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Aims and Scope

Journal of Trauma and Injury (J Trauma Inj, JTI) is the official journal of the Korean Society of Traumatology. Due to the special circumstances between South Korea (hereinafter referred to as Korea) and North Korea, JTI collaborates closely with the Armed Forces Medical Command and the Armed Forces Capital Hospital of Korea.

As a peer-reviewed, open access journal, JTI aims to provide education and training in the field of trauma and to promote communication and information exchange among medical staff, ultimately helping to save the lives of injured patients.

The scope of JTI includes basic and clinical research in trauma-related fields such as general surgery, thoracic surgery, orthopedics, neurosurgery, plastic surgery, head and neck surgery, obstetrics and gynecology, ophthalmology, emergency medicine, anesthesiology, neuropsychiatry, rehabilitation medicine, diagnostic radiology, and interventional radiology. Its scope also encompasses the role of emergency medical technicians and nurses, social infrastructure and systems for caring for injured patients, government policy and support, and wartime trauma research. The regional scope is mainly Korea, but JTI welcomes submissions from researchers worldwide.

JTI was launched in June 1988 with articles published in both Korean and English. Since 2016, it has been published in English only. Publication types include original articles, case reports/series, reviews, editorials, and correspondence. The editor usually commissions reviews. JTI is published quarterly on the last day of March, June, September, and December.

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Near-death experiences in 19th century Korean tales

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A near-death experience (NDE) takes place during clinically diagnosed death or a life-threatening coma due to an accident or an illness [1]. Trauma patients are at the edge of life and death. Trauma doctors play tug of war against the grim reaper. If we win, the trauma victim lives. If we lose, the patient dies [2]. Thereafter, NDE is not uncommon phenomenon in trauma patients.

NDEs usually consist of components such as an out-of-body experience, a tunnel experience, encountering a "being of light," standing in front of a wall, and returning to their body. Even though there are some differences among NDEs according to each person's unique circumstances, they appear very similar as a whole [3,4].

In Korean tales, there are many tales of returning from the underworld after several days or even weeks; however, there are very few examples of personal NDEs at the moment of impending death [5]. I introduce two cases of NDEs at the moment of impending death from a book named *Tales from the Green Hills*, which represents the reality and customs of Korean society in the 18th and 19th century Joseon dynasty [6].

Case 1. *Tales from the Green Hills*, book 4, chapter 9

One day, Mr. Nam fell ill, and all medicines proved useless. His status became critical, and his caregiver began to prepare for his death. Everyone was startled and lost their heads. At dawn, the patient suddenly rolled in bed and sobbed and said, "It's strange." Everyone marveled and asked, "What is strange?" Mr. Nam asked for thin rice gruel, and the family prepared it. After taking two or three sips, he sat up and said, "Two messengers from the underworld took me to a government official of the underworld, stopped and left me outside the door, and went in. After a while, an official came out and asked me: 'Aren't you Mr. Nam living in Gyeongseong?' [. . .] He said, 'I am the grandfather of Mr. Shin, who lives in a village of Bongsan. In the dark underworld, I was deeply moved by the grace you showed to my grandson. There was no way to repay you because we were living in different worlds. Now your life has expired, and the angels of death were sent to take you. It is time to express my gratitude beyond the grave. A while ago, I lengthened the span of your life in my list of lifespans (Fig. 1). You are relieved now; go back.' Immediately, he ordered the messengers to escort him. Owing to the late grandfather of Mr. Shin, I was brought back to life." After that, he became especially kind to Mr. Shin [6].

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Case 2. *Tales from the Green Hills*, book 9, chapter 3

Jonghee alone was taking care of his sick father. He felt that his father was getting cold. Jonghee hurriedly boiled a thin rice gruel, made a stab wound in his fingers with a knife, and mixed the blood into the thin rice gruel. He opened his father's mouth and poured the blood-mixed gruel into it (Fig. 2). After consuming half of the bowl, his father began to breathe again through the nose and mouth. After finishing the entire bowl, he was completely revived. Everyone in the family heard a voice saying: "Jonghee, heaven was touched by your devotion, and the underworld allowed your father to return." The family members acknowledged that the voice was from Jonghee's maternal grandfather, Yoon Kyum, who had passed away a long time ago. Jonghee's father gradually recovered [6].

In case 1, before the deceased arrived at the gates of the underworld and was tried before King Yama, the grandfather of an acquaintance, who was now an official of the underworld, extended the sick man's lifespan to repay him for his kindness. Thereafter, he was able to return to this world again. This episode shows the Buddhist concept of causal retribution, known as karma.

Case 2 portrays details scenes of a devoted son dripping blood from his fingers into a thin boiled rice gruel to save his sick father. In the background of the miraculous recovery of his father, we can note the Buddhist concepts of causality, Confucian recognition of the grace of his action by his maternal grandfather, and the way of heaven being touched by the son's devotion and prolonging his father's life [5].

An NDE is a personal experience associated with impending death, encompassing multiple possible sensations, including detachment from the body, feelings of levitation, total serenity, security, warmth, and the presence of a light. In case 1, the patient experienced detachment from the body followed by returning. In case 2, the patient, as well as his family, heard the voice of their deceased ancestor, for whom they held Confucian memorial services [7].

