J Korean Med Sci. 2022 Dec 26;37(50):e349
https://doi.org/10.3346/jkms.2022.37.e349
eISSN 1598-6357·pISSN 1011-8934

JKMS

Original Article

Emergency & Critical Care Medicine

National Follow-up Survey of Preventable Trauma Death Rate in Korea

Junsik Kwon,[1] **Myeonggyun Lee**,[2] **Jonghwan Moon**,[1] **Yo Huh**,[1] **Seoyoung Song**,[3] **Sora Kim**,[3] **Seung Joon Lee**,[4] **Borami Lim**,[4] **Hyo Jin Kim**,[4] **Yoon Kim**,[5] **Hyung il Kim**,[6] **Jung-Ho Yun**,[7] **Byungchul Yu**,[8] **Gil Jae Lee**,[8] **Jae Hun Kim**,[9] **Oh Hyun Kim**,[10] **Wook Jin Choi**,[11] **Myungjae Jung**,[12] **and Kyoungwon Jung** [1]

[1]Division of Trauma Surgery, Department of Surgery, Ajou University School of Medicine, Suwon, Korea
[2]Division of Biostatistics, Department of Population Health, New York University Grossman School of Medicine, New York, NY, USA
[3]Gyeonggi South Regional Trauma Center, Ajou University Hospital, Suwon, Korea
[4]National Emergency Medical Center, National Medical Center, Seoul, Korea
[5]Department of Health Policy and Management, Seoul National University College of Medicine, Seoul, Korea
[6]Department of Emergency Medicine, Dankook University Hospital, Cheonan, Korea
[7]Department of Neurosurgery, Trauma Center, Dankook University Hospital, Cheonan, Korea
[8]Department of Traumatology, Gachon University College of Medicine, Gachon University Gil Medical Center, Incheon, Korea
[9]Department of Trauma and Surgical Critical Care and Medical Research Institute, Pusan National University Hospital, Busan, Korea
[10]Department of Emergency Medicine, Yonsei University Wonju College of Medicine, Wonju, Korea
[11]Department of Emergency Medicine, Ulsan University College of Medicine, Ulsan, Korea
[12]Department of Trauma Surgery Hanyang University of Medicine, Myongi Hospital, Goyang, Korea

Received: Jul 21, 2022
Accepted: Sep 26, 2022
Published online: Nov 29, 2022

Address for Correspondence:
Kyoungwon Jung, MD, PhD
Division of Trauma Surgery, Department of Surgery, Ajou University School of Medicine, 164 World cup-ro, Yeoungtong-gu, Suwon 16499, Republic of Korea.
Email: jake98@daum.net
jake98@ajou.ac.kr

ORCID iDs
Junsik Kwon
https://orcid.org/0000-0003-3164-4995
Myeonggyun Lee
https://orcid.org/0000-0002-0064-2770
Jonghwan Moon
https://orcid.org/0000-0002-4630-3301
Yo Huh
https://orcid.org/0000-0002-1220-1534
Seoyoung Song
https://orcid.org/0000-0003-3359-9526
Sora Kim
https://orcid.org/0000-0001-9787-2339
Seung Joon Lee
https://orcid.org/0000-0003-1655-0878
Borami Lim
https://orcid.org/0000-0001-6007-2776

ABSTRACT

Background: The preventable trauma death rate survey is a basic tool for the quality management of trauma treatment because it is a method that can intuitively evaluate the level of national trauma treatment. We conducted this study as a national biennial follow-up survey project and report the results of the review of the 2019 trauma death data in Korea.
Methods: From January 1, 2019 to December 31, 2019, of a total of 8,482 trauma deaths throughout the country, 1,692 were sampled from 279 emergency medical institutions in Korea. All cases were evaluated for preventability of death and opportunities for improvement using a multidisciplinary panel review approach.
Results: The preventable trauma death rate was estimated to be 15.7%. Of these, 3.1% were judged definitive preventable deaths, and 12.7% were potentially preventable deaths. The odds ratio for preventable traumatic death was 2.56 times higher in transferred patients compared to that of patients who visited the final hospital directly. The group that died 1 hour after the accident had a statistically significantly higher probability of preventable death than that of the group that died within 1 hour after the accident.
Conclusion: The preventable trauma death rate for trauma deaths in 2019 was 15.7%, which was 4.2%p lower than that in 2017. To improve the quality of trauma treatment, the transfer of severe trauma patients to trauma centers should be more focused.

