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Incidence, demographics and outcomes of patients with penetrating injury: a Japanese nationwide 10-year retrospective study

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ABSTRACT

Background Unintentional injury remains the leading cause of death among Japanese people younger than 35 years; however, data are limited on the evaluation of characteristics, long-term mortality trend and mortality risk of patients with penetrating injury in Japan. This prevents the development of effective strategies for trauma care in patients with penetrating injury.
Methods This retrospective cohort study investigated 313 643 patients registered in the Japan Trauma Data Bank (JTDB) dataset between 1 January 2009 and 31 March 2018. The inclusion criteria comprised patients with penetrating injuries transferred from the injury site by emergency vehicles. Moreover, the patients registered in the JTDB dataset were included in this study regardless of age and sex. Outcomes measured were nationwide trends of characteristics, in-hospital mortality and in-hospital mortality risk among Japanese patients with penetrating injury. The mortality risk was analysed by hospital admission year, age, Injury Severity Score (ISS) and emergency procedures.
Results Overall, 7132 patients were included. Median age significantly increased during the 10-year study periods (from 48 to 54 years, p=0.002). Trends for the mechanism of injury did not change; the leading cause of penetrating injury was stab wounds (SW: 76%–82%). Overall, the in-hospital mortality rate significantly decreased (4.0% to 1.7%, p=0.008). However, no significant improvement was observed in the in-hospital mortality trend in all ISS groups with SW and active bleeding. Patients with active bleeding who underwent urgent transcatheter arterial embolization had significantly lower mortality risk (p=0.043, OR=0.12, 95% CI=0.017 to 0.936). Conversely, the surgical procedure for haemostasis did not improve the mortality risk of patients with SW and active bleeding.
Conclusion The severity-adjusted mortality trend in patients with penetrating injuries did not improve. Moreover, patients with active bleeding who underwent urgent surgical procedure for haemostasis had a higher mortality risk.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is the first nationwide epidemiological 10-year study of penetrating injuries in Japan.
⇒ Outcomes investigated that the severity-adjusted mortality trend in patients with penetrating injuries did not improve from 2009 to 2018.
⇒ The Japanese nationwide dataset with more missing data may have led to selection bias.

INTRODUCTION

Previous reports have shown that in-hospital mortality has decreased among injured Japanese patients over the past decade, owing to improvements in trauma education programmes and trauma care systems.[1–3] However, unintentional injury remains the leading cause of death among Japanese people younger than 35 years.[4]

Several nationwide cohort studies have reported that the mortality rate and risk of patients with severe injuries vary according to age, injury mechanism and/or injury severity.[1–3 5–7] Injured patients with older age, penetrating injury and/or a higher Injury Severity Score (ISS) have a higher mortality risk.[6 7] Specifically, severely injured patients with active bleeding have significantly high mortality risk and require early haemodynamic stabilisation to improve mortality rates.[8] Therefore, it is essential to analyse mortality and morbidity based on risk-adjusted measurements using a nationwide database that includes patients with various characteristics.

To the best of our knowledge, data for evaluating the characteristics, long-term mortality trend and mortality risk of patients with penetrating injury by age, mechanism of injury and injury severity is limited in Japan. Therefore, this study aimed to analyse the nationwide trends of characteristics, in-hospital mortality and in-hospital mortality risk among Japanese patients with penetrating injury between 2009 and 2018 to identify a more effective strategy of trauma care in patients with penetrating injuries.

METHODS

Study setting and population

This retrospective nationwide cohort study included data from the Japan Trauma Data Bank (JTDB), the largest trauma registry in Japan.[9] The total number of participating hospitals in the JTDB dataset was 280 hospitals, including 92% of Japanese government approved tertiary emergency medical centres in 2018. The JTDB collected prehospital and in-hospital data, including demographics, injury types, mechanism of injury, vital signs, injury severity, prehospital treatment, in-hospital procedures and in-hospital mortality. The Japan Association for the Surgery of Trauma permitted open access and updating of existing medical information and the Japan Association for Acute Medicine evaluated the submitted data.[9]

This study used the JTDB dataset, which included 313 643 patients registered between 1January 2009 and 31 December 2018. The Abbreviated Injury Scale (AIS) coding system that used the 1990 version of AIS (AIS90) changed to a new AIS coding system that uses the 2008 version of AIS (AIS 2008) from January 2019. Therefore, we used the JTDB dataset from 2009 to 2018 registered using the same AIS coding system (AIS90) to describe the 10-year trend of patients with penetrating injury in Japan. The inclusion criteria of this study included patients with penetrating injuries who were transferred from the injury site by ambulance car and/or helicopter. Patients with burns, blunt injury, cardiac arrest at the hospital, missing data on age, mechanism of injury, ISS and/or survival outcome were excluded from this study. The patients registered in the JTDB dataset were included in this study regardless of age and sex. Figure 1 shows the flow diagram of patient selection in this study.