NDE is a fascinating phenomenon and some trauma victims experience during physical crises or periods of apparent clinical death. When trauma surgeons as well as critical care trauma nurses are familiar with the characteristics of the experience, medical personnel can assist trauma victims to understand available information about NDEs. Moreover, we are able to assist victims and their families to understand the meanings of the NDE and how it affects their lives [8].

Tales from the Green Hills, published in the middle of the 19th century, is an excellent source for understanding the language and customs of the 18th and 19th century Joseon dynasty. Although it is not an official history, the above two cases are thought to be the oldest records of NDEs in Korea.

Fig. 1. An official of the underworld lengthened the lifespan of Mr. Nam, who had just arrived at the gates of the underworld. Illustration by Hye Won Hu, MA.

Fig. 2. A devoted son is dripping blood from his fingers into a thin boiled rice gruel to save his sick father. Illustration by Hye Won Hu, MA.

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NOTES

Conflicts of interest

Kun Hwang serves on the Editorial Board of *Journal of Trauma and Injury*, but was not involved in the peer reviewer selection, evaluation, or decision process of this article. The author has no conflicts of interest to declare.

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Quality monitoring of resuscitative endovascular balloon occlusion of the aorta using cumulative sum analysis in Korea: a case series

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Purpose: Resuscitative endovascular balloon occlusion of the aorta (REBOA) is a state-of-the-art lifesaving procedure. However, due to its high mortality and morbidity, including ischemia and reperfusion injury, well-trained medical staff and effective systems are needed. This study was conducted to investigate the learning curve for REBOA in Korea.

Methods: To monitor this learning curve, we used cumulative sum (CUSUM) analysis and graphs of mortality and aortic occlusion time within 60, 90, and 120 minutes for consecutive patients. The procedures performed between July 2017 and June 2021 were divided into pre-trauma center (pre-TC; July 2017–February 2020) and TC (February 2020–June 2021) periods.

Results: REBOA was performed for 31 consecutive patients with trauma. The pre-TC (n=12) and TC (n=19) periods did not differ significantly with regard to Injury Severity Score, age, injury mechanism, initial systolic blood pressure, prehospital cardiopulmonary resuscitation (CPR), or CPR in the emergency department. At the 17th consecutive patient during the TC period, CUSUM failure graphs for mortality and aortic occlusion time exhibited a downward inflection, indicating an improvement in performance.

Conclusions: The mortality and aortic occlusion time of REBOA improved, and these parameters can be monitored using CUSUM analysis at the hospital level.

Keywords: Aorta; Balloon occlusion; Endovascular procedures

INTRODUCTION

Severe hemorrhage due to torso injury is a leading cause of death [1,2]. To reduce mortality from severe torso hemorrhage, damage control surgery and resuscitation have been introduced [1]. The core concept of damage control is prompt hemostasis, such as via emergency surgery or interventional radiology [1]. However, some patients are vulnerable to severe bleeding before effective hemostasis can be achieved and die before surgery or interventional radiology is performed. To rescue such patients, resuscita-

tive endovascular balloon occlusion of the aorta (REBOA) was introduced for the temporary cessation or limitation of aortic blood flow [3]. REBOA is used as a bridge until definitive hemorrhagic control is achieved [4]. Resuscitative thoracotomy is substantially invasive and has high morbidity [5]; thus, REBOA has received considerable attention [6]. Moreover, the introduction of a 7F or 8F sheath minimizes iatrogenic limb ischemia.

Well-trained staff and well-organized medical resources are required for an effective REBOA procedure. Medical staff should demonstrate proficiency in hemorrhage detection, diagnosis, vascular approach, identification of balloon position, and subsequent prompt hemostatic procedures such as damage control surgery and interventional radiology. Facilities and equipment such as trauma bays, interventional radiology rooms, operating rooms, point-of-care ultrasonography, and portable X-ray equipment should be well-organized. However, training and experience with medical resources are time-consuming. Moreover, experience with REBOA is insufficient in most trauma centers because the procedure is usually performed only in rare situations, such as in patients in severe shock [6,7]. Recently, centers with high REBOA utilization were found to be associated with lower mortality than low-utilization centers [8]. This implies that the learning curve at the hospital level is crucial. However, the learning curve associated with REBOA has not been examined in previous studies. Recently, the learning curve for damage control laparotomy in a Korean regional trauma center was evaluated using cumulative sum (CUSUM) analysis, which is a useful method for monitoring the performance of procedures [9–11]. Here, we investigated the improvement in the quality of the REBOA procedure and associated mortality using CUSUM at the hospital level.

METHODS

Ethics statements

This study was approved by the Institutional Review Board of Cheju Halla General Hospital (No. 2022-L03-01). The requirement for informed consent was waived due to the retrospective nature of the study.