Keywords: Injuries and Wounds; Trauma Centers; Mortality; Korea

Hyo Jin Kim
https://orcid.org/0000-0002-7983-7553
Yoon Kim
https://orcid.org/0000-0001-7257-1679
Hyung il Kim
https://orcid.org/0000-0002-2843-5597
Jung-Ho Yun
https://orcid.org/0000-0003-4091-1346
Byungchul Yu
https://orcid.org/0000-0002-2444-2343
Gil Jae Lee
https://orcid.org/0000-0002-7943-5933
Jae Hun Kim
https://orcid.org/0000-0003-4504-9898
Oh Hyun Kim
https://orcid.org/0000-0002-8415-0318
Wook Jin Choi
https://orcid.org/0000-0001-8779-0081
Myungjae Jung
https://orcid.org/0000-0002-9128-1180
Kyoungwon Jung
https://orcid.org/0000-0001-7895-0362

Funding

This study was funded by the Ministry of Health and Welfare, Republic of Korea (2020-10-16). The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Disclosure

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Jung K, Kwon J. Data curation: Lee SJ, Lim B, Kim HJ. Formal analysis: Jung K, Lee M. Investigation: Jung K, Kwon J, Moon J, Huh Y, Song S, Kim S, Kim HI, Yu B, Lee GJ, Kim JH, Kim OH, Yun JH, Choi WJ, Jung M. Methodology: Jung K, Kwon J, Kim Y. Shin J. Writing - original draft: Jung K, Kwon J, Lee M. Writing - review & editing: Jung K, Kwon J, Lee SJ, Lim B, Kim HJ, Lee M, Moon J, Huh Y, Song S, Kim S, Kim HI, Yu B, Lee GJ, Kim JH, Kim OH, Yun JH, Choi WJ, Jung M, Kim Y.

INTRODUCTION

Trauma, both in Korea and globally, is a major cause of death in populations aged 39 years or younger. Unlike cancer and cardiovascular diseases, most nations treat trauma as an important public health issue, since it causes deaths and disabilities in the socioeconomically active age groups of the population.[1-4] To reduce the massive socioeconomic losses caused by trauma, trauma care quality must be strictly managed at the national level.[5] Expert panel review of trauma deaths is a traditional method of quality management for trauma treatment, both for evaluating its quality and for identifying issues in the treatment.[1,6] Despite many limitations, this method of evaluation remains critical for the intuitive verification of a nation's competency for treating traumatic injuries. The preventable trauma death rate (PTDR), which is derived from the method mentioned above, is defined as the ratio of patients who have died from injuries they could have survived had they received appropriate treatment after being quickly transported to a suitable hospital within an acceptable time frame.[7] In Korea, PTDR has been recorded periodically, starting from the late 1990s. Korea's PTDR, which was alarmingly high at 40.5% when first measured in 1997, started to decrease with the establishment of the national trauma treatment system (e.g. establishment of the first regional trauma center [RTC] in 2012).[8-11] PTDR had decreased significantly to 30.5% in 2015, and was reportedly 19.9% in the 2017 mortality statistics: this was the lowest reported value compared to previous studies conducted in Korea.[12-14] The current study was conducted as a follow-up study of the national survey of trauma deaths, with the goal of establishing a reliable metric for preventable death rates based on the 2019 trauma mortality statistics, and securing foundational data that could be used to design enhancements for the quality management of trauma treatment, by analyzing issues related to preventable death rates.

METHODS

Study population

The current study was conducted using data from patients who had died from traumatic injuries after visiting emergency centers between January 1, 2019 and December 31, 2019. The definition of trauma patients was the presence of one or more S or T codes according to the seventh edition of the Korean Standard Classification of Diseases.[15] However, cases were excluded if the only trauma-related code was due to nonspecific influence of external factors (e.g. frostbite, poisoning, intoxication, drowning, first-degree burns, and others) or complications related to surgery and other medical reasons. As of December 31, 2019, 8,482 trauma-related deaths occurred in 363 of 402 emergency medicine institutions throughout Korea. Among these deaths, 1,675 patients had died on arrival (DOA) in the first facility, 508 patients died in the emergency department (ED) in the first facility, 4,067 patients died after hospital admission in the first facility, and 2,232 patients died after transfer to a second facility.

Sampling

The Korean National Emergency Department Information System (NEDIS)[16] was used as a sampling framework for the mortality statistics of trauma patients. The NEDIS is a national database that includes clinical and administrative data of all patients who visit the ED. To create an unbiased sample that reflects the population characteristics, a stratified two-stage cluster sampling method was used, with a double layer design for stratification. The variables used for the first stratification were region (Seoul, Gyeonggi/Incheon, Daejeon/Sejong/

Chungcheong, Gangwon, Gwangju/Jeolla, Busan/Daegu/Ulsan/Gyeongsang, Jeju), type of hospital (RTC, regional emergency medical center, local emergency medical center, and local emergency medical institution), and number of deaths (≥ 100, 50–99, 30–49, 10–29, and < 10). Then, for the second stratification, the variables of time of death (DOA in the first facility, death in the ED in the first facility, death after hospital admission in the first facility, death after inter-hospital transfer) and patient age (≤ 14 years, 15–54 years, ≥ 55 years) were used. All patients under 14 years of age were included in the sample, even though they could have been excluded due to the small number of deaths. Also, for accurate identification of the process and reasons for death, all patients who died at RTCs and regional emergency medical centers, which are mainly responsible for the treatment of patients with severe trauma, were included in the sample.