Data collection

The following variables were collected from the JTDB dataset: age in years, sex, mechanism of injury, type of transportation, transfer process, AIS of injury region, ISS, emergency procedures (blood transfusion within 24 hours from hospital admission, urgent angiography, urgent transcatheter arterial embolization (TAE), urgent surgical procedure for haemostasis), time interval from emergency call to hospital arrival and from hospital arrival to the start of TAE and surgical procedure for haemostasis, and in-hospital mortality. The surgical procedure for haemostasis was defined as an emergency procedure for patients with active bleeding performed within 24 hours after admission, which includes craniotomy, craterization, thoracotomy, celiotomy and endoscopic surgery, but excludes TAE.

Statistical analysis

In the primary analysis, the nationwide trends of characteristics and in-hospital mortality were analysed among

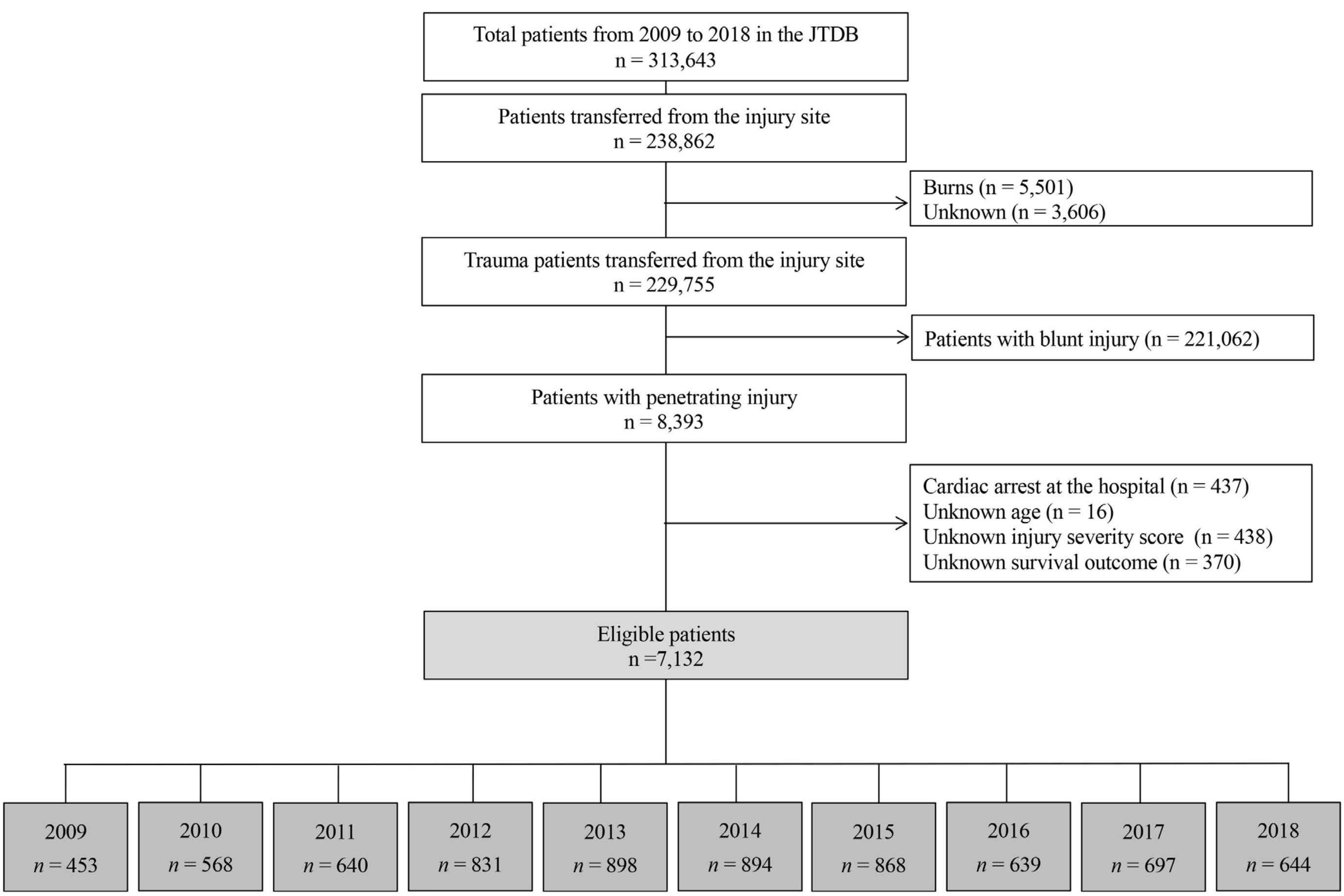


Figure 1 Flow diagram of the patient selection process. JTDB, Japanese Trauma Data Bank.

Japanese patients with penetrating injury from 2009 to 2018 by splitting the data according to: (1) ISS range (ISS 0–15, 16–25, ≥26); (2) patients with stab wounds (SW), the leading cause of penetrating injury in Japan[9]; and (3) patients with active bleeding. Patients with active bleeding were defined as patients who underwent blood transfusions within 24 hours from hospital admission.

In the secondary analysis, the mortality risk was analysed by splitting the data according to: (1) year of hospital admission (10 groups from 2009 to 2018); (2) age (children, 0–17 years; adults, 18–64 years; older adults, ≥65 years); (3) ISS range (ISS 0–15, 16–25, ≥26); and (4) emergency procedures performed. The mortality risk was defined as a measure of association between the exposure and survival outcome. Mortality risk was also used to compare the relative risks of mortality in trauma patients.

