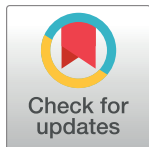# Recent trends in 30-day mortality in patients with blunt splenic injury: A nationwide trauma database study in Japan

Chie Tanaka[1], Takashi Tagami[1,2]*, Hisashi Matsumoto[3], Kiyoshi Matsuda[4], Shiei Kim[5], Yuta Moroe[1], Reo Fukuda[1], Kyoko Unemoto[1], Hiroyuki Yokota[4]

1 Department of Emergency and Critical Care Medicine, Nippon Medical School Tama Nagayama Hospital, Tokyo, Japan, 2 Department of Clinical Epidemiology and Health Economics, School of Public Health, The University of Tokyo, Tokyo, Japan, 3 Department of Emergency and Critical Care Medicine, Nippon Medical School Chiba Hokusoh Hospital, Chiba, Japan, 4 Department of Emergency and Critical Care Medicine, Nippon Medical School Musashikosugi Hospital, Kanagawa, Japan, 5 Department of Emergency and Critical Care Medicine, Nippon Medical School Hospital, Tokyo, Japan

* t-tagami@nms.ac.jp

Abstract

Background

Splenic injury frequently occurs after blunt abdominal trauma; however, limited epidemiological data regarding mortality are available. We aimed to investigate mortality rate trends after blunt splenic injury in Japan.

Methods

We retrospectively identified 1,721 adults with blunt splenic injury (American Association for the Surgery of Trauma splenic injury scale grades III–V) from the 2004–2014 Japan Trauma Data Bank. We grouped the records of these patients into 3 time phases: phase I (2004–2008), phase II (2009–2012), and phase III (2013–2014). Over the 3 phases, we analysed 30-day mortality rates and investigated their association with the prevalence of certain initial interventions (Mantel-Haenszel trend test). We further performed multiple imputation and multivariable analyses for comparing the characteristics and outcomes of patients who underwent TAE or splenectomy/splenorrhaphy, adjusting for known potential confounders and for within-hospital clustering using generalised estimating equation.

Results

Over time, there was a significant decrease in 30-day mortality after splenic injury ($p < 0.01$). Logistic regression analysis revealed that mortality significantly decreased over time (from phase I to phase II, odds ratio: 0.39, 95% confidence interval: 0.22–0.67; from phase I to phase III, odds ratio: 0.34, 95% confidence interval: 0.19–0.62) for the overall cohort. While the 30-day mortality for splenectomy/splenorrhaphy diminished significantly over time ($p = 0.01$), there were no significant differences regarding mortality for non-operative management, with or without transcatheter arterial embolisation ($p = 0.43$, $p = 0.29$, respectively).

Conclusions

In Japan, in-hospital 30-day mortality rates decreased significantly after splenic injury between 2004 and 2014, even after adjustment for within-hospital clustering and other factors independently associated with mortality. Over time, mortality rates decreased significantly after splenectomy/splenorrhaphy, but not after non-operative management. This information is useful for clinicians when making decisions about treatments for patients with blunt splenic injury.

Introduction

Splenic injury is one of the most frequent injuries after blunt abdominal trauma [1, 2]. There have been a few studies regarding mortality after splenic injury. Richardson [3] reported that, despite changes in the management of splenic injury, total mortality remained at 6–7%. Cirocchi et al. [4] reported that mortality after splenic injury was 14% in patients treated with non-operative management (NOM) and 17% in patients treated with splenectomy/splenorrhaphy. According to a large cohort study using a nationwide trauma database, the overall in-hospital mortality in the United States was 6.1% [5]. However, these previous studies did not investigate the epidemiologic trends in mortality for splenic injury patients.

The strategy for management of blunt splenic injury, which may have an impact on mortality, has changed in the last decade. Until the 1990s, splenectomy/splenorrhaphy was the standard treatment strategy for patients with blunt splenic injury. Subsequently, several studies reported that NOM with or without transcatheter arterial embolisation (TAE) has become more common in hemodynamically stable patients with blunt splenic injury, and mortality rates in such patients have decreased [6–9]. However, most of those reports came from single-centre or small-scale studies. Although several other reports have focused on the criteria for NOM indication and the cause of NOM failure in splenic injury patients, the trends in mortality were not fully investigated [3, 10–13]. Other factors that may influence mortality rates include the grade of splenic injury, as well as the incidence and nature of concomitant injuries. Nevertheless, there were few studies that investigated the relationship between mortality and the grade of splenic injury or associated injuries [6, 7].

We hypothesised that, over the last decade, mortality after blunt splenic injury has been decreasing. In the present study, we aimed to investigate the epidemiologic changes in the rate of in-hospital mortality among patients with blunt splenic injury in Japan, while adjusting for other factors related to mortality.

Methods

The present study was approved by the ethics committee of the Nippon Medical School Tama Nagayama Hospital. The requirement for informed consent was waived because our analysis did not include personal identification information.

Study design and data source

We conducted a retrospective cohort study using data from the Japan Trauma Data Bank (JTDB) [14–17]. The JTDB is a large national trauma database that is administered by the Japan Trauma Care and Research, and includes trauma cases classified as Abbreviated Injury Scale (AIS) [18] grade 3 or more, that were managed at 1 of 244 participating hospitals in

Japan. The database contains data regarding the patients' age, sex, vital signs on scene, vital signs at the emergency department, mechanism of injury, diagnosis, treatment, AIS scores, Injury Severity Score (ISS) [19], and survival [14–16].

Definitions and variables

For spleen injuries, the AIS grades 3, 4, and 5 are equivalent, respectively, to grades III, IV, and V of the spleen injury scale proposed by the American Association for the Surgery of Trauma (AAST) [20]. A patient was defined to be under cardiac arrest on arrival if their respiratory and heart rates were zero. In addition to the baseline characteristics on scene and at the time of admission, several other variables were evaluated. We used the Japan Coma Scale (JCS) and the Glasgow Coma Scale (GCS) to evaluate the consciousness level [21, 22]. Further, we defined the initial management of splenic injury as the therapeutic interventions performed within 6 hours of arrival at the hospital. If patients had undergone both TAE and splenectomy/ splenorrhaphy, we grouped them with the group of patients with splenectomy/splenorrhaphy.