Data collection and data type

The patient's medical records were collected from 279 facilities, those that provided treatment for patients who died from trauma and were included in the sample. The corresponding hospitals were asked to provide the necessary medical records in cooperation with the Ministry of Health and Welfare, according to the "Emergency Medical Service Act" and the "Medical Service Act." Key imaging data were saved in CDs before being mailed. The purpose was to ensure that the copy of the mandatory records included records of the initial visit to the ED, progress notes, nursing care chart, official imaging reading paper, blood test results and discharge records. If additional data was needed during the panel review, the facility was asked for records from hospitals involved in the transfer process; 119 Emergency Medical Service records were also collected.

Multi-staged and multidisciplinary mortality case review

For reviewing medical records, we used a structured review form with an audit filter included (**Supplementary Data 1**). This form was developed based on the data sheet suggested by the World Health Organization (WHO) guidelines for trauma quality improvement programs.[1] Trauma coordinators (total 32), working in RTCs, were tasked with the initial review of mandatory records, after they completed the course of study for investigators working on cases of death, provided by the National Medical Center (NMC). The coordinators organized the information needed by the expert panel to determine the "preventability of trauma death," such as the general characteristics of the patients, information related to transfer events, and information related to the transfer and treatment of patients. To review and determine death cases, 25 doctors who work at RTCs and specialize in treating trauma patients were selected for the panel. They are case investigation experts currently in charge of independent panel investigations on the preventable trauma deaths in the centers they are currently working at and have all completed the related coursework provided by the NMC. They were divided into five teams, each comprising two general surgeons, one thoraco-vascular surgeon, one neurosurgeon, and one emergency physician. Furthermore, the Trauma Death Review Committee (TDRC), composed of five senior trauma surgeons, developed guidelines for the overall review process and was responsible for educating the other panel members. Multiple workshops were held to introduce the guidelines and instructions for panel screening procedures. Also, when the "preventability" of a trauma death was not determined in the panel discussions at the team level, the TDRC reviewed the case once again to make the final decision. To evaluate the reliability of panel reviews conducted by each team, two teams—arbitrarily determined from the five teams—were to judge a part of the case judged by the other teams: then, the results were compared (**Fig. 1**).

https://doi.org/10.3346/jkms.2022.37.e349

Fig. 1. Formation of the preliminary investigators and the panel of experts and the review process.

Judging criteria for the "preventability" of trauma deaths

The basic framework for investigating trauma death cases used the method suggested in the "Guidelines for trauma quality improvement programs," published by the WHO.[1] This standard considers the severity of trauma and the appropriateness of the treatment provided to judge the "preventability" of an individual case of trauma death. Preventable trauma deaths were aggregated to include both "definite preventable (P)" and "potentially preventable (PP)" deaths.

Statistical analysis

The population was estimated with the sample weight values of the sample group. To maintain continuity with existing research, the methods for estimating and adjusting the mortality rate were identical to those used in the previous survey.[9] Using multiple logistic regression analysis, risk factors for preventable trauma deaths were identified; variables estimated to have potential influence on the PTDR were used as explanatory variables. The variables included in the logistic regression model were the following: age, hospital type, transfer between hospitals, time from accident to death, time from accident to hospital arrival, and mechanism of injury. Rather than the estimated population, the actual number of deaths was used to analyze the risk factors. Additionally, Cohen's Kappa coefficient was used to analyze the conformity rate between the judgments of panels, establishing the reliability of the results.

Ethics statement

The current study was approved by the Institutional Review Board of Ajou University (AJIRB-MED-EXP-20-473). Due to the observational characteristic of the study, the board renounced the requirement for prior consent.

RESULTS

General characteristics of the patients included in the study

Of the 279 medical facilities extracted from the sample, 243 (87.1%) facilities provided data for 1,460 (86.3%) of the 1,692 cases in the study, all included in the case review. By region, 43 hospitals in Seoul (261 deaths), 64 in Gyeonggi/Incheon (431 deaths), 49 in Gangwon/Daejeon/Chungcheong (309 deaths), 52 in Gwangju/Jeolla/Jeju (243 deaths), and 71 in Busan/Daegu/Ulsan/Gyeongsang (448 deaths) were included in the sample (**Table 1**). Among these, 397 cases were excluded for being unrelated to trauma, four for the patients still alive, and 57 cases for lacking the minimum information required for judgment. Finally, the "preventability" could be judged for 1,002 cases. For all the cases judged, the raking ratio method was applied to calculate the final weight, which amounted to 1,208 cases (**Fig. 2**). Their average age was 62.0 years (standard deviation, 20.3 years), of whom 845 (70.0%) were men, with most of the injury mechanisms being blunt injury (96.4%). The number of patients who died at RTC was almost half (542 cases, 44.9%) of the total, the largest inclusion. The number of cases with at least one transfer was 268 (22.2%). Regarding the mode of transport, most used the 119 ambulances (895 cases, 74.1%) (**Table 2**).