Study design

We reviewed the Korean Trauma Database for records from our trauma center from July 2017 to June 2021 to identify patients with trauma who underwent REBOA. Patients who died before REBOA, who did not undergo balloon inflation, or who underwent balloon insertion into the inferior vena cava due to a retrohepatic inferior vena cava injury were excluded from the study. Patient demographic and clinical data including mechanism of injury, age, sex, laboratory findings, vital signs, Injury Severity Score, Abbreviated Injury Scale score, postoperative outcomes, and REBOA-related time parameters were collected and analyzed.

At our trauma center, two dedicated trauma bays, two operating rooms, and one interventional radiology room near the trauma bay were equipped for use by dedicated trauma staff. We divided our study into pre-trauma center (pre-TC; July 2017–February 2020) and TC (February 2020–June 2021) periods. Before February 2020 (the pre-TC period), trauma procedures were performed in the emergency department (ED), where nontrauma patients were also managed. From February 2020 onward (the TC period), all trauma procedures and patients were managed by attending trauma surgeons in a trauma bay. In the pre-TC period, the ultrasonographic image quality was poor due to aging equipment. Surgical instruments for laparotomy or thoracotomy were not prepared in the ED, and surgeons had to bring them from the operating room. In addition, the nursing staff members were not proficient in preparing REBOA kits, and most of them did not even know what REBOA was. The angiography room was located on a different floor from the ED, so patients had to be transferred by elevator. In contrast, in the TC period, point-of-care ultrasonography, a REBOA kit, portable X-ray equipment, surgical equipment for ED laparotomy and ED thoracotomy, and a trauma angiography room next door to the trauma bay were available after the establishment of dedicated trauma facilities. The dedicated nursing staff members were educated regarding the REBOA kit and surgical instruments and became more proficient at preparing them. In the pre-TC period, only three to five dedicated trauma surgeons worked at the trauma center. During the TC period, six to ten trauma surgeons and four emergency medicine faculty members were assigned to the trauma center.

The indications for REBOA were patients with unstable vital signs (systolic blood pressure [SBP] <90 mmHg) and patients with severe intra-abdominal or pelvic hemorrhage. Femoral arterial puncture for REBOA was performed by a trauma surgeon using point-of-care ultrasonography or a blind method. The surgeon inflated the REBOA balloon by infusing 5 to 20 mL of saline. The balloon position was identified using portable X-ray equipment. When prompt hemostasis was required, ED laparotomy was performed appropriately. For patients with impending cardiac arrest before or after the REBOA procedure, ED thoracotomy was performed. After the return of spontaneous circula-

tion, the aortic clamp used during the thoracotomy was converted to a REBOA setup. A hemostatic procedure was defined as the control of bleeding by laparotomy or angioembolization. The total REBOA occlusion time was measured from the time of initial balloon inflation to that of full deflation. A procedure was considered successful if the REBOA occlusion time was within 60, 90, or 120 minutes; this is because prolonged REBOA occlusion time can induce ischemic injury, which is associated with bowel ischemia, acute kidney injury, and limb ischemia. The primary outcome of our study was mortality, and the secondary outcome was aortic occlusion time. We hypothesized that aortic occlusion time is a surrogate marker of success in REBOA procedures.

Statistical analysis

Continuous data are presented as medians and interquartile ranges, and data were analyzed using the Mann-Whitney U-test. Categorical data are presented as proportions. Proportions were compared using the chi-square test or the Fisher exact test, as appropriate. P-values less than 0.05 were considered to indicate statistical significance. All statistical analyses were performed using Microsoft Excel (Microsoft Corp) and R ver. 4.1.2 (R Foundation for Statistical Computing).

CUSUM analysis

The CUSUM procedure is a graphical method that is widely used for quality monitoring [9–11]. In this study, the CUSUM was calculated as follows: $S_n = (X_i - p_{0i})$, where S_n is the summation of the score, $X_i = 0$ for success (for example, patient survival) and $X_i = 1$ for failure (for example, patient death), and p_{0i} denotes the predicted probability of failure of the procedure. The graph starts at 0 and is plotted from left to right on a horizontal axis. The curve moves up by $1 - p_{0i}$ for every case of failure (penalty) and down by p_{0i} for every case of success (reward) on the cumulative failure graph. The improvement or deterioration of surgical outcomes can be identified intuitively based on the inflection of the CUSUM curve.