In the primary analysis, the Jonckheere-Terpstra test was used to evaluate trends in continuous variables, and the Cochran-Armitage test was used to evaluate trends in categorical variables by hospital admission years. In the secondary analysis, the OR with a 95% CI for in-hospital mortality was calculated using a logistic regression model. The following variables were included in the multiple logistic regression analysis: admission year, age, ISS and emergency procedures. The results are expressed as medians and IQRs (IQR, Q1–Q3) for continuous variables and frequencies and percentages for categorical variables. All statistical analyses were performed using the STATA/SE software (V.17.0; StataCorp, College Station, Texas, USA). Statistical significance was defined as a two-tailed p value of <0.05.

Patient and public involvement

Neither patients nor the public were involved in the design, conduct, reporting or dissemination of this research. We intended not to directly disseminate our findings to the involved participants, but rather to disseminate them through the publication of this study.

RESULTS

During the 10-year study period, the JTDB dataset included 229 755 patients with unintentional injury who were transferred from the injury site. Of these patients, 8393 (3.7%) had penetrating injury and 7132 were eligible for inclusion in this study (figure 1). The median age and ISS were 51 years (IQR, 36–66) and 9 (IQR, 4–10), respectively. The overall in-hospital mortality rate was 3.4%. Online supplemental table 1 shows the demographics and characteristic trends of patients with penetrating injuries during the 10-year study period.

The median age in years significantly increased (from 48 years in 2008 to 54 years in 2018, p=0.002). The proportion of adults aged 18–64 years decreased significantly, while that of older adults aged≥65 years increased significantly. Trends for the mechanism of injury did not change; the leading cause of penetrating injury continued to be SWs (76%–82% of all patients with penetrating injury) over the 10-year study period.

The proportion of patients with an ISS 0–15 increased significantly (from 77% in 2008 to 83% in 2018, p=0.002), and the proportion of patients with an ISS 16–25 decreased significantly (from 18% in 2008 to 14% in 2018, p=0.008). This resulted in a significant decrease in the overall in-hospital mortality rate (4.0% in 2008 to 1.7% in 2018, p=0.005) (online supplemental table 1). However, in-hospital mortality trends in all ISS groups (figure 2), in patients with SW, and in those with active bleeding (figure 3) did not significantly improve during the 10-year study period.