https://doi.org/10.3346/jkms.2022.37.e349

Table 1. Distribution of the sample facilities and trauma deaths according to regions and types of facilities

Regions	Total	Regional emergency medical center	Local emergency medical center		Local emergency medical institution	
			< 30 deaths	≥ 30 deaths	< 30 deaths	≥ 30 deaths
Total	279 (1,692)[a]	38 (739)	70 (231)	47 (477)	122 (230)	2 (15)
Seoul	43 (261)	5 (62)	10 (38)	15 (119)	11 (27)	2 (15)
Gyeonggi/Incheon	64 (431)	9 (215)	25 (82)	10 (99)	20 (35)	0 (0)
Gangwon/Daejeon/Chungbuk/Chungnam	49 (309)	7 (138)	10 (35)	9 (95)	23 (41)	0 (0)
Gwangju/Jeju/Jeonbuk/Jeonam	52 (243)	7 (143)	14 (38)	2 (16)	29 (47)	0 (0)
Busan/Daegu/Ulsan/Gyeongbuk/Gyeongnam	71 (448)	10 (181)	11 (38)	11 (146)	39 (80)	0 (0)

[a]All values are presented as the number of sample facilities (number of trauma deaths).

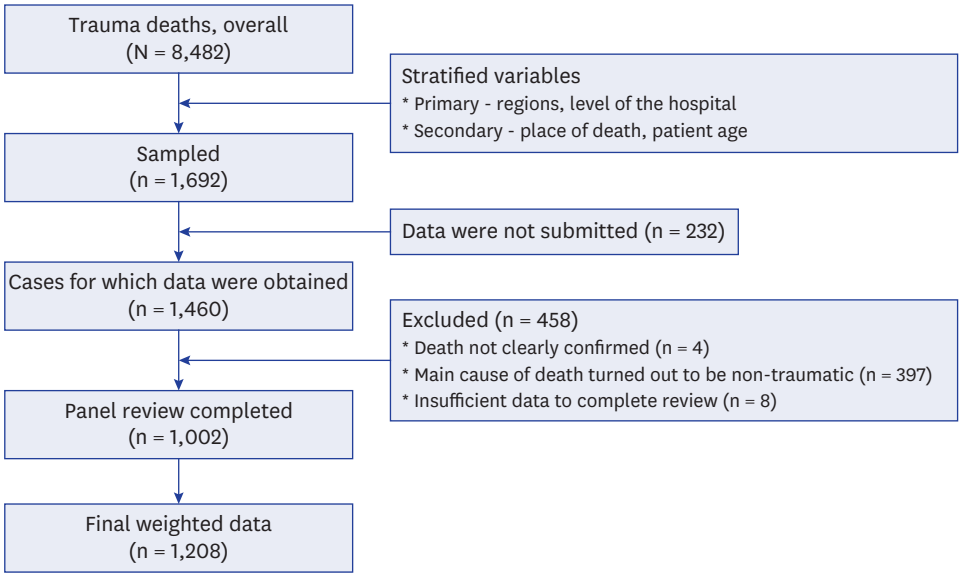

Fig. 2. Study design and sampling.

PTDR and related factors

Korea's PTDR, derived from the review of the 2019 trauma mortality statistics, was 15.7%: From this value, 3.1% were P, and 12.7% were PP (**Table 3**). Cohen's Kappa index of inter-rater reliability between raters, conducted with a convenience sample of 56 cases, had a value of 0.4, placing it in the moderate category. Factors such as age, time of death, type of emergency medical facility, whether the patient was transferred or not, method of transportation to the medical facility, and time from accident to death showed statistically significant differences between the univariate groups of preventable (P + PP) and non-preventable deaths (non-preventable [NP] + non-preventable, but with care that could have been improved [NPCI]) (**Table 4**).

Regression analysis on the judgment of preventable trauma deaths and related factors

The results of the regression model for the prediction of preventable trauma death—made using factors such as age, the type of final emergency medical facility where the death occurred, and the number of transfers between hospitals—indicated that the probability of the prediction of preventable trauma death was higher in cases "once through another hospital" compared to cases "directly visited the last hospital" with statistical significance, with an odds ratio of 2.56. The cases of "More than twice through another hospital" also had statistically higher probabilities of being judged as preventable trauma deaths, with a probability ratio of 3.72. In a model using the variable "time from accident to death" instead of the variable

Table 2. Baseline characteristics of the study participants (N = 1,208)