RESULTS

This is a case series. From July 2017 to June 2021, the REBOA procedure was performed for 31 trauma patients who were admitted to our hospital. A total of five trauma surgeons performed REBOA, with 20 procedures performed by one surgeon, eight procedures by another surgeon, and one procedure each by the remaining three surgeons. The baseline characteristics and a comparison between the pre-TC and TC periods are summarized in Table 1. Twelve (38.7%) and 19 patients (61.3%) were admitted during the pre-TC and TC periods, respectively. Twenty-nine patients (93.55%) experienced blunt trauma. The initial SBP levels of 13 patients (41.9%) could not be determined. Seven patients (22.6%) underwent prehospital cardiopulmonary resuscitation (CPR). Nine (29.0%) and eight patients (25.8%) underwent thoracotomy and laparotomy, respectively, in the ED. The median time from admission to REBOA was 31.0 minutes (interquartile range [IQR], 18.0–67.0 minutes). The median total REBOA occlusion time was 60.0 minutes (IQR, 47.5–90.5 minutes). In 30 patients (96.8%), the balloon used during REBOA was placed in zone 1 (above the celiac axis), while it was placed in zone 3 (between the inferior mesenteric artery and the iliac bifurcation) in one patient (3.2%). Twelve patients (38.7%) survived the REBOA procedure. No significant differences were present in age, sex, SBP, Injury Severity Score, or Abbreviated Injury Scale score between the pre-TC and TC periods. The median REBOA occlusion time was shorter in the TC than in the pre-TC period, although the difference was not statistically significant (62.5 minutes [IQR, 44.0–134.5 minutes] in the pre-TC period vs. 53.0 minutes [IQR, 47.5–78.5 minutes] in the TC period, P = 0.465). The survival rate was higher in the TC than in the pre-TC period, although the difference was also not significant (three patients [25.0%] in the pre-TC period vs. nine patients [47.4%] in the TC period, P = 0.386). Table 2 shows a summarized comparison between nonsurvivors and survivors. The initial SBP was significantly lower in the nonsurvivor group. Nonsurvivors were significantly more likely to have undergone CPR at ED, ED thoracotomy, and ED laparotomy. However, no patient in the survivor group underwent CPR at ED, ED thoracotomy, or ED laparotomy.

The CUSUM failure graph for survival is shown in Fig. 1. The CUSUM failure graphs for aortic occlusion time within 60 minutes, 90 minutes, and 120 minutes are shown in Figs. 2, 3, and 4, respectively. All CUSUM graphs showed an upward slope during the pre-TC period. At the 17th patient (indicated by arrows) in the TC period, a downward inflection was observed and a downward slope was observed after 17th case.

DISCUSSION

To our knowledge, this is the first study to illustrate the learning curve associated with REBOA using CUSUM analysis. The results indicated that the quality of the REBOA procedure improved. The accumulation of experience with the REBOA procedure may enhance performance. Additionally, we believe that the

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Table 1. Comparison between pre-TC and TC period

Variable	Total	Pre-TC	TC	P-value
No. of patients	31 (100)	12 (38.7)	19 (61.3)	
Age (yr)	45.0 (35.0–57.5)	49.0 (35.5–59.0)	42.0 (32.0–54.0)	0.612
Injury type				>0.999
Blunt	29 (93.5)	11 (91.7)	18 (94.7)	
Penetrating	2 (6.5)	1 (8.3)	1 (5.3)	
Male sex	24 (77.4)	9 (75.0)	15 (78.9)	>0.999
Injury Severity Score	34.0 (25.0–44.0)	33.5 (18.0–52.5)	34.0 (28.0–36.5)	0.919
Abbreviated Injury Scale				
Head and neck	3.0 (0–4.5)	2.5 (0–5.0)	3.0 (0–4.0)	0.801
Face	0 (0–0.5)	0 (0–0.5)	0 (0–1.0)	0.771
Chest	3.0 (0.5–3.0)	2.0 (0–3.0)	3.0 (2.0–3.0)	0.291
Abdomen	3.0 (2.0–4.0)	3.0 (2.5–4.0)	2.0 (1.0–4.0)	0.347
Pelvis	0 (0–3.0)	0 (0–3.5)	2.0 (0–3.0)	0.427
Extremity	0 (0–1.0)	0 (0–1.0)	1.0 (0–1.0)	0.151
Initial systolic blood pressure (mmHg)				0.206
≥100	5 (16.1)	4 (33.3)	1 (5.3)	
80–99	5 (16.1)	2 (16.7)	3 (15.8)	
50–79	8 (25.8)	2 (16.7)	6 (31.6)	
Not checked	13 (41.9)	4 (33.3)	9 (47.4)	
Prehospital CPR	7 (22.6)	3 (25.0)	4 (21.1)	>0.999
CPR at the ED	15 (48.4)	7 (58.3)	8 (42.1)	0.609
Balloon type of REBOA				0.032
12F (ReliantTM)	4 (12.9)	4 (33.3)	0	
7F (RescueTM)	27 (87.1)	8 (66.7)	19 (100)	
Target zone				>0.999
Zone 1	30 (96.8)	12 (100)	18 (94.7)	
Zone 3	1 (3.2)	0	1 (5.3)	
Identification of REBOA balloon position	15 (48.4)	7 (58.3)	8 (42.1)	0.609
Time from admission to REBOA (min)	31.0 (18.0–67.0)	64.5 (31.0–93.0)	21.0 (14.5–43.5)	0.007
REBOA occlusion time (min)	60.0 (47.5–90.5)	62.5 (44.0–134.5)	53.0 (47.5–78.5)	0.465
Within 60 min	17 (54.8)	6 (50.0)	11 (57.9)	0.952
Within 90 min	23 (74.2)	7 (58.3)	16 (84.2)	0.237
Within 120 min	24 (77.4)	7 (58.3)	17 (89.5)	0.114
ED thoracotomy	9 (29.0)	2 (16.7)	7 (36.8)	0.424
ED laparotomy	8 (25.8)	3 (25.0)	5 (26.3)	>0.999
Angioembolization	4 (12.9)	0	4 (21.1)	0.249
Laparotomy	19 (61.3)	9 (75.0)	10 (52.6)	0.386
Preperitoneal pelvic packing	2 (6.5)	1 (8.3)	1 (5.3)	>0.999
Hemostasis (surgery or angioembolization)	20 (64.5)	8 (66.7)	12 (63.2)	>0.999
PRBC transfusion within 24 hr (unit)	11.0 (6.0–17.0)	13.0 (5.5–17.5)	11.0 (6.0–15.5)	0.951
FFP transfusion within 24 hr (unit)	5.0 (2.5–10.0)	6.0 (2.5–10.0)	5.0 (2.5–11.0)	>0.999
Platelet transfusion within 24 hr (unit)	0 (0–8.0)	0 (0–6.5)	0 (0–8.0)	0.751
PRBC transfusion within 4 hr (unit)	8.0 (6.0–14.5)	10.0 (5.5–15.5)	7.0 (6.0–13.5)	0.902
FFP transfusion within 4 hr (unit)	4.0 (2.0–7.0)	5.0 (2.0–7.0)	4.0 (2.0–7.0)	0.790
Platelet transfusion within 4 hr (unit)	0 (0–0)	0 (0–0)	0 (0–0)	0.739
Hemodialysis due to AKI	1 (3.2)	1 (8.3)	0	0.814
Limb ischemia	0	0	0	-
Survival (in-hospital)	12 (38.7)	3 (25.0)	9 (47.4)	0.386
Cause of mortality				0.396
Central nervous system	3 (9.7)	2 (16.7)	1 (5.3)	
Hypovolemic	15 (48.4)	7 (58.3)	8 (42.1)	
Multiple organ dysfunction syndrome	1 (3.2)	0	1 (5.3)	