The standard management strategy for blunt splenic injury has changed in the past decades, with the focus shifting from splenectomy/splenorrhaphy to NOM. There have been 3 major guidelines regarding the management of blunt splenic injury issued in the last decade. In 2003, the Eastern Association for the Surgery of Trauma (EAST) [23] published the first practice guidelines for the NOM of blunt injury to the liver and spleen. Next, the Western Trauma Association (WTA) [24] addressed the critical decisions about the management of adult blunt splenic injury. The WTA guidelines recommended that TAE of the splenic artery might serve as adjunctive therapy in the NOM of splenic injury patients. The EAST management guidelines were revised in 2012 as follows [25]: routine splenectomy/splenorrhaphy was no longer indicated in hemodynamically stable patients, and angiography would be considered for patients with severe splenic injury and presence of a contrast blush on CT scan. We considered that the treatment of splenic injury might have changed as the guidelines changed, estimating a delay of at least 1 year between the issue of the guidelines and change in clinical practice. Therefore, we stratified patients according to the following 3 phases. The first was phase I (2004–2008), starting 1 year after the issue of the first EAST NOM guidelines in 2003 and before the adoption of the WTA critical decisions in 2008. The second was phase II (2009–2012), starting 1 year after publication of the WTA critical decisions in 2008 but before adoption of the revision of the EAST guidelines in 2012. The third was phase III (2013–2014), starting 1 year after the revision of the EAST guidelines in 2012.

Patient selection

The present study included blunt splenic injury patients registered in the JTDB between 2004 and 2014, and whose splenic injury was classified with an AIS code of 3 or more. We selected patients aged 15 years and above. We excluded patients who were under cardiac arrest on arrival.

After stratifying the patients according to phases I, II, and III, we compared the data regarding patients with isolated splenic injury against data regarding multiple injury patients who also had splenic injury, in order to assess the impact of concomitant injuries on the outcomes of the treatment. The other terms used to designate the region of the trauma were head, chest, abdomen, spine, neck, face, and periphery (peripheral injury), according to the AIS classification [18]. Finally, we evaluated the association between mortality and the initial management of splenic injury (NOM without TAE, NOM with TAE, or splenectomy/splenorrhaphy).

Outcome measures

The primary outcome measure was 30-day all-cause in-hospital mortality.

Statistical analysis

We compared the patients' background characteristics, treatment, and mortality over time (i.e., phases I, II, and III) using the Mantel-Haenszel trend test. One-way analysis of variance was used for continuous variables as appropriate. We further performed multiple imputation and multivariable analyses for comparing the characteristics and outcomes of patients who underwent TAE or splenectomy/splenorrhaphy, adjusting for known potential confounders and for within-hospital clustering. Only with complete and available case analyses provide inefficient, though valid, results when missing data are missing completely at random, but biased results when missing data are missing not at random (MNAR) or missing at random (MAR) [26–28]. A multiple imputation approach leads to unbiased results with correct standard errors, in situations where missing data are either MNAR or MAR [26–28]. Therefore, we performed multiple imputation and handled with missing data appropriately for the multivariate analysis. First, we performed multiple imputation [26, 27] whereby each missing value was replaced with a set of 5 substitute plausible values, in order to reduce bias caused by incomplete data. A multivariable regression model was constructed for each imputed data set, and the results of the 5 imputed data sets were combined into a single model, from which the statistical inference was taken. Second, we analysed the temporal changes in the primary outcome using a multiple logistic regression model adjusted for the within-hospital clustering effect using generalised estimating equation. We also adjusted for factors independently associated with mortality as suggested by previous studies (i.e. age, gender, splenic injury grade, Injury Severity Score, time from emergency call to hospital arrival, time from hospital arrival to intervention, conscious level on admission, systolic blood pressure, type of injury, and intervention type [7, 29–31]). We assumed that the time from arrival to intervention was one of the most important factors associated with mortality. Since patients treated with NOM without TAE cannot be associated with the variable of "time from arrival to intervention", we did not include patients with NOM without TAE in this logistic regression analysis. The statistical significance threshold was set at $p < 0.05$. All analyses were carried out using IBM SPSS version 23 (IBM Corp., Armork, NY, USA).

Results

During study phases I, II, and III, respectively, there were: 528, 1019, and 459 patients with AAST splenic injury grade 3 or more; 23, 42, and 13 patients with cardiopulmonary arrest on arrival; and 89, 106, and 139 participant hospitals. A total of 1,721 patients were selected (Fig 1), with 444 patients in phase I, 615 in phase II, and 659 in phase III. The basic characteristics, severity of the injury, pre-hospital information, and in-hospital information are summarised in Table 1. The mean ISS values were similar among the 3 phases ($p = 0.33$); besides, there were no significant differences in the proportions of patients with a given AAST splenic injury grade ($p = 0.16$). The proportion of patient who needed transfusion within 24 hours after injury significantly decreased over time ($p = 0.01$). Finally, there were no statistically significant differences regarding pre-hospital vital signs.

