | | | |
| Negative | Ref. | | | |
| Positive | 2.395 | 1.204 | 4.765 | P = 0.013 |
| Age | 1.050 | 1.033 | 1.068 | P < 0.001 |
| GCS | 0.768 | 0.707 | 0.834 | P < 0.001 |
| AIS of abdomen | 1.401 | 1.145 | 1.713 | P = 0.001 |
transportation and usage of whole-body computed tomography (CT) were associated with improved mortality rates for severe trauma patients. Japan has the highest number of CT scanners per capita in the world. Furthermore, in most emergency departments and critical care centres, high-speed CT scanners are located close to the trauma bay. Hybrid emergency rooms, which have recently been installed in several facilities, are also associated with increased survival after potentially fatal trauma.

In the years between the two study periods, laws requiring seatbelt usage in rear seats and strengthened penalties for drunk driving were established. In 2008, the Road Traffic Law was revised so that rear-seat passengers were required to wear a seatbelt, in addition to four-wheeled vehicle drivers and front-seat passengers. The rates of seatbelt use by rear-seat passengers dramatically increased from 8.8% in 2007 to 30.8% in 2008. Because of improved awareness that seatbelts should be fastened while driving, the respective rates of seatbelt use for drivers, front-seat passengers, and rear-seat passengers increased from 93.8%, 83.4%, and 7.5% in 2006 to 98.5%, 94.9%, and 36.0% in 2016.

Following increased public awareness that ‘drunk driving is unacceptable’, police implemented the revised Traffic Law in 2007, which includes stricter regulations and penalties targeting drunk driving and any environments that enable drunk driving. When a person is arrested for drunk driving, an in-depth investigation is conducted not only of the driver, but also of the other vehicle passengers or persons who provided the alcohol to the driver. The revised Road Traffic Law also promotes penalties to fellow passengers or other persons who enabled the drunk driving. After the implementation of this revised Road Traffic Law, the number of traffic collisions caused by drunk driving decreased from 11,625 in 2006 to 3,757 in 2016. We expect further improvements with increased public awareness and decreased social tolerance for alcohol-impaired driving. Furthermore, improved motor vehicle engineering and safety devices might positively affect in-hospital mortality.

The factors independently influencing the occurrence of fatalities in each period were determined by multivariate analyses. From 2004–2008, fatalities were more likely to involve older male front-seat passengers with low d-BP, BT, and GCS values, and high AIS of the neck and abdomen. However, in 2016–2017, being a front-seat passenger or having low d-BP, low BT, and high AIS of the neck were not significant independent predictors of fatality. As mortality rates decreased in the 10 years specified above, the indices related to severe or fatal injuries, such as d-BP, BT, and AIS score of the neck, were not selected. With the introduction of laws on mandating seatbelt use in the rear seat and increased awareness of the importance of seatbelt use, the seatbelt use rate gradually improved, even in the front seats. For front-seat passengers, seatbelt use on general roads increased from 83.4% in 2006 to 94.9% in 2016. Because most people sitting in the front passenger seat are restrained and have airbag protection, being a passenger in the front seat was not significantly associated with fatality in 2016–2017.

In both groups, the associations of low GCS and increased age with an increased fatality rate are well understood. The GCS is well correlated with fatality after head injuries. A systematic review and meta-analysis of trauma patients reported that older patients had higher mortality than younger patients. Older patients have higher mortality and morbidity than younger patients, even in MVCs of equal severity. It has been suggested that the physical vulnerability of older patients leads to a worse prognosis after MVC. Injury severity after a MVC is influenced by many age-related physical changes, such as muscle weakness, osteoporosis, and reduction in organ system function.

In addition to the AIS of the abdomen, a positive FAST finding became an independent factor influencing fatality in 2016–2017. As the prevalence of seatbelt use increased and airbags became the norm in the driver and front passenger seats, the occurrence of severe chest and head injuries decreased. Seatbelt use prevents severe contact between the chest and abdomen and the vehicle interiors, but the seatbelt itself can apply force that injures the abdominal organs, as the abdomen has no skeletal protection.