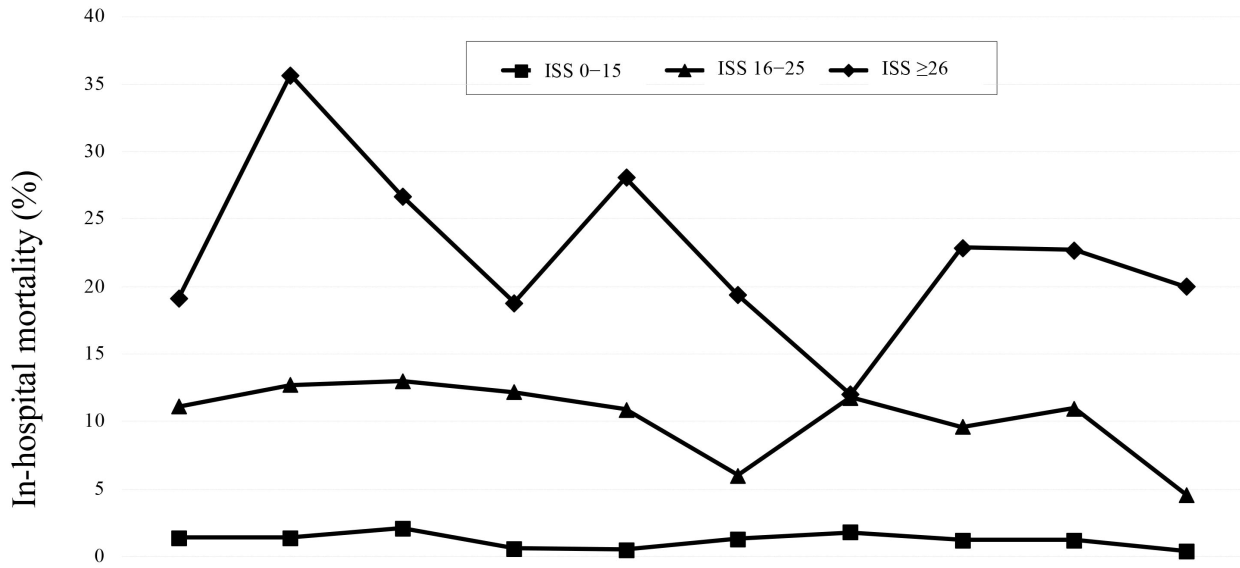
Online supplemental table 2 shows the trend in the frequency of emergency procedures and the time interval from emergency call to hospital arrival and from hospital arrival to the beginning of the urgent procedure. The time intervals from hospital arrival to the administration of TAE and surgical procedure for haemostasis did not statistically change and both median values were over 90 min (103 min and 95 min in 2018).

Online supplemental table 3 shows the results of multiple logistic regression analysis. Overall, the mortality risk of patients with penetrating injuries admitted in 2018, which was set as a reference group, was significantly lower than that of patients admitted before 2012. Compared with the mortality risk of patients aged≥65 years, mortality risks of patients aged 0–17 and 18–64 years were significantly lower (p=0.006, OR=0.06, 95% CI=0.008 to 0.459 and p<0.001, OR=0.35, 95% CI=0.267 to 0.467, respectively). Compared with the mortality risk in patients with ISS≥26, mortality risks in patients with ISS 0–15 and ISS 16–25 were significantly lower (p<0.001, OR=0.04, 95% CI=0.029 to 0.063 and p<0.001, OR=0.34, 95% CI=0.239 to 0.490, respectively). In urgent procedures, the mortality risk of patients who underwent blood transfusions 24 hours after hospital admission, who had active bleeding, significantly increased (p<0.001, OR=1.88, 95% CI=1.403 to 2.517). In contrast, the mortality risk of patients who underwent TAE and surgical procedure for haemostasis significantly decreased (p=0.020, OR=0.09, 95% CI=0.012 to 0.682 and p=0.046, OR=0.66, 95% CI=0.439 to 0.993, respectively).

Among patients with SW, the mortality risk of patients admitted in 2018 was significantly lower than that of patients admitted before 2012. Among patients with active bleeding, however, the mortality risk did not chronologically improve during the 10-year study period. In patients with both SW and active bleeding, patients aged≥65 years and patients with ISS≥26 had high mortality risk. Patients with active bleeding who underwent urgent TAE had lower mortality risk significantly (p=0.043, OR=0.12, 95% CI=0.017 to 0.936). Conversely, the surgical procedure for haemostasis did not improve the mortality risk for patients with SW and active bleeding.