Fig 2 shows significant decreasing trends in 30-day mortality for all splenic injury patients and for splenic injury patients with multiple trauma across the 3 phases ($p < 0.01$ and $p < 0.01$, respectively). The 30-day mortalities in patients with isolated splenic injury were 2.5%, 0.6%, 1.8% for phase I, II, and III, respectively, and there was no significant difference among the phases ($p = 0.75$).
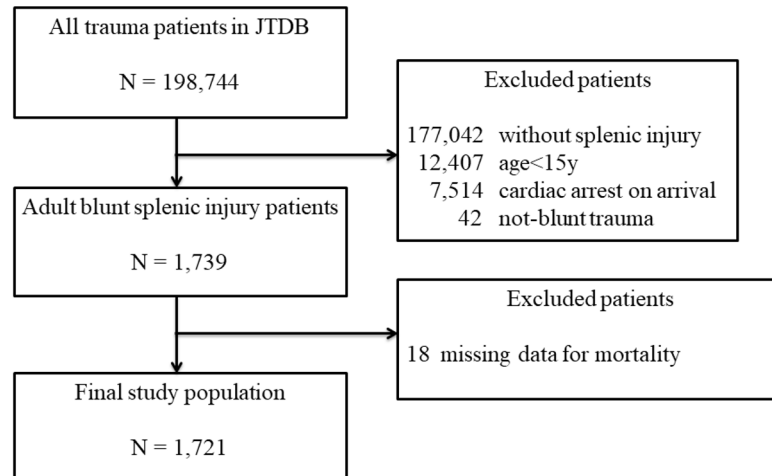
Fig 1. Patient selection.

Table 2 shows the prevalence of the 3 forms of management for splenic injury in each phase. The management trends for isolated splenic injury were similar to those for the management of multiple injuries. The proportion of patients undergoing NOM with TAE significantly increased, and the proportion of patients undergoing splenectomy/splenorrhaphy significantly decreased over time ($p = 0.01$). The numbers of patients who underwent both TAE and an operative procedure for splenic injury were 4 (2.8%) in phase I, 9 (6.0%) in phase II, and 12 (9.1%) in phase III.

Table 3 shows the 30-day mortality of the 3 forms of management for splenic injury in each phase. There was a significant trend towards decreasing 30-day mortality rates over the three phases for total splenic injury patients who underwent splenectomy/splenorrhaphy ($p < 0.01$). On the other hand, there were no significant differences among the phases regarding 30-day mortality of patients managed by NOM with or without TAE.

Logistic regression analysis adjusted for factors independently associated with mortality revealed that 30-day mortality significantly decreased over time (from phase I to phase II, odds ratio: 0.39, 95% confidence interval: 0.22–0.67; from phase I to phase III, odds ratio: 0.34, 95% confidence interval: 0.19–0.62) in patients treated either with TAE or with splenectomy/splenorrhaphy (Table 4).

Discussion

The present study examined the records from a Japanese nationwide trauma registry to investigate the current trends in 30-day mortality of patients with blunt splenic injury. The results demonstrated that, in Japan, the all-cause 30-day in-hospital mortality rate decreased over a 10-year period (2004–2014) decreased significantly in patients with blunt splenic injury, even after adjustment for within-hospital clustering and other factors independently associated with mortality (e.g., splenic injury grade and ISS).

The strength of our study lies in its design, as it was based on records that contain pre-hospital information, severity of trauma injury, and in-hospital information from over 10 years of nationwide, multicentre experience (244 hospitals). A previous large-cohort study using a nationwide trauma database in the United States reported only overall mortality, without adjustment for other factors related to mortality [5]. Other previous multi-institutional retrospective studies regarding blunt splenic injury have focused mainly on the rates of NOM

Table 1. Demographic and clinical characteristics of patients with blunt splenic injury, stratified by time periods.

Variables		Phase I (n = 444)		Phase II (n = 615)		Phase III (n = 659)		p-value
Age, years		35.0	(22.0–56.0)	37.5	(24.0–62.0)	39.0	(23.0–61.0)	0.009
Male sex		332/444	(74.8)	450/615	(73.2)	482/659	(73.1)	0.57
Injury severity score		25.0	(17.0–36.0)	27.0	(17.0–37.5)	25.0	(16.0–34.0)	0.33
AAST Splenic Injury Scale grade								0.16
	3	264/444	(59.5)	404/615	(65.7)	418/659	(63.4)	
	4	138/444	(31.1)	164/615	(26.7)	193/659	(29.3)	
	5	42/444	(9.5)	47/615	(7.6)	48/659	(7.3)	
Isolated splenic injury		129/444	(29.1)	183/614	(29.8)	213/659	(32.3)	0.23
Splenic injury with head injury		93/444	(20.9)	138/614	(22.5)	118/659	(17.9)	0.16
Splenic injury with chest injury		245/444	(55.2)	348/615	(56.6)	371/659	(56.3)	0.74
Splenic injury with abdominal injury		94/444	(21.2)	100/615	(16.3)	108/659	(16.4)	0.06
Splenic injury with spine injury		21/444	(4.7)	30/615	(4.9)	31/659	(4.7)	0.97
Splenic injury with neck and face injury		2/444	(0.5)	5/615	(0.8)	4/659	(0.6)	0.81
Splenic injury with peripheral injury		108/444	(24.3)	137/615	(22.3)	126/659	(19.1)	0.04
Pre-hospital Japan Coma Scale score								0.81
	0	161/355	(45.4)	194/473	(41.0)	212/502	(42.2)	
	1	94/355	(26.5)	155/473	(32.8)	150/502	(29.9)	
	2	36/355	(10.1)	48/473	(10.1)	55/502	(11.0)	
	3	64/355	(18.0)	76/473	(16.1)	85/502	(16.9)	
Pre-hospital systolic blood pressure		110	(94–133)	110	(92–130)	112	(94–131)	0.22
Pre-hospital pulse rate		90	(73–104)	90	(74–107)	90	(77–105)	0.39
Pre-hospital respiratory rate		24	(18–28)	24	(18–30)	24	(20–30)	0.92
Time from emergency call to hospital arrival		35	(27–47)	38	(30–55)	37	(29–50)	0.03
In-hospital Japan Coma Scale								0.21
	0	172/366	(47.0)	228/499	(45.7)	244/503	(48.5)	
	1	72/366	(19.7)	127/499	(25.5)	113/503	(22.5)	
	2	54/366	(14.8)	65/499	(13.0)	81/503	(16.1)	
	3	64/366	(17.5)	79/499	(15.8)	65/503	(12.9)	
In-hospital Glasgow Coma Scale								0.76
	3–8	71/422	(16.8)	94/590	(15.9)	81/634	(12.8)	
	9–14	124/422	(29.4)	198/590	(33.6)	211/634	(33.3)	
	15	227/422	(53.8)	298/590	(50.5)	342/634	(53.9)	
In-hospital systolic blood pressure		111	(90–131)	110	(87–129)	113	(96–133)	0.006
In-hospital heart rate		94	(78–115)	92	(75–111)	90	(76–108)	0.005
In-hospital respiratory rate		24	(20–30)	24	(20–30)	22	(19–28)	0.001
In-hospital body temperature		36.4	(35.8–36.8)	36.2	(35.5–36.7)	36.3	(35.8–36.8)	0.13
Computed tomography during ER evaluation		275/444	(61.9)	381/615	(62.0)	423/659	(64.2)	0.41
Time from arrival to splenectomy/ splenorrhaphy		104	(70–163)	123	(84–172)	110	(76–157)	0.92
Time form arrival to TAE		110	(79–162)	111	(65–165)	104	(68–147)	0.42
Transfusion within 24 hours		191/444	(43.0)	270/615	(43.9)	239/659	(36.3)	0.01