With appropriate seatbelt use, the forward movement of the passenger is suppressed during a collision. However, if the seatbelt is not appropriately positioned, there is a higher possibility of abdominal injury caused by the seatbelt. A recent study suggested that 40% of rear-seat passengers showed inappropriate seatbelt positioning, with the lap belt moving from the right or left anterior superior iliac spine. This phenomenon may lead to compression of the abdomen, causing abdominal organ injury during a collision. Therefore, abdominal injuries may influence the outcome. A positive FAST result indicates that abdominal injuries are present. With the increased popularity of the JATEC, FAST quickly became widely performed throughout Japan, providing an additional factor for evaluation of the abdomen.

One limitation of this study is that it did not include all injured vehicle passengers in Japan. However, the JTDB represents trauma cases to a similar degree as databases in North America, Europe, and Oceania. In addition, all certificated trauma educational institutions and many critical care centres participated in this database. Because the JTDB is the only prospective, nationwide, hospital-based trauma registry, we believe our analyses provided representative results. Second, information on crashes, such as collision details (a type of car, collision direction, and velocity), seatbelt use, and airbag deployment was not present in the JTDB registry. Because our study was based on medical data, analyses lacking these details do not have decreased reliability. However, future studies should examine connections between accident data collected by the police department and medical data based on hospital records in Japan. Third, the JTDB contained flawed information. In the JTDB, numerical values or applicable items are registered via the website, while freely written information cannot be entered. Therefore, some of the items had missing data. However, as unclear or missing data were excluded before analysis in the present study, the analyzed data had a high level of reliability. Fourth, as this database was hospital-based, cases of instant death pronounced at the collision scene were not included. Furthermore, patients experiencing cardiopulmonary arrest on arrival were excluded from this study. In these cases, the physiological parameters and details of the injuries were not obtained because of the lack of examinations. Therefore, including these out-of-hospital deaths likely would not improve the reliability of the present analyses.
Conclusion
Our study identified independent factors influencing vehicle passenger fatalities. With the increasing average age in Japan, changing manners of injury in motor vehicle accidents, and development of new traffic safety measures, analyses similar to the present study should be performed regularly in the future.

Received: 5 August 2019; Accepted: 10 February 2020;
Published online: 24 February 2020