Characteristics	Values[a]
Sex	
Male	845 (70.0)
Female	364 (30.1)
Age, yr	62.0 ± 20.3
≤ 14	16 (1.3)
15–54	372 (30.8)
≥ 55	821 (68)
Time of death	
DOA in first facility	381 (31.5)
Death in ED in the first facility	97 (8.0)
Death after hospital admission in the first facility	462 (38.2)
Death after inter-hospital transfer	267 (22.1)
Area	
Seoul	162 (13.4)
Gyeonggi/Incheon	305 (25.2)
Gangwon/Daejeon/Chungbuk/Chungnam	225 (18.6)
Gwangju/Jeju/Jeonbuk/Jeonam	175 (14.5)
Busan/Daegu/Ulsan/Gyeongbuk/Gyeongnam	342 (28.3)
Type of emergency medical institutions	
Regional trauma center	542 (44.9)
Regional emergency medical center	173 (14.3)
Local emergency medical center	363 (30.0)
Local emergency medical institution	121 (10.0)
Mechanism of injury	
Blunt	1,164 (96.4)
Penetrating	16 (13.0)
Not further specified	29 (2.4)
Transfer	
Directly visited to the last hospital	941 (77.9)
Transferred from another hospital	268 (22.2)
One time via other hospital	249 (20.6)
More than two times via other hospital	19 (1.6)
Mode of transport	
119	895 (74.1)
Hospital ambulance	42 (3.5)
129	184 (15.2)
Others and unknown	82 (6.8)

Values are presented as number (%) or mean ± standard deviation.
[a]All percentage values are weighted. Thus, there may be differences in the sum of each factor.

Table 3. Preventable trauma death rate (N = 1,208)

Variables	No. (%)	95% confidence interval
PTD (P + PP)	190 (15.7)	11.3–21.1
P	37 (3.1)	0.8–10.2
PP	153 (12.7)	8.4–18.3
Non-PTD (NP + NPCI)	1,018 (84.3)	82.0–86.4
NP	686 (56.8)	53.1–60.4
NPCI	332 (27.5)	23.0–32.3

PTD = preventable trauma death, P = preventable, PP = potentially preventable, NP = nonpreventable, NPCI = nonpreventable, but with care that could have been improved.

"inter-hospital transfer," time to death was correlated with the judgment of preventable trauma deaths. Compared to the group where death occurred within one hour of the accident, all groups where death occurred one or more hours after the accident had a higher probability being judged as preventable trauma deaths, with statistical significance (**Table 5**).

https://doi.org/10.3346/jkms.2022.37.e349

Table 4. Factors associated with preventable trauma death (N = 1,208)

Variables	P + PP[a]	NP + NPCI[a]	χ^2 (*P*)
Sex			0.657 (0.418)
Male	138 (16.3)	707 (83.7)	
Female	52 (14.3)	312 (85.7)	
Age, yr			21.339 (< 0.001)
≤ 14	1 (6.3)	15 (93.8)	
15–54	33 (8.9)	339 (91.1)	
≥ 55	157 (19.1)	664 (80.9)	
Time of death			115.28 (< 0.001)
DOA in first facility	3 (0.8)	378 (99.2)	
Death in ED in the first facility	31 (32.0)	66 (68.0)	
Death after hospital admission in the first facility	81 (17.5)	381 (82.5)	
Death after inter-hospital transfer	75 (28.1)	192 (71.9)	
Type of emergency medical institutions			115.28 (< 0.001)
Regional Trauma Center	76 (14.0)	466 (86.0)	
Regional emergency medical center	41 (23.7)	132 (76.3)	
Local emergency medical center	47 (12.9)	316 (87.1)	
Local emergency medical institution	23 (19.0)	98 (81.0)	
Mechanism of injury[b]			0.003 (0.958)
Blunt	188 (16.2)	976 (83.8)	
Penetrating	2 (12.5)	14 (87.5)	
Transfer			40.345 (< 0.001)
Directly visited to the last hospital	115 (12.2)	826 (87.8)	
Transferred from the other hospital	75 (28.0)	193 (72.0)	
One time via other hospital	68 (27.3)	181 (72.7)	
More than two times via other hospital	7 (36.8)	12 (63.2)	
Mode of transport			41.549 (< 0.001)
119	107 (12.0)	788 (88.0)	
Hospital ambulance	15 (35.7)	27 (64.3)	
129	50 (27.2)	134 (72.8)	
Others and unknown	16 (19.5)	66 (80.5)	
Time from accident to death			39.756 (< 0.001)
≤ 1 hr	11 (3.9)	274 (96.1)	
1–6 hr	43 (18.1)	194 (81.9)	
6–24 hr	16 (17.0)	78 (83.0)	
1–7 days	46 (21.8)	165 (78.2)	
8–30 days	35 (18.4)	155 (81.6)	
> 30 days	17 (17.9)	78 (82.1)	

P = preventable, PP = potentially preventable, NP = nonpreventable, NPCI = nonpreventable, but with care that could have been improved, DOA = died on arrival, ED = emergency department.
[a]All percentage values were weighted so there may be differences in the sum of each factor; [b]Excluding "Others/unknown" from the mechanism of injury.