Analysis based on records from the Japan Trauma Data Bank: phase I (2004–2008), phase II (2009–2012), and phase III (2013–2014). Data given as number of positive observations/total number of observations (percentage) or as median (interquartile range). For each variable, the number of missing observations can be obtained as the difference between the total number of patients in each phase and the total number of observations.

AAST, American Association for the Surgery of Trauma; ER, emergency room; TAE, transcatheter arterial embolization
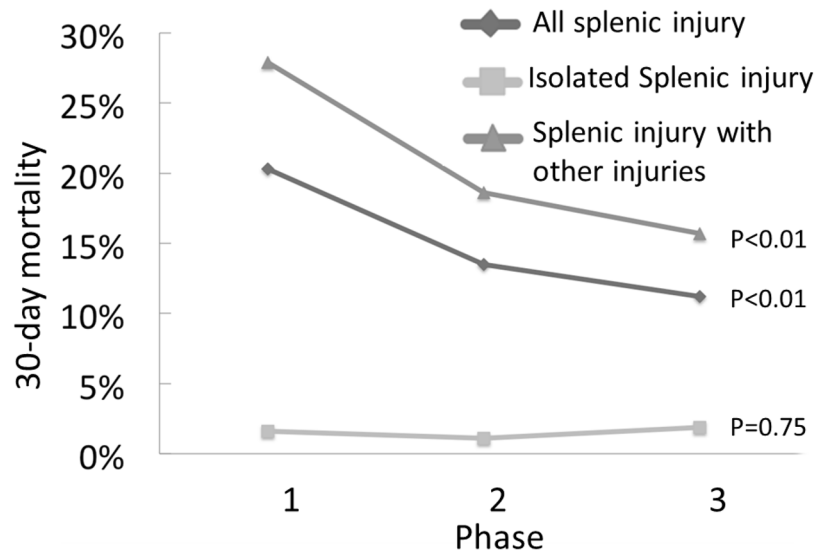
Fig 2. Comparison of 30-day mortality rates in patients with splenic injury, with or without associated injuries.

failure [11, 32–34]. Therefore, our study is the first nationwide cohort study that demonstrated the epidemiologic time-related trends in mortality after blunt splenic injury.

Compared to previous reports, our data suggested higher mortality rates after splenic injury [3–5, 35], which is likely related to the fact that our study population included patients with splenic injury grade 3 or more, indicating higher severity and ISS grade. Our data showed a significant increasing trend in the proportion of patients treated with NOM (with or without TAE) between 2004 and 2014, with a decreasing trend in the proportion of patients treated with splenectomy/splenorrhaphy. The present study also determined the trend in 30-day mortality associated with each management strategy. The mortality of patients treated with splenectomy/splenorrhaphy tended to decrease, while the mortality of patients treated with NOM

Table 2. Choice of initial management strategy for splenic injury, stratified by time periods.

	Groups	Phase I		Phase II		Phase III		*p*-value
Total patients		(n = 444)		(n = 615)		(n = 659)		0.01
	NOM without TAE	230	(51.8)	348	(56.6)	372	(56.4)	
	NOM with TAE	71	(16.0)	116	(18.9)	155	(23.5)	
	Splenectomy/Splenorrhaphy	143	(32.2)	151	(24.6)	132	(20.0)	
Isolated splenic injury		(n = 129)		(n = 183)		(n = 213)		0.71
	NOM without TAE	86	(66.7)	125	(68.3)	137	(64.3)	
	NOM with TAE	19	(14.7)	30	(16.4)	58	(27.2)	
	Splenectomy/Splenorrhaphy	24	(18.6)	28	(15.3)	18	(8.5)	
Splenic injury with other injuries		(n = 315)		(n = 431)		(n = 446)		0.01
	NOM without TAE	144	(45.7)	223	(51.7)	235	(52.7)	
	NOM with TAE	52	(16.5)	86	(20.0)	97	(21.7)	
	Splenectomy/Splenorrhaphy	119	(37.8)	122	(28.3)	114	(25.6)	

Analysis based on records from the Japan Trauma Data Bank: phase I (2004–2008), phase II (2009–2012), and phase III (2013–2014).

Data given as total number (percentage).

NOM, non-operative management; TAE, transcatheter arterial embolization

Table 3. 30-day mortality of initial management strategy for splenic injury, stratified by time periods.