References
1. OECD. OECD Health Statistics 2019 Definitions, Sources and Methods 2019, http://www.oecd.org/health/health-data.htm (2019-11-20).
2. Global status report on road safety - World Health Organization, https://apps.who.int/iris/bitstream/handle/10665/44122/9789241563840_ eng.pdf?sequence=1 (2020-1-22).
3. Global status report on road safety 2018, https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/ (2019-10-29).
4. Peden, M. et al. World report on road traffic injury prevention. Geneva, 2004, World Health Organization, https://www.who.int/violence_injury_prevention/publications/road_traffic/world_report/summary_en_rev.pdf (2019-06-10).
5. Organisation for Economic Co-operation and Development (OECD)/International Transport Forum (ITF). Towards zero, ambitious road safety targets and the safe system approach, Summary document, 2008, OECD/ITF, https://www.oecd-ilibrary.org/sites/ default/files/docs/@0targetssummary.pdf (2019-06-10).
6. Jermakian, I. S. Crash avoidance potential of four passenger vehicle technologies. Accid. Anal. Prev. 43, 732–740 (2011).
7. Russell, G., Gerald, M. & Jeffrey, K. Decomposition analysis of the effects of vehicle safety technologies on the motor vehicle collision-related mortality rate from 1994 to 2015. Traffic Injury Prev. 19, S169–S172 (2018).
8. Fitzpatrick, C. D., Harrington, C. P., Knoedler, M. A. Jr. & Romoser, M. R. E. The influence of clear zone size and roadside vegetation on driver behavior. Saf. Res. 49, 97–104 (2014).
9. Shubhayu, A., Paul, S., Amanda, N. & Jeremy, H. Adverse weather conditions and fatal motor vehicle crashes in the United states, 1994-2012. Environ. Heal. 15, 104 (2016).
10. Ministry of Land, Infrastructure and Transport Japan. Traffic Safety Measures in Japan, https://www.mlit.go.jp/road/management-e_pdf/0403_5.pdf (2019-04-21).
11. 10th Road Safety Basic Plan of Japan in 2016, https://www8.ca.go.jp/koutu/kihon/keikakub/10/pdf/kihon_keikaku.pdf (2020-01-22).
12. Traffic safety white paper of Japan in 2017, https://www8.ca.go.jp/koutu/taisaku/b30kou_haku/pdf/zenben/1-1-1.pdf (2019-11-20).
13. Kahani, A. T., Shariati-Mohaymany, A. & Ranjbari, A. Analysis of factors associated with traffic injury severity on rural roads in Iran. J. Infect. Violence Res. 4, 36–41 (2012).
14. Chang, L. Y. & Wang, H. W. Analysis of traffic injury severity: an application of non-parametric classification tree techniques. Accid. Anal. Prev. 38, 1019–1027 (2006).
15. Yan, X. & Radwan, E. Analyses of rear-end crashes based on classification tree models. Traffic Inf. Prev. 7, 276–282 (2006).
16. Bedard, M., Guyatt, G. H., Stones, M. J. & Hirdes, J. P. The independent contribution of driver, crash, and vehicle characteristics to driver injury. Accid. Anal. Prev. 34, 717–727 (2002).
17. Japan Trauma Care and Research. Japan Trauma Datebank, https://www.jtcr-jatec.org/traumabank/index.htm (2019-01-10).
18. Japan Trauma Date Bank Report 2013-2017, https://www.jtcr-jatec.org/traumabank/dataroom/data/JTDB2018e.pdf (2019-04-21).
19. Japan Trauma Care and Research. Japan trauma data bank annual report 2011–2015, http://www.jtcr-jatec.org/traumabank/
20. Yumoto, T. et al. Impact of Cushing’s sign in the prehospital setting on predicting the need for immediate neurosurgical intervention in trauma patients: a nationwide retrospective observational study. Scand. J. Trauma. Resusc. Emerg. Med. 24, 147 (2016).
21. Shoko, T., Shiraishi, A., Kaji, M. & Otomo, Y. Effect of pre-existing medical conditions in hospital mortality: analysis of 20,257 trauma patients in Japan. J. Am. Coll. Surg. 211, 338–346 (2010).
22. Research of Current Population Estimates as of October 1, 2006, https://www.stat.go.jp/english/data/jinsui/2006np/index.html (2020-01-22).
23. Research of Current Population Estimates as of October 1, 2016, https://www.stat.go.jp/english/data/jinsui/2016np/index.html (2020-01-22).
24. Research of General Welfare and Labour Ministry of Health, Labor and Welfare, https://www.mhlw.go.jp/english/wp/wp-hw11/d01e.pdf (2020-01-22).
25. Nagata, I., Abe, T., Uchida, M., Saitoh, D. & Tamiya, N. Ten-year inhospital mortality trends for patients with trauma in Japan: a multicentre observational study. BMJ Open. 8, 1–9 (2018).
26. Curtis, K. A. et al. Injury trends and mortality in adult patients with major trauma in New South Wales. Med. J. Aust. 197, 233–237 (2012).