Values are presented as number (%) or median (interquartile range).
TC, trauma center; CPR, cardiopulmonary resuscitation; ED, emergency department; REBOA, resuscitative endovascular balloon occlusion of aorta; PRBC, packed red blood cell; FFP, fresh frozen plasma; AKI, acute kidney injury.

Table 2. Comparison between nonsurvivor and survivor (n=31)

Variable	Nonsurvivor (n=19)	Survivor (n=12)	P-value
Group			0.386
Pre-TC	9 (47.4)	3 (25.0)	
TC	10 (52.6)	9 (75.0)	
Age (yr)	48.0 (32.0–60.5)	39.5 (35.0–49.5)	0.310
Injury type			>0.999
Blunt	18 (94.7)	11 (91.7)	
Penetrating	1 (5.3)	1 (8.3)	
Male sex	15 (78.9)	9 (75.0)	>0.999
Injury Severity Score	34.0 (27.0–49.0)	33.5 (21.0–34.0)	0.166
Abbreviated Injury Scale			
Head and neck	2.0 (0–5.0)	3.5 (0–4.0)	0.784
Face	0 (0–0)	0 (0–2.0)	0.076
Chest	3.0 (1.5–4.0)	2.5 (0–3.0)	0.157
Abdomen	3.0 (2.0–4.0)	3.0 (2.0–3.0)	0.530
Pelvis	0 (0–3.5)	3.0 (0–3.0)	0.321
Extremity	1.0 (0–1.0)	0 (0–1.0)	0.151
Initial systolic blood pressure (mmHg)			0.001
≥100	3 (15.8)	2 (16.7)	
80–99	1 (5.3)	7 (58.3)	
50–79	2 (10.5)	3 (25.0)	
Not checked	13 (68.4)	0	
Prehospital CPR	7 (36.8)	0	0.051
CPR at ED	15 (78.9)	0	>0.001
Balloon type of REBOA			0.958
12F (ReliantTM)	3 (15.8)	1 (8.3)	
7F (RescueTM)	16 (84.2)	11 (91.7)	
Target zone			0.814
Zone 1	19 (100)	11 (91.7)	
Zone 3	0	1 (8.3)	
Identification of REBOA balloon position	8 (42.1)	7 (58.3)	0.609
Time from admission to REBOA (min)	31.0 (19.5–70.0)	34.0 (15.0–66.0)	0.626
REBOA occlusion time (min)	60.0 (43.5–105.5)	64.0 (48.0–83.5)	0.855
Within 60 min	11 (57.9)	6 (50.0)	0.952
Within 90 min	13 (68.4)	10 (83.3)	0.615
Within 120 min	14 (73.7)	10 (83.3)	0.853
ED thoracotomy	9 (47.4)	0	0.015
ED laparotomy	8 (42.1)	0	0.029
Angioembolization	1 (5.3)	3 (25.0)	0.295
Laparotomy	12 (63.2)	7 (58.3)	>0.999
Preperitoneal pelvic packing	2 (10.5)	0	0.681
Hemodialysis due to AKI	1 (5.3)	0	>0.999
Limb ischemia	0	0	-
Hemostasis (surgery or angioembolization)	12 (63.2)	8 (66.7)	>0.999
PRBC transfusion within 24 hr (unit)	11.0 (6.0–17.5)	11.5 (6.5–15.5)	0.968
FFP transfusion within 24 hr (unit)	4.0 (2.0–9.5)	7.0 (4.5–12.5)	0.186
Platelet transfusion within 24 hr (unit)	0 (0–0)	7.0 (1.5–10.0)	0.007
PRBC transfusion within 4 hr (unit)	10.0 (5.5–16.5)	6.5 (6.0–12.0)	0.595
FFP transfusion within 4 hr (unit)	4.0 (2.0–5.5)	4.5 (2.0–8.0)	0.595
Platelet transfusion within 4 hr (unit)	0 (0–0)	0 (0–0)	0.274
Cause of mortality			<0.001
Central nervous system	3 (15.8)	0	
Hypovolemic	15 (78.9)	0	
Multiple organ dysfunction syndrome	1 (5.3)	0	