	Groups	Phase I		Phase II		Phase III		p-value
Total patients		(n = 444)		(n = 615)		(n = 659)		
	NOM without TAE	28	(12.2)	44	(12.6)	36	(9.7)	0.29
	NOM with TAE	5	(7.0)	11	(9.5)	8	(5.2)	0.43
	Splenectomy/Splenorrhaphy	57	(39.9)	28	(25.0)	30	(23.6)	<0.01
Isolated splenic injury		(n = 129)		(n = 183)		(n = 213)		
	NOM without TAE	0	(0)	1	(0.8)	1	(0.7)	0.53
	NOM with TAE	0	(0)	0	(0)	0	(0)	0
	Splenectomy/Splenorrhaphy	2	(8.3)	1	(3.6)	3	(16.7)	0.40
Splenic injury with other injuries		(n = 315)		(n = 431)		(n = 446)		
	NOM without TAE	28	(19.4)	43	(19.3)	35	(14.9)	0.22
	NOM with TAE	5	(9.6)	11	(12.8)	8	(8.2)	0.66
	Splenectomy/Splenorrhaphy	55	(46.2)	26	(21.3)	27	(23.7)	<0.01

Analysis based on records from the Japan Trauma Data Bank: phase I (2004–2008), phase II (2009–2012), and phase III (2013–2014).

Data given as total number (percentage).

NOM, non-operative management; TAE, transcatheter arterial embolization

(with or without TAE) did not change across the phases. Nevertheless, a significant decrease in 30-day mortality was found for this period of time in the patients with splenic injury included

Table 4. Multiple logistic regression analysis for risk of 30-day mortality among patients treated with transcatheter arterial embolization (TAE) or splenectomy/splenorrhaphy.

	Original data set			After multiple imputation		
	Odds ratio	95%CI	p-value	Odds ratio	95%CI	p-value
Phase III (2013–2014)	0.31	0.17–0.57	<0.001	0.34	0.19–0.62	<0.001
Phase II (2009–2012)	0.37	0.21–0.66	0.001	0.39	0.22–0.67	0.001
Phase I (2004–2008)(reference)	1			1		
Male sex	1.26	0.70–2.29	0.44	1.40	0.79–2.48	0.25
Female sex (reference)	1			1		
Spleen injury grade 5	1.45	0.67–3.12	0.35	1.63	0.73–3.65	0.23
Spleen injury grade 4	0.71	0.43–1.17	0.18	0.81	0.51–1.29	0.38
Spleen injury grade 3 (reference)	1			1		
GCS on arrival 3–8	8.98	4.52–17.84	<0.001	9.12	4.77–17.45	<0.001
GCS on arrival 9–14	2.73	1.59–4.70	<0.001	2.58	1.54–4.94	<0.001
GCS on arrival 15 (reference)	1			1		
Age	1.02	1.01–1.04	<0.001	1.03	1.01–1.04	<0.001
Injury Severity Score	1.03	1.01–1.06	0.002	1.04	1.02–1.06	<0.001
Time from emergency call to hospital arrival	0.99	0.97–0.99	0.005	0.99	0.97–0.99	<0.001
Time from hospital arrival to intervention	0.98	0.97–0.99	<0.001	0.98	0.99–1.00	0.003
SBP on arrival	0.99	0.98–1.00	0.011	0.99	0.98–1.00	0.003
Injury type (Multiple)	1.68	0.59–4.81	0.34	1.66	0.62–4.49	0.31
Injury type (Isolated) (reference)	1			1		
Intervention type (Splenectomy/Splenorrhaphy)	3.37	1.74–6.53	<0.001	2.84	1.56–5.17	0.001
Intervention type (TAE) (reference)	1			1		

Analysis based on records from the Japan Trauma Data Bank: phase I (2004–2008), phase II (2009–2012), and phase III (2013–2014).

GCS, Glasgow Coma Scale; SBP, Systolic Blood Pressure; TAE, Transcatheter Arterial Embolization. CI, confidence interval

in the present study. This decrease was significant even after adjusting for within-hospital clustering and other factors independently associated with mortality.

The Ministry of Internal Affairs and Communications on Japan reported that, in general, the time from emergency call to hospital arrival increased by about 10 minutes over the 10-year period evaluated in our study. Indeed, as shown previously, the time from emergency call to hospital arrival increased significantly for cardiac arrest cases [36, 37]. Our results of the logistic regression analysis showed that the time from emergency call to hospital arrival was one of the independent factors associated with a poor outcome. Importantly, our results suggest that the outcomes of patients with blunt splenic injury improved despite the increase in the time from emergency call to hospital arrival.

Hamlat and colleagues [5] previously reported that inclusive trauma systems appeared to improve the outcomes of patients with splenic injury in the United States. We speculated that the decrease in 30-day mortality noted between 2004 and 2014 in the current study may, at least in part, be related to the progress of emergency medical services in Japan [38]. First, there was an improvement in the system of pre-hospital trauma-care education. The Japan Prehospital Trauma Evaluation and Care [39] (JPTEC) course started in 2003 and aimed to train rapid on-site observation, urgent treatment, and timely transportation of trauma patients. A decade later, the number of certified JPTEC providers in Japan had increased to 37,392 [40]. Second, there was an improvement in education regarding initial trauma management. The Japan Advanced Trauma Evaluation and Care [38] (JATEC) education program started in 2002 with 171 doctors, a number that had increased to 8,643 by 2012 [41]. The purpose of JATEC was to educate doctors regarding the emergency room management of patients with severe trauma, including splenic injury. Based on our results and previous observations [38], it is likely that such trauma training programs account for part of the decrease in mortality rates observed between 2004 and 2014 in splenic injury patients.