DISCUSSION

PTDR is a fundamental metric for the intuitive evaluation of trauma treatment competency for a nation or region. Unlike Korea, which has not yet completed its system for the systematic treatment of trauma patients, nations with leading competencies in trauma treatment (e.g. the United States and Canada) have an established regional trauma system that is centered around designated trauma centers, with reported PTDR of approximately 5% since the early 2000s.[17,18] A 2016 report from the U.S. National Academies of Sciences, Engineering, and Medicine recommends a number of measures to improve the quality of trauma treatment, demanding the goal of 0% PTDR.[19] Korea, as a realistic goal, aimed to reach 15% PTDR by 2021. For this, massive financial resources have been invested to establish RTCs in 15 cities and provinces around the country to initiate the establishment of a trauma system. The national PTDR is regularly evaluated to review the results of said efforts. The

https://doi.org/10.3346/jkms.2022.37.e349

Table 5. Factors related to preventability analyzed by logistic regression (N = 1,208)

Variables	P + PP[a]	NP + NPCI[a]	Model 1[*]		Model 2[*]	
			OR (95% CI)	*P*	OR (95% CI)	*P*
Age, yr						
≤ 14	1	15	1.00		1.00	
15–54	33	339	0.85 (0.17–12.89)	0.869	1.13 (0.22–16.78)	0.903
≥ 55	157	664	1.89 (0.38–28.37)	0.526	2.42 (0.49–35.36)	0.376
Type of emergency medical institutions						
Regional trauma center	76	466	1.00		1.00	
Regional emergency medical center	41	132	1.48 (0.92–2.36)	0.107	1.13 (0.69–1.84)	0.628
Local emergency medical center	47	316	1.10 (0.59–1.99)	0.747	0.73 (0.34–1.46)	0.387
Local emergency medical institution	23	98	0.97 (0.62–1.50)	0.888	0.78 (0.49–1.21)	0.262
Transfer						
Directly visited to the last hospital	115	826	1.00			
Transferred from another hospital						
One time via other hospital	68	181	2.56 (1.75–3.74)	< 0.001		
More than two times via other hospital	7	12	3.72 (1.21–10.59)	0.016		
Time from accident to death						
≤ 1 hr	11	274			1.00	
1–6 hr	43	194			5.43 (2.65–12.27)	< 0.001
6–24 hr	16	78			4.89 (2.05–12.24)	< 0.001
1–7 days	46	165			6.47 (3.16–14.61)	< 0.001
≥ 8 days	35	155			5.11 (2.53–11.44)	< 0.001

P = preventable, PP = potentially preventable, NP = nonpreventable, NPCI = nonpreventable, but with care that could have been improved, OR = odds ratio, CI = confidence interval.

[a]All percentage values were weighted so there may be differences in the sum of each factor.

[*]For goodness of fit, we conducted the Hosmer-Lemeshow test, and the *P* values for model 1 and model 2 were 0.692 and 0.166, respectively.

current study is a national follow-up study conducted at the request of the Ministry of Health and Welfare, 2 years after the last investigation conducted using 2017 mortality statistics.

The final PTDR derived from the current study using mortality statistics for 2019 was 15.7%. Here, the definitive PTDR was 3.1%, which is 3.0%p lower than 6.1% from the 2017 survey of trauma death cases, and the PP death rate was 12.7%, which is 1.1%p lower than 13.8% of the preceding study. Consequently, the final PTDR has decreased by 4.2%p compared to the previous study. This result indicates that Korea's PTDR has been continuously decreasing over the past 20 years. Such improvements in PTDR can be hypothesized to result from the establishment of four new RTCs since the previous study. During the investigation period, there was an increase of 253 beds including 80 sickbeds in the intensive care units exclusively for trauma patients, indicating an increase in national capacity to provide final treatment to patients with severe trauma. Previous research supports such improvements in trauma treatment outcomes because of an increased demand factor of trauma patients in RTCs, which was possible through establishments of additional RTCs and enhanced patient categorization capabilities before arriving at the hospital.[12]

The results of the current study suggest that the possibility of preventable trauma death increases in the case of a patient transfer, with the risk increasing with each additional transfer. This is because transfers between hospitals delay the time of critical treatment. This has been commonly noted in numerous studies on PTDR.[20-22] In a study on patients who died in trauma centers, Bratton et al.[23] reported unexpected deaths as being more common and the time spent in the intensive care unit as being longer when comparing patients who had been transferred to the hospital with patients who had arrived directly at the trauma centers. Similar results were reported in a study conducted in Korea based on the 2015 mortality statistics, with a strong correlation between patient transfers and preventable

trauma deaths, specifically for patients with two or more transfers who had a 2.99 times higher risk of preventable trauma deaths.[9] While it is important to improve the quality of care at the hospital level to improve the prognosis of trauma patients,[24] it is as important to select an initial hospital on the field that can provide the final treatment for patients with severe trauma to prevent unnecessary transfers.