Values are presented as number (%) or median (interquartile range).
TC, trauma center; CPR, cardiopulmonary resuscitation; ED, emergency department; REBOA, resuscitative endovascular balloon occlusion of aorta; AKI, acute kidney injury; PRBC, packed red blood cell; FFP, fresh frozen plasma.

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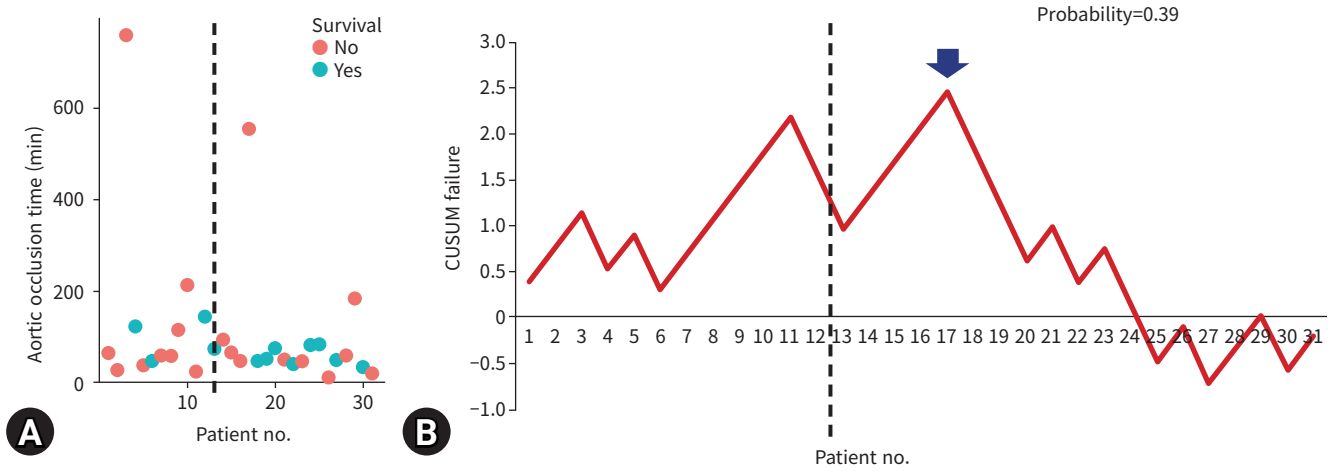

Fig. 1. Cumulative sum (CUSUM) failure graph for patient survival. (A) The scatter plot of aortic occlusion time and (B) CUSUM graph. The dotted line denotes the establishment of a regional trauma center (pre-trauma center period, patient no. 1–12; trauma center period, patient no. 13–31).