In addition to the spread of education about prehospital care and initial trauma management, we thought that the decrease of mortality was partially due to the progress in trauma management itself. For example, the guidelines about bleeding and coagulopathy following major trauma were published in 2007 and updated in 2010, 2013, and 2016 [42]. In addition, other practice management guidelines were published by EAST and there have been many papers about resuscitation for trauma patients [43–45]. These might contribute to improving resuscitation for severe trauma patients. From our study, the proportion of transfusion within 24 hours after injury tended to dwindle over the 10-year period. Thus, we speculated that progress in initial trauma management, including treatment for bleeding and coagulopathy, may have contributed to the decrease of in mortality after splenic injury.

We also considered that the specific guidelines in place at the time of admission might have an effect on the choice of treatment strategy for splenic injury. The guidelines suggested that the patient's physical condition and the results of CT scans were important factors in the decision regarding the treatment of splenic injury; for example, recent guidelines recommend NOM for hemodynamically stable patients [23–25]. In our study, patients were stratified based on the time period during which specific guidelines were in effect. We found that the proportion of patients treated with NOM indeed increased over time, while mortality decreased in splenectomy/splenorrhaphy patients. From these results, we surmised that patient selection for a certain management strategy improved over the years, in accordance with the guidelines. However, there were no data that would allow us to evaluate the direct connection between the guidelines in effect at the time of admission and the choice of treatment in individual cases. Thus, we were not able to determine whether the guidelines had a direct effect on the choice and outcome of the treatment. Further studies are warranted in this direction.

There were several limitations to the current study. First, although the present study was a nationwide database survey, sampling of the 244 participating hospitals was not randomised or population-based. Besides, the number of patients per year increased in each phase because the number of hospitals participating in the database increased over time. The choice of management strategy is seemingly reflective of practice in specific trauma centres, and the increase in the number of participating hospitals over time might have had some effect on the results obtained in this study. However, we used the logistic regression model adjusted for the within-hospital clustering effect to account for this possibility. Second, there is a possibility that the initial rate of NOM failure (i.e., patients who were initially treated with NOM but converted to splenectomy/splenorrhaphy after 6 hours) status, re-interventions, or intervention-related complications have affected the mortality after splenic injury. However, the JTDB contains neither information about these factors, advancements in health care with resource utilisation, prehospital administered care on scene, nor the cause of death, so that we could not evaluate directly the effect of the management for splenic trauma on the outcome of our study. Third, we could not assess the quality of the intervention (e.g., skills of the surgeon performing splenectomy/splenorrhaphy, devices used during TAE, etc.), that of the perioperative management, or the cause of death, as such data are not available in the JTDB. Additionally, TAE might have involved not only angioembolisation of spleen bleeding, but also that of liver or kidney bleeding, and we did not account for the potential effect of this additional angioembolisation on mortality. Finally, we could not evaluate the direct effect of NOM on 30-day mortality. As suggested in the guidelines [23, 24], NOM is indicated only for hemodynamically stable patients. Hemodynamic states (i.e., vital signs) tend to change dramatically in the early stages after splenic injury; however, the JTDB only contained information regarding vital signs upon admission to the emergency room. The comparison of 30-day mortality between patients managed with NOM and those managed with splenectomy/splenorrhaphy would not be reliable in the context of the data included in our analysis. Further studies are required to evaluate the effect of NOM on mortality after splenic injury.

Conclusions

The results of our nation-wide study suggest that, although the severity of injuries in Japan remained at the same level between 2004 and 2014, in-hospital 30-day mortality after blunt splenic injury decreased significantly, even after adjustment for within-hospital clustering and other factors independently associated with mortality. This information is useful for clinicians when making decisions about treatments for patients with blunt splenic injury. Nevertheless, as the present study did not elucidate the complex causes underlying the observed trends, further studies are required to confirm our results.

Author Contributions

Resources: Hiroyuki Yokota.

Supervision: Kiyoshi Matsuda, Shiei Kim, Yuta Moroe, Reo Fukuda, Kyoko Unemoto, Hiroyuki Yokota.

Writing – original draft: Chie Tanaka, Takashi Tagami, Hisashi Matsumoto.

Writing – review & editing: Chie Tanaka, Takashi Tagami, Hisashi Matsumoto, Kiyoshi Matsuda, Shiei Kim, Yuta Moroe, Reo Fukuda, Kyoko Unemoto, Hiroyuki Yokota.

References

1. Raza M, Abbas Y, Devi V, Prasad KV, Rizk KN, Nair PP. Non operative management of abdominal trauma—a 10 years review. World J Emerg Surg. 2013; 8:14. https://doi.org/10.1186/1749-7922-8-14 PMID: 23561288

2. Jacoby RC, Wisner DH. Injury to the Spleen. In: Feliciano DV, Mattox KL, Moore EE, editors. Trauma. Sixth ed. the United States of America: The McGraw-Hill Companies; 2008. p. 661–680.

3. Richardson JD. Changes in the management of injuries to the liver and spleen. J Am Coll Surg. 2005; 200:648–669. https://doi.org/10.1016/j.jamcollsurg.2004.11.005 PMID: 15848355

4. Cirocchi R, Corsi A, Castellani E, Barberini F, Renzi C, Cagini L, et al. Case series of non-operative management vs. operative management of splenic injury after blunt trauma. Ulus Travma Acil Cerrahi Derg. 2014; 20:91–96. https://doi.org/10.5505/tjtes.2014.99442 PMID: 24740333

5. Hamlat CA, Arbabi S, Koepsell TD, Maier RV, Jurkovich GJ, Rivara FP. National variation in outcomes and costs for splenic injury and the impact of trauma systems: a population-based cohort study. Ann Surg. 2012; 255:165–170. https://doi.org/10.1097/SLA.0b013e31823840ca PMID: 22156925

6. Sabe AA, Claridge JA, Rosenblum DI, Lie K, Malangoni MA. The effects of splenic artery embolization on nonoperative management of blunt splenic injury: a 16-year experience. J Trauma. 2009; 67:565–572; discussion 571–562. https://doi.org/10.1097/TA.0b013e3181b17010 PMID: 19741401

7. Rosati C, Ata A, Siskin GP, Megna D, Bonville DJ, Stain SC. Management of splenic trauma: a single institution's 8-year experience. Am J Surg. 2015; 209:308–314. https://doi.org/10.1016/j.amjsurg.2014.06.034 PMID: 25457232

8. van der Vlies CH, van Delden OM, Punt BJ, Ponsen KJ, Reekers JA, Goslings JC. Literature review of the role of ultrasound, computed tomography, and transcatheter arterial embolization for the treatment of traumatic splenic injuries. Cardiovasc Intervent Radiol. 2010; 33:1079–1087. https://doi.org/10.1007/s00270-010-9943-6 PMID: 20668852

9. Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative Management of Blunt Splenic Injury: A 5-Year Experience. The Journal of Trauma: Injury, Infection, and Critical Care. 2005; 58:492–498.