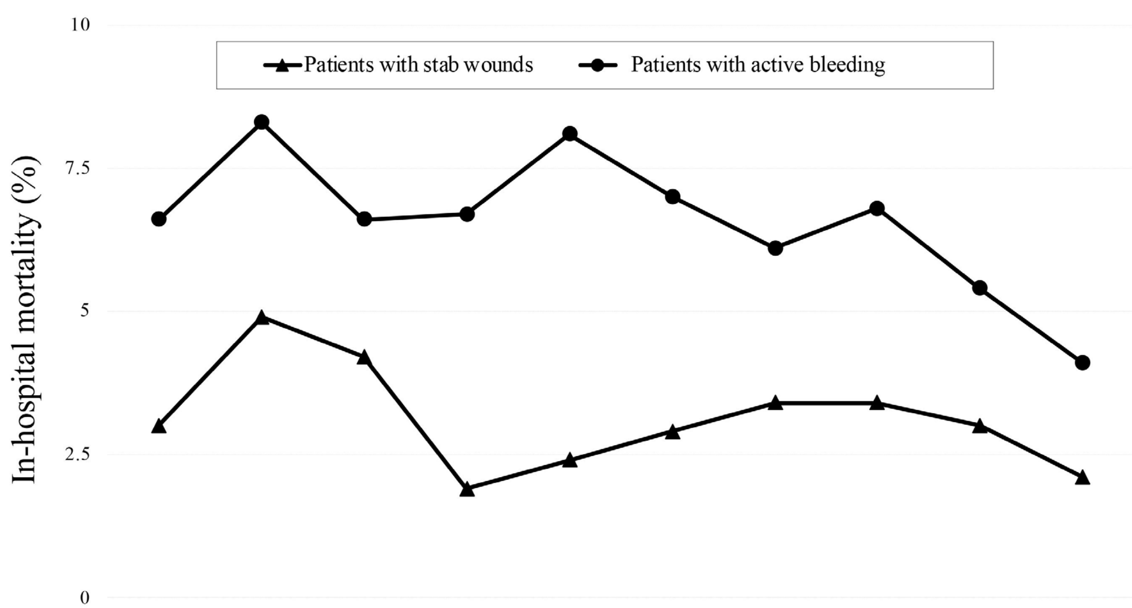
DISCUSSION

To the best of our knowledge, this was the first nationwide epidemiological study of penetrating injuries in



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	*p*-value
ISS 0–15	5 (1.4)	6 (1.4)	11 (2.1)	4 (0.6)	4 (0.5)	9 (1.3)	13 (1.8)	6 (1.2)	7 (1.2)	2 (0.4)	0.295
ISS 16–25	9 (11.1)	14 (12.7)	12 (13.0)	14 (12.2)	14 (10.9)	9 (6.0)	13 (11.8)	10 (9.6)	10 (11.0)	4 (4.6)	0.102
ISS ≥26	4 (19.1)	10 (35.7)	8 (26.7)	6 (18.8)	9 (28.1)	6 (19.4)	3 (12.0)	8 (22.9)	5 (22.7)	5 (20.0)	0.091

Figure 2 In-hospital mortality trends among patients with penetrating injuries in all ISS groups. The in-hospital mortality rates in patients with penetrating injuries with ISS 0–15, 16–25 and ≥26 did not decrease during the past decade. ISS, Injury Severity Score.



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	*p*-value
Patients with stab wounds	11 (3.0)	21 (4.9)	21 (4.2)	13 (1.9)	17 (2.4)	20 (2.9)	23 (3.4)	17 (3.4)	16 (3.0)	11 (2.1)	0.216
Patients with active bleeding	11 (6.6)	15 (8.3)	12 (6.6)	15 (6.7)	20 (8.1)	17 (7.0)	14 (6.1)	13 (6.8)	9 (5.4)	9 (4.1)	0.154

Figure 3 In-hospital mortality trends among penetrating injuries with stab wounds and active bleeding. The in-hospital mortality trend in patients with stab wounds and in patients with active bleeding showed no significant improvement during the 10-year study period.