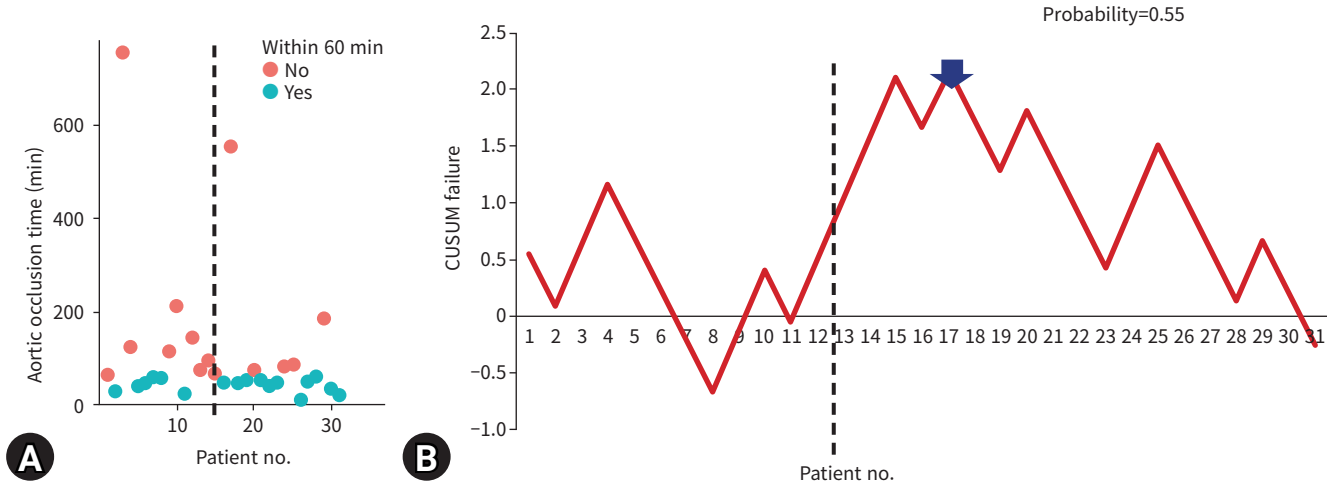

Fig. 2. Cumulative sum (CUSUM) failure graph for aortic occlusion time ≤60 minutes. (A) The scatter plot of aortic occlusion time and (B) CUSUM graph. The dotted line denotes the establishment of a regional trauma center (pre-trauma center period, patient no. 1–12; trauma center period, patient no. 13–31).

establishment of trauma centers plays an important role in improving the skill and knowledge of faculty and the number of dedicated facility members, which helps improve the quality of the procedure. CUSUM-based monitoring appears to be useful for the REBOA procedure. REBOA is generally performed in extremely rare situations; therefore, achieving proficiency may be difficult. We believe that the outcomes, mortality rate, and aortic occlusion time are potential indicators of the performance of REBOA. An improvement in aortic occlusion time represents prompt hemostasis and the reduction of ischemia.

Although enthusiasm has grown regarding the use of REBOA for trauma patients with severe hemorrhage, the procedure's indications and outcomes, including mortality and morbidity, are controversial [6,12]. In a recent systematic review and meta-analysis [6], REBOA was associated with lower mortality than ED thoracotomy, whereas no significant difference was observed between patients who underwent REBOA and those who did not. However, this meta-analysis included a limited number of studies (three and five studies comparing REBOA with ED thoracotomy and non-REBOA, respectively), and all included studies were observational. Thus, the exact effect size is unclear due to substantial selection bias. In a retrospective cohort study using the American College of Surgeons National Trauma Database with propensity score matching [7], REBOA was associated with increased mortality, even after adjustment for measured confounders. The authors reported that REBOA was not associated with

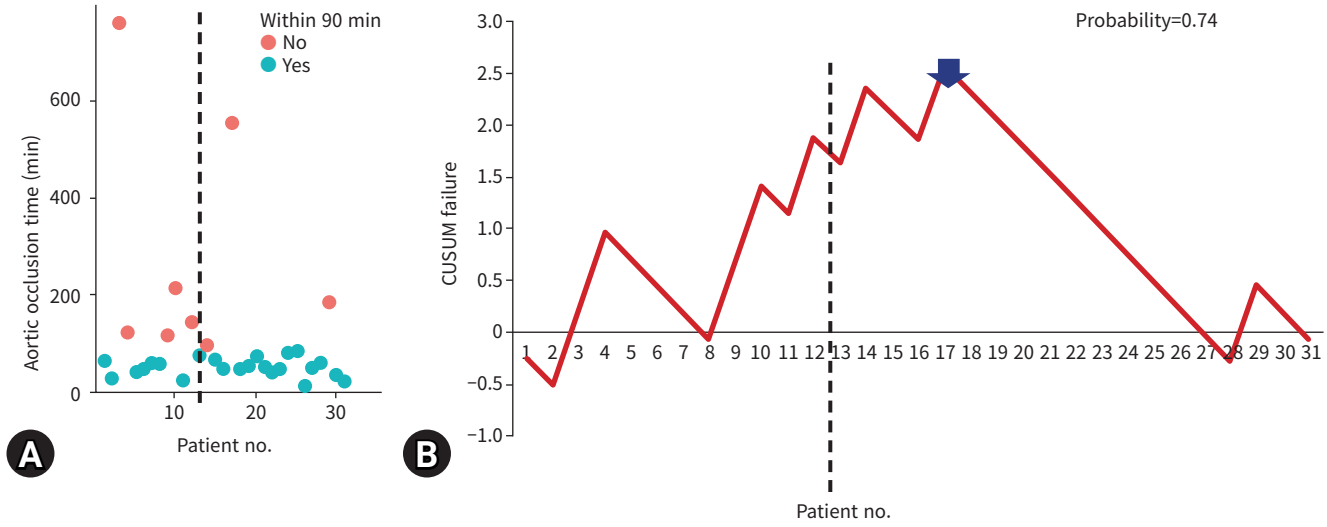

Fig. 3. Cumulative sum (CUSUM) failure graph for aortic occlusion time ≤90 minutes. (A) The scatter plot of aortic occlusion time and (B) CUSUM graph. The dotted line denotes the establishment of a regional trauma center (pre-trauma center period, patient no. 1–12; trauma center period, patient no. 13–31).