There were no statistical differences between the judgment of preventable trauma death of patients who died in RTCs and patients who died in other emergency medical facilities. As the index simply investigates the type of final institution where deaths have occurred, this result cannot be interpreted to mean there are no differences between the trauma treatment capabilities of RTCs and other emergency medical facilities. Often patients who died at RTCs, the decisive error occurred in the "previous hospital arrival" or "transfer between hospitals" stages. Kwon et al.[25] reported in 2019 that the ratio of patients dying from decisive errors committed during treatment in RTCs was 10.3% among all cases of preventable trauma deaths, with the other 89.7% caused by errors committed in the "premium to arrival at hospital" and "transfer between hospitals" stages, and "at an emergency medical facility other than RTCs." These results provide evidence supporting the distinct differences between the trauma treatment capabilities of RTCs and those of other emergency medical facilities. Our results should also identify the stages where errors occurred, by conducting additional research that includes the qualitative analysis of trauma death cases.

The time from accident to death had an influence on the preventable trauma-to-death judgment. All groups where death had occurred 1 or more hours after the accident had a higher probability of receiving the preventable trauma death judgment, with statistical significance. Compared to the group where the death occurred within one hour of the accident, the groups where the death occurred after six hours, 24 hours, seven days and more than seven days had almost five times the likelihood of receiving the preventable trauma death judgment. This is because deaths within one hour of trauma are likely caused by severe trauma that has no possible means of treatment. However, since autopsy is rarely performed in Korea, patients who died before arrival at hospitals might have been excluded from the study due to the lack of the minimum information required to determine the preventability of death or due to having received inaccurate judgments.[26,27] The current study evaluates patient care prior to arrival at the hospital and did not exclude patients who died before arrival at the hospital, to maintain continuity with previous research. To evaluate the quality of trauma patient care before arrival at the hospital, it is necessary to universally perform at least the minimum investigations required to accurately determine the cause of death of trauma patients suffering early deaths, such as autopsies or post-mortem imaging.

This study has some limitations. First, the retrospective study design precluded the analysis of unrecorded factors or missing values. Especially we could not adjust injury severity appropriately due to the limited quality of information and data collected retrospectively for trauma death cases. Second, the evaluation of "preventability" relied entirely on the analysis by expert panels, which has limitations in objective reproducibility, although the Cohen's Kappa index indicated fair reliability similar to that in previous studies. Third, although the final results were supplemented to some extent by statistical analysis methodology, the data collection rate was lower than in previous studies. In a previous survey on 2017 trauma deaths, 117 of 118 institutions (99.2%) submitted medical records, whereas in this survey, only 243 of 279 institutions (87.1%) submitted medical records. One of the reasons was the lower compliance of emergency medical institutions to the data collection than in previous

https://doi.org/10.3346/jkms.2022.37.e349

surveys. This may have been partially due to the coronavirus disease 2019 pandemic. Finally, this study only analyzed changes in the PTDR and the correlation between some variables and their preventability but did not determine the reason for the improvement in the PTDR. Further studies comparing the results of this study with those of previous studies may help to identify additional reasons for the decrease in the PTDR.

The current study is a follow-up of the national PTDR survey, conducted once every two years at the request of the Ministry of Health and Welfare. In 2019, the PTDR for deceased patients was 15.7%, which is 4.2%p less than that reported in the preceding survey. The risk of preventable trauma death judgment increased with the occurrence of inter-hospital transfers or increased time from accident to death. To achieve additional decreases in PTDR, there needs to be greater focus on patient transfers to RTCs, and post-mortem testing of deceased patients prior to hospital arrival should be performed more frequently for a detailed quality assessment of pre-hospital trauma care.

ACKNOWLEDGMENTS

The authors especially thank all the hospitals that participated in this study, the National Emergency Medical Center and the Ministry of Health and Welfare who assisted the research.

SUPPLEMENTARY MATERIAL

Supplementary Data 1

Preventable Trauma Death Pre review & Panel Review Form

Click here to view

REFERENCES

1. World Health Organization. *Guidelines for Trauma Quality Improvement Programmes*. Geneva, Switzerland: WHO Press; 2009.
2. World Health Organization. *The Global Burden of Disease*. Geneva, Switzerland: WHO Press; 2008.
3. Centers for Disease Control and Prevention. Key injury and violence data. http://www.cdc.gov/injury/wisqars/overview/key_data.html. Updated 2021.
4. Korean Statistical Information Service. *Leading Causes of Death Reports 1983–2019*. Seoul, Korea: Korean Statistical Information Service; 2020.
5. Coccolini F, Kluger Y, Moore EE, Maier RV, Coimbra R, Ordoñez C, et al. Trauma quality indicators: internationally approved core factors for trauma management quality evaluation. *World J Emerg Surg* 2021;16(1):6.
PUBMED | CROSSREF
6. Cales RH, Trunkey DD. Preventable trauma deaths. A review of trauma care systems development. *JAMA* 1985;254(8):1059-63.
PUBMED | CROSSREF
7. MacKenzie EJ. Review of evidence regarding trauma system effectiveness resulting from panel studies. *J Trauma* 1999;47(3 Suppl):S34-41.
PUBMED | CROSSREF
8. Jung KY, Kim JS, Kim Y. Problems in trauma care and preventable deaths. *J Korean Soc Emerg Med* 2001;12(1):45-56.