Japan over 10 years. The in-hospital mortality trend significantly decreased in all patients with penetrating injuries. However, the severity-adjusted mortality trend in patients with penetrating injury did not improve, as seen in the ISS groups 0–15, 16–25 and ≥26, patients with SW and/or those with active bleeding during the 10-year study period. The time interval from hospital arrival to the start of urgent surgical procedure for haemostasis did not change during the 10-study period and both median values were over 90 min. The surgical procedure for haemostasis did not improve the mortality risk for patients with SW and active bleeding.

Different distributions of penetrating injury have been reported in other countries.[10–13] Our results showed that 79% of penetrating injury was caused by stabbing and 0.4% by gunshot. The few gunshot wounds (GSW) in Japan could be attributed to the strict gun control policy implemented by the Japanese government and the absence of large-scale acts of terrorism in Japan in more than 10 years. Therefore, the ratio of patients with SW to that of patients with other injuries in Japan increases. In adult patients admitted with penetrating injuries between 2012 and 2018 in Sweden, 56% were SW and 37% were GSW.[10] Between 2000 and 2005 in England and Wales, 73% were SW and 19% were GSW.[11] In Germany, between 2008 and 2013, 81% were SW and 19% were GSW.[12] In contrast, the USA showed equal distributions of SW and GSW between 2007 and 2014.[13] In Japan, it may be more effective to establish therapeutic strategies focusing on SW rather than GSW for patients with penetrating injury to decrease in-hospital mortality, because there was no changed noted in the incidence rate during the 10-year study period. Furthermore, in line with the ageing population in Japan,[4] the median age of Japanese patients was 51 years (IQR 36–66). This was much higher than that in other countries, with a median age of 30 years in Sweden and a mean age of 31 years in London and 39 years in Germany.[10–12] Previous reports have shown that there were differences in the medical resources available for the trauma care and mortality risk according to age, mechanism, injury region and injury severity.[6 7 10–13] Therefore, it may be effective to focus on these mechanism-specific and age-specific characteristics and outcomes of patients with penetrating injury in order to establish a trauma care system suitable for Japanese patients.

Massive haemorrhage after injury is the leading cause of potentially preventable deaths.[13] Early haemodynamic stabilisation is an important factor for improving mortality and morbidity in severely injured patients in a haemodynamically unstable state.[14–16] Our results showed that the OR for in-hospital mortality in patients with active bleeding who underwent urgent blood transfusions was high as 1.88. The mortality risk of these patients showed no yearly improvement during the 10-year study period. Previous studies have shown that the clinical failure and mortality risk of urgent TAE and/or surgical procedure for haemostasis are associated with the amount of blood loss and the delay from hospital admission to haemodynamic stabilisation.[17 18] In our study, active bleeding was defined as a blood transfusion within 24 hours of admission. Because the JTDB dataset did not include the amount of blood transfusion, we could not clarify the per cent of the patients with active bleeding who received massive transfusion, which is usually defined as the transfusion of more than 10 units of packed red blood cells within 24 hours or corresponding blood loss of more than 1–1.5-fold of the body's entire blood volume.[19] However, there is a very big difference between patients who receive a small amount of blood transfusion and those who receive massive transfusion. Therefore, in a future study, it would be necessary to perform subclass analysis according to the amount of blood transfusion to evaluate the mortality risk of patients with massive haemorrhage. Moreover, our results showed that neither the time interval from emergency call to hospital arrival nor that from hospital arrival to TAE initiation and surgical procedure for haemostasis changed with significant power, indicating the influence of these time intervals on clinical course and outcome during the 10-year study period. Therefore, establishing strategies for the rapid administration of emergency procedures such as TAE and/or surgical procedure for haemodynamically unstable patients with penetrating injuries and active bleeding may improve in-hospital mortality. Moreover, it is important to provide high-quality trauma care to improve the mortality of patients with severe injuries. Several studies have reported that a higher hospital admission volumes resulted in lower mortality among severely injured patients because the increased volume of severely injured patients per hospital was correlated with an increased number of urgent procedures required for severely injured patients, such as blood transfusions, TAE and/or surgical intervention.[20 21] Moreover, previous studies showed that patients with penetrating injuries had a survival benefit if they were centrally triaged to higher-level trauma centres.[22] Our results showed that 3.9% of all injured patients during the 10-year study period had penetrating injuries (7132 patients in total), and of those, 2054 (29%) underwent urgent blood transfusions, 98 (1%) underwent TAE and 1171 (16%) underwent urgent procedures for haemostasis. These may indicate that the number of severely injured patients with penetrating injuries and unstable haemodynamic states per participating hospital was extremely low because trauma care and centralised systems specialised in treating severely injured patients with penetrating injury and active bleeding have yet to be established throughout Japan. These results suggest that the lack of change in mortality rates according to ISS groups and the lack of improvement in mortality of patients with active bleeding who underwent the surgical procedure for haemostasis was caused by the delay in performing the surgical procedure and the immature trauma care for severely injured patients with active bleeding. Therefore, timely and safe centralisation of patients with severe penetrating injury to a trauma centre with high-quality and high-volume trauma care may provide a huge opportunity for implementation of trauma care systems within Japan to improve survival outcomes.