27. Hondo, K., Shiraiishi, A., Fujie, S., Saitoh, D. & Otomo, Y. In-hospital trauma mortality has decreased in Japan possibly due to trauma education. J. Am. Coll. Surg. 217, 850–857 (2013).
28. Kuchholz, S. et al. Reduction in mortality of severely injured patients in Germany. Dtsch. Arztebl. int. 105, 225–231 (2008).
29. Moore, L., Turgeon, A. F., Lauzier, F. & Emond, M. Evolution of patient outcomes over 14 years in a mature, inclusive Canadian trauma system. World J. Surg. 39, 1397–1405 (2015).
30. Matsuyama, T. et al. Motor vehicle accident mortality by elderly drivers in the super-aging era. Med. 38, e12350 (2018).
31. JATEC in Japanese, https://www.jtcr-jatec.org/index_jatec.html (2019-04-21).
32. Galván, S. M. et al. Association between helicopter vs ground emergency medical services and survival for adults with major trauma. (MMA 307, 1602–1610 (2012).
33. Abe, T., Takahashi, O., Saitoh, D. & Tokuda, Y. Association between helicopter with physician versus ground emergency medical services and survival of adults with major trauma in Japan. Crit. Care 18, R146 (2014).
34. Caputo, N. D., Stahmer, C., Lim, G. & Shah, K. Whole-body computed tomography vs selective radiological imaging on outcomes in major trauma patients: a meta-analysis. Scand. J. Trauma. Resusc. Emerg. Med. 22, 54 (2014).
35. Jiang, L. et al. Comparison of whole-body computed tomography vs selective radiological imaging on outcomes in major trauma patients: a meta-analysis. Scand. J. Trauma. Resusc. Emerg. Med. 22, 54 (2014).
36. Pater, K. OECD iLibrary. J. Bus. Financ. Librarianship 20, 339–343 (2015).
37. Kinoshita, T. et al. The Survival Benefit of a Novel Trauma Workflow that Includes Immediate Whole-body Computed Tomography, Surgery, and Interventional Radiology; All in One Trauma Resuscitation Room: A Retrospective Historical Control Study. Ann. Surg. 269, 370–376 (2019).
38. Research of Japan Automobile Federation in 2016, http://www.jaf.or.jp/eco-safety/safety/data/driver2016.htm (2019-06-10).
39. Road safety white paper in Cabinet office of Japan, https://www8.cao.go.jp/koutu/taisaku/index-t.html (2020-01-22).
40. The Survival Benefit of a Novel Trauma Workflow that Includes Immediate Whole-body Computed Tomography, Surgery, and Interventional Radiology; All in One Trauma Resuscitation Room: A Retrospective Historical Control Study. Ann. Surg. 269, 370–376 (2019).
42. Sammy, I., Lecky, F., Sutton, A., Leaviss, J. & O’ Cathain, A. Factors affecting mortality in older trauma patients-A systematic review and meta-analysis. Injury 47, 1170–1183 (2016).
43. Azami-Aghdash, S., Aghaei, M. H. & Sadeghi-Bazarghani, H. Epidemiology of Road Traffic Injuries among Elderly People; A Systematic Review and Meta-Analysis. Bull. Emerg. Trauma. 6, 279–291 (2018).
44. Lyman, S., Ferguson, S. A., Braver, E. R. & Williams, A. Older driver involvements in police reported crashes and fatal crashes: trends and projections. Int. J. Prev. 8, 116–120 (2002).
45. Richter, M., Pape, H. C., Otte, D. & Krettek, C. The current status of road user injuries among the elderly in Germany: a medical and technical accident analysis. J. Trauma. 58, 591–595 (2005).
46. Hitosugi, M. et al. Shorter pregnant women restrained in the rear seat of a car are at risk for serious neck injuries: biomechanical analysis using a pregnant crash test dummy. Forensic Sci. Int. 291, 133–137 (2018).
47. Hitosugi, M. et al. Seatbelt paths of the pregnant women sitting in the rear seat of a motor vehicle. Chin. J. Traumatol. 20, 343–346 (2017).
48. Mizuno, K. et al. The effect of inboard shoulder belt and lap belt loading on chest deflection. Stapp Car Crash J. 62, 67–91 (2018).

Acknowledgements
We thank the staff who maintain the JTDB and all personnel at the participating institutions who facilitated the data. We thank Katrina Krogh, MD, and Kelly Zammit, BVSc, from Edanz Group (www.edanzediting.com/ac), for editing a draft of this manuscript.

Author contributions
W.I. designed the study, analysed the data, and drafted the manuscript. M.H. designed the study and drafted the manuscript. A.T. analysed the data. M.B analysed the data and performed statistical analyses. R.I. reviewed the work critically for important intellectual content.

Competing interests
The authors declare no competing interests.

Additional information
Correspondence and requests for materials should be addressed to W.I.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/.

© The Author(s) 2020