9. Kim H, Jung KY, Kim SP, Kim SH, Noh H, Jang HY, et al. Changes in preventable death rates and traumatic care systems in Korea. *J Korean Soc Emerg Med* 2012;23(2):189-97.
10. Yoon HD. Background and progress of regional trauma center development. *J Korean Med Assoc* 2016;59(12):919-22.
CROSSREF
11. Park DJ, Park CY, Cho HM, Lee KH, Han H. Current status and future prospects of trauma centers in Korea. *J Korean Med Assoc* 2017;60(7):530-2.
CROSSREF
12. Jung K, Kim I, Park SK, Cho H, Park CY, Yun JH, et al. Preventable trauma death rate after establishing a national trauma system in Korea. *J Korean Med Sci* 2019;34(8):e65.
PUBMED | CROSSREF
13. Kim Y, Jung KY, Cho KH, Kim H, Ahn HC, Oh SH, et al. Preventable trauma deaths rates and management errors in emergency medical system in Korea. *J Korean Soc Emerg Med* 2006;17(5):385-94.
14. Jung K, Kwon J, Huh Y, Moon J, Hwang K, Cho HM, et al. National trauma system establishment based on implementation of regional trauma centers improves outcomes of trauma care: a follow-up observational study in South Korea. *PLOS Glob Public Health.* 2022;2(1):e0000162.
CROSSREF
15. Korean Statistical Information Service. Korean Standard Classification of Diseases, 7th Revision (KCD-7). http://kssc.kostat.go.kr/ksscNew_web/kssc/common/selectIntroduce.do?gubun=2&bbsId=kcd_ug#. Updated 2021. Accessed August 30, 2022.
16. National Emergency Medical Center. Emergency Medical Statistics Annual Report 2019. https://www.e-gen.or.kr/nemc/statistics_annual_report.do. Updated 2022. Accessed August 30, 2022.
17. Sanddal TL, Esposito TJ, Whitney JR, Hartford D, Taillac PP, Mann NC, et al. Analysis of preventable trauma deaths and opportunities for trauma care improvement in utah. *J Trauma* 2011;70(4):970-7.
PUBMED | CROSSREF
18. Teixeira PG, Inaba K, Hadjizacharia P, Brown C, Salim A, Rhee P, et al. Preventable or potentially preventable mortality at a mature trauma center. *J Trauma* 2007;63(6):1338-46.
PUBMED | CROSSREF
19. National Academies of Sciences, Engineering, and Medicine. *A National Trauma Care System: Integrating Military and Civilian Trauma Systems to Achieve Zero Preventable Deaths After Injury*. Washington, D.C., USA: National Academies Press; 2016.
20. Pigula FA, Wald SL, Shackford SR, Vane DW. The effect of hypotension and hypoxia on children with severe head injuries. *J Pediatr Surg* 1993;28(3):310-4.
PUBMED | CROSSREF
21. Sampalis JS, Denis R, Fréchette P, Brown R, Fleiszer D, Mulder D. Direct transport to tertiary trauma centers versus transfer from lower level facilities: impact on mortality and morbidity among patients with major trauma. *J Trauma* 1997;43(2):288-95.
PUBMED | CROSSREF
22. Young JS, Bassam D, Cephas GA, Brady WJ, Butler K, Pomphrey M. Interhospital versus direct scene transfer of major trauma patients in a rural trauma system. *Am Surg* 1998;64(1):88-91.
PUBMED
23. Bratton SL, Chestnut RM, Ghajar J, McConnell Hammond FF, Harris OA, Hartl R, et al. Guidelines for the management of severe traumatic brain injury. VIII. Intracranial pressure thresholds. *J Neurotrauma* 2007;24 Suppl 1:S55-8.
PUBMED | CROSSREF
24. Huh Y, Kwon J, Moon J, Kang BH, Kim S, Yoo J, et al. An evaluation of the effect of performance improvement and patient safety program implemented in a new regional trauma center of Korea. *J Korean Med Sci* 2021;36(22):e149.
PUBMED | CROSSREF
25. Kwon J, Lee JH, Hwang K, Heo Y, Cho HJ, Lee JC, et al. Systematic preventable trauma death rate survey to establish the region-based inclusive trauma system in a representative province of Korea. *J Korean Med Sci* 2020;35(50):e417-20.
PUBMED | CROSSREF
26. MacKenzie EJ. Review of evidence regarding trauma system effectiveness resulting from panel studies. *J Trauma* 1999;47(3 Suppl):S34-41.
PUBMED | CROSSREF
27. West JG. Validation of autopsy method for evaluating trauma care. *Arch Surg* 1982;117(8):1033-5.
PUBMED | CROSSREF