This study has several limitations. First, a selection bias existed, as not all Japanese hospitals that treat injured patients participated and the number of participating hospitals in the JTDB differed during the 10-year study period. A total of 280 participated in the JTDB registry, including 92% of Japanese government approved tertiary emergency medical centres in 2018. Unfortunately, the number of patients in the JTDB did not cover the entire population of Japan. Moreover, there are missing data in the JTDB dataset. Figure 1 shows the rate of missing data, resulting in the exclusion of 9.8% (824 patients) of the 8393 patients with penetrating injuries. Second, analysing a small study cohort and using a retrospective study design may have resulted in biased conclusions. Third, there are several statistical biases. Although we used the multiple logistic regression analysis to eliminate the confounding effect, confounding factors such as year groups and ISS groups, which have similar trend by year, might persist even after adjustment. A small sample size and a dataset with dispersion during the 10-year study period may cause a misunderstanding of the results obtained using the Cochrane-Armitage test and Jonckheere-Terpstra tests. Based on expert opinion from a statistician, we additionally performed secondary analysis using multiple logistic regression analysis. Fourth, previous studies have shown that the clinical feature and mortality of severely injured patients were associated with physiological risk factors, such as hypotension and consciousness disorder, and being worst in elderly people.[6 23] However, we did not evaluate the in-hospital mortality trend and mortality risk by subclass analysis using physiological variables and age groups (eg, 65–74 years, 75–84 years and >85 years). Further study should be conducted to clarify the factors which affect the mortality of patients with severe penetrating injury by splitting the data according to physiological variables and/or age year among elderly people. Finally, with regard to the preventable deaths in severely injured patients, it is essential to evaluate the cause of death in the prehospital setting as well as in the in-hospital setting. In the future, it is necessary to evaluate the mortality risk in severely injured patients with penetrating injuries not only in in-hospital settings, but also in prehospital settings; as well as evaluating injury prevention by examining variables such as quality of care and structure of the trauma care system.

In this first nationwide epidemiological study of penetrating injuries in Japan spanning 10 years, the in-hospital mortality trend significantly decreased in all patients with penetrating injuries. However, the severity-adjusted mortality trend in patients with penetrating injuries did not improve. Moreover, patients with active bleeding who underwent urgent surgical procedure for haemostasis had a higher mortality risk. A trauma care system that centralises patients with severe penetrating injury to a high-volume trauma centre with high-quality trauma care should be established.

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Contributors Conceptualisation, TN and CT; methodology, CT; software, CT; validation, TN and CT; formal analysis, CT; investigation, TN and CT; resources, TN and CT; data curation, CT; writing—original draft preparation, TN and CT; writing—review and editing, TN, CT, and NM; visualisation, TN and CT; supervision, NM; project administration and funding acquisition, CT; guarantor, CT. All the authors have read and agreed to the published version of the manuscript.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants. This study was approved by the institutional ethics committees of Yokohama City University Medical Center (approval no. B170900003). Approval authority for data access was provided by the Japanese Association for the Surgery of Trauma (Trauma Registry Committee). Due to the observational study design, the need for consent for study participation was waived by the institutional ethics committees that approved our study. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. Data are not publicly available. The approving authority for data access was the Japan Trauma Care and Research (JTCR). Data are only available on request to the JTCR and access requires appropriate ethical and governance clearances regarding data availability.

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