10. Olthof DC, Joosse P, van der Vlies CH, de Haan RJ, Goslings JC. Prognostic factors for failure of nonoperative management in adults with blunt splenic injury: a systematic review. J Trauma Acute Care Surg. 2013; 74:546–557. https://doi.org/10.1097/TA.0b013e31827d5e3a PMID: 23354249

11. Velmahos GC, Zacharias N Fau—Emhoff TA, Emhoff Ta Fau—Feeney JM, Feeney Jm Fau—Hurst JM, Hurst Jm Fau—Crookes BA, Crookes Ba Fau—Harrington DT, et al. Management of the most severely injured spleen: a multicenter study of the Research Consortium of New England Centers for Trauma (ReCONECT). 2010.

12. Cirocchi R, Boselli C, Corsi A, Farinella E, Listorti C, Trastulli S, et al. Is non-operative management safe and effective for all splenic blunt trauma? A systematic review. Crit Care. 2013; 17:R185. https://doi.org/10.1186/cc12868 PMID: 24004931

13. Scarborough JE, Ingraham AM, Liepert AE, Jung HS, O'Rourke AP, Agarwal SK. Nonoperative Management Is as Effective as Immediate Splenectomy for Adult Patients with High-Grade Blunt Splenic Injury. J Am Coll Surg. 2016; 223:249–258. https://doi.org/10.1016/j.jamcollsurg.2016.03.043 PMID: 27112125

14. Kimura A, Tanaka N. Whole-body computed tomography is associated with decreased mortality in blunt trauma patients with moderate-to-severe consciousness disturbance: a multicenter, retrospective study. J Trauma Acute Care Surg. 2013; 75:202–206. https://doi.org/10.1097/TA.0b013e3182905ef7 PMID: 23702629

15. Norii T, Crandall C, Terasaka Y. Survival of severe blunt trauma patients treated with resuscitative endovascular balloon occlusion of the aorta compared with propensity score-adjusted untreated patients. J Trauma Acute Care Surg. 2015; 78:721–728. https://doi.org/10.1097/TA.0000000000000578 PMID: 25742248

16. Inoue J, Shiraishi A, Yoshiyuki A, Haruta K, Matsui H, Otomo Y. Resuscitative endovascular balloon occlusion of the aorta might be dangerous in patients with severe torso trauma: A propensity score analysis. J Trauma Acute Care Surg. 2016; 80:559–566; discussion 566–557. https://doi.org/10.1097/TA.0000000000000968 PMID: 26808039

17. Suzuki K, Inoue S, Morita S, Watanabe N, Shintani A, Inokuchi S, et al. Comparative Effectiveness of Emergency Resuscitative Thoracotomy versus Closed Chest Compressions among Patients with Critical Blunt Trauma: A Nationwide Cohort Study in Japan. PLoS One. 2016; 11:e0145963. https://doi.org/10.1371/journal.pone.0145963 PMID: 26766574

18. Medicine AftAoA. Abbreviated Injury Scale 2005 update 2008. Barrington Illinois: Association for the Advancement of Automotive Medicine; 2008.

19. Baker SP, O'Neill B, Haddon W Jr., Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma. 1974; 14:187–196. PMID: 4814394

20. Moore EE, Moore FA. American Association for the Surgery of Trauma Organ Injury Scaling: 50th anniversary review article of the Journal of Trauma. J Trauma. 2010; 69:1600–1601. https://doi.org/10.1097/TA.0b013e318201124e PMID: 21150537

21. Chikuda H, Yasunaga H, Takeshita K, Horiguchi H, Kawaguchi H, Ohe K, et al. Mortality and morbidity after high-dose methylprednisolone treatment in patients with acute cervical spinal cord injury: a propensity-matched analysis using a nationwide administrative database. Emerg Med J. 2014; 31:201–206. https://doi.org/10.1136/emermed-2012-202058 PMID: 23449889

22. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet. 1974; 2:81–84. PMID: 4136544

23. Eastern Association for the Surgery of Trauma (EAST) Ad Hoc Committee on Practice Management Guideline Development. Non-operative management of blunt injury to the liver and spleen 2003. 2003 [updated 2003; cited 2016 February 14]. Available from: https://www.east.org/content/documents/livspleen.pdf

24. Moore FA, Davis JW, Moore EE Jr., Cocanour CS, West MA, McIntyre RC Jr. Western Trauma Association (WTA) critical decisions in trauma: management of adult blunt splenic trauma. J Trauma. 2008; 65:1007–1011. https://doi.org/10.1097/TA.0b013e31818a93bf PMID: 19001966

25. Stassen NA, Bhullar I, Cheng JD, Crandall ML, Friese RS, Guillamondegui OD, et al. Selective nonoperative management of blunt splenic injury: an Eastern Association for the Surgery of Trauma practice management guideline. J Trauma Acute Care Surg. 2012; 73:S294–300. https://doi.org/10.1097/TA.0b013e3182702afc PMID: 23114484

26. Little RJ, D'Agostino R, Cohen ML, Dickersin K, Emerson SS, Farrar JT, et al. The prevention and treatment of missing data in clinical trials. N Engl J Med. 2012; 367:1355–1360. https://doi.org/10.1056/NEJMsr1203730 PMID: 23034025

27. Janssen KJ, Donders Ar Fau—Harrell FE Jr., Harrell Fe Fau—Vergouwe Y Jr, Vergouwe Y Fau—Chen Q, Chen Q Fau—Grobbee DE, Grobbee De Fau—Moons KGM, et al. Missing covariate data in medical research: to impute is better than to ignore. J Clin Epidemiol. 2010; 63:721–727. https://doi.org/10.1016/j.jclinepi.2009.12.008 PMID: 20338724

28. Donders AR, van der Heijden GJ, Stijnen T, Moons KG. Review: a gentle introduction to imputation of missing values. J Clin Epidemiol. 2006; 59:1087–1091. https://doi.org/10.1016/j.jclinepi.2006.01.014 PMID: 16980149

29. Surgeons ACo. ATLS, Advanced Trauma Life Support Prgram for Doctors. 8 ed: American College of Surgeons; 2008.

30. Lerner EB, Moscati RM. The golden hour: scientific fact or medical "urban legend"? Acad Emerg Med. 2001; 8:758–760. PMID: 11435197

31. Hubbard AE, Ahern J Fau—Fleischer NL, Fleischer Nl Fau—Van der Laan M, Van der Laan M Fau—Lippman SA, Lippman Sa Fau—Jewell N, Jewell N Fau—Bruckner T, et al. To GEE or not to GEE: comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. Epidemiolofy. 2010; 21:467–474.

32. Peitzman AB, Harbrecht BG, Rivera L, Heil B, Eastern Association for the Surgery of Trauma Multiinstitutional Trials W. Failure of observation of blunt splenic injury in adults: variability in practice and adverse consequences. J Am Coll Surg. 2005; 201:179–187. https://doi.org/10.1016/j.jamcollsurg.2005.03.037 PMID: 16038813

33. Peitzman AB, Heil B, Rivera L, Federle MB, Harbrecht BG, Clancy KD, et al. Blunt splenic injury in adults: Multi-institutional Study of the Eastern Association for the Surgery of Trauma. J Trauma. 2000; 49:177–187; discussion 187–179. PMID: 10963527

34. Bhullar IS, Frykberg ER, Siragusa D, Chesire D, Paul J, Tepas JJ 3rd, et al. Selective angiographic embolization of blunt splenic traumatic injuries in adults decreases failure rate of nonoperative

management. J Trauma Acute Care Surg. 2012; 72:1127–1134. https://doi.org/10.1097/TA.
0b013e3182569849 PMID: 22673236

35. El-Matbouly M, Jabbour G, El-Menyar A, Peralta R, Abdelrahman H, Zarour A, et al. Blunt splenic trauma: Assessment, management and outcomes. Surgeon. 2016; 14:52–58. https://doi.org/10.1016/j.surge.2015.08.001 PMID: 26330367

36. SOS-KANTO_2012_study_group. Changes in treatments and outcomes among elderly patients with out-of-hospital cardiac arrest between 2002 and 2012: A post hoc analysis of the SOS-KANTO 2002 and 2012. Resuscitation. 2015; 97:76–82. https://doi.org/10.1016/j.resuscitation.2015.09.379 PMID: 26410571

37. SOS-KANTO_2012_study_group. Changes in pre- and in-hospital management and outcomes for out-of-hospital cardiac arrest between 2002 and 2012 in Kanto, Japan: the SOS-KANTO 2012 Study. Acute Medicine & Surgery. 2015; 2:225–233.

38. Hondo K, Shiraishi A, Fujie S, Saitoh D, Otomo Y. In-hospital trauma mortality has decreased in Japan possibly due to trauma education. J Am Coll Surg. 2013; 217:850–857 e851. https://doi.org/10.1016/j.jamcollsurg.2013.05.026 PMID: 23993144

39. Mashiko K. Trauma systems in Japan: history, present status and future perspectives. J Nippon Med Sch. 2005; 72:194–202. PMID: 16113489

40. Tagami T, Yokota H, Hirata K, Takashige T, Satake M, Matsui J, et al. Response to letter regarding article, "Implementation of the fifth link of the chain of survival concept for out-of-hospital cardiac arrest". Circulation. 2013; 127:e567. PMID: 23741746

41. Accumulation Number of JATEC courses and prvidors. Available from: http://www.jtcr-jatec.org/jatec_decade.html.

42. Rossaint R, Bouillon B, Cerny V, Coats TJ, Duranteau J, Fernandez-Mondejar E, et al. The European guideline on management of major bleeding and coagulopathy following trauma: fourth edition. Crit Care. 2016; 20:100. https://doi.org/10.1186/s13054-016-1265-x PMID: 27072503

43. Hoff WS, Holevar M, Nagy KK, Patterson L, Young JS, Arrillaga A, et al. Practice management guidelines for the evaluation of blunt abdominal trauma: the East practice management guidelines work group. J Trauma. 2002; 53:602–615. https://doi.org/10.1097/01.TA.0000025413.43206.97 PMID: 12352507

44. Cannon JW, Khan MA, Raja AS, Cohen MJ, Como JJ, Cotton BA, et al. Damage control resuscitation in patients with severe traumatic hemorrhage: A practice management guideline from the Eastern Association for the Surgery of Trauma. J Trauma Acute Care Surg. 2017; 82:605–617. https://doi.org/10.1097/TA.0000000000001333 PMID: 28225743

45. Cotton BA, Gunter OL, Isbell J, Au BK, Robertson AM, Morris JA Jr., et al. Damage control hematology: the impact of a trauma exsanguination protocol on survival and blood product utilization. J Trauma. 2008; 64:1177–1182; discussion 1182–1173. https://doi.org/10.1097/TA.0b013e31816c5c80 PMID: 18469638