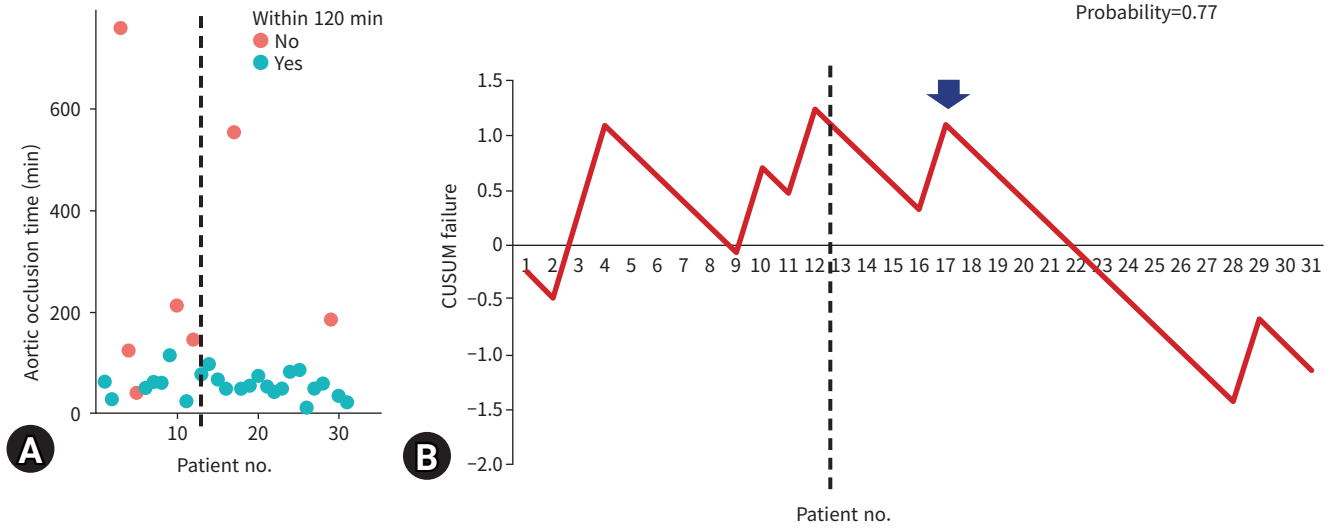

Fig. 4. Cumulative sum (CUSUM) failure graph for aortic occlusion time ≤120 minutes. (A) The scatter plot of aortic occlusion time and (B) CUSUM graph.The dotted line denotes the establishment of a regional trauma center (pre-trauma center period, patient no. 1–12; trauma center period, patient no. 13–31).

acute kidney injury or amputation. In our study, only one patient underwent hemodialysis, and none underwent lower extremity amputation. However, these complications are rare. In a recent review on the opinions of trauma providers regarding REBOA, interest was revealed to be widespread, but the need for training persists [13]. Thus, clinical results may need to be re-evaluated after the teaching of technical skills and dissemination of information regarding indications and complications. In our study, all patients with initial SBP levels that could not be assessed died. Further study is warranted for such patients, and more rigorous indication may be needed.

In a 5-year retrospective analysis based on the American Association for the Surgery of Trauma's Aortic Occlusion in Resuscitation for Trauma and Acute Care Surgery (AORTA) multi-institutional database [8], a center was defined as high-volume if it had more than 30 cases of REBOA over 5 years, low-volume if it had less than 10, and average-volume if it had 11 to 30 cases. The results indicated that survival was higher in high-volume

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centers than in low-volume ones [8]. From this perspective, our trauma center can be regarded as high-volume because over 5 years, REBOA was performed for 31 patients. Moreover, we used CUSUM analysis to demonstrate that the performance of the REBOA procedure improved after the 17th case. We believe that this study provides new insights for trauma surgeons. REBOA is a bridge procedure used prior to achieving definitive hemostasis. REBOA requires the prompt availability of medical staff and facilities such as a proficient trauma or vascular surgeon, well-trained nurses, point-of-care ultrasonography and portable X-ray equipment, a vascular access device, a trauma bay, an operating room, an interventional radiology room, and a REBOA kit [4]. Harmoniously organizing these components may be time-consuming. At our trauma center, more than 17 cases were needed to achieve proficiency in the REBOA procedure. We believe that assigning dedicated medical staff and facilities via trauma centers may promote such improvements. Such organization may enhance the proficiency of staff and the effectiveness of the overall trauma system. Trauma surgeons may also improve their understanding of REBOA after a trauma center has been established.

Our study had several limitations. First, it was retrospective and observational. However, no randomized controlled trials have been conducted regarding REBOA. Second, the single-cohort nature and small sample size of the study are crucial limitations, and larger-scale prospective studies are needed. Third, the most important limitation is the variation in the skill and experience of the surgeons. This may have impeded consistency in proficiency in the REBOA procedure. However, investigation at the hospital level is crucial because REBOA requires a multidisciplinary approach. Fourth, conventional statistical methods showed no statistically significant difference between the pre-TC and TC periods, although mortality and occlusion time differed non-significantly between them. This lack of significant findings may have been due to the small number of patients (n=31) studied. However, acquiring sufficient datasets is very difficult because REBOA is rarely performed. Therefore, CUSUM monitoring is a potential alternative method. Fifth, the contribution of the establishment of trauma centers to the improvement in REBOA outcomes remains ambiguous. Further studies are required to confirm this hypothesis. However, we observed that the performance of the procedure improved after the 17th patient. This may provide meaningful insights to trauma surgeons who wish to begin performing the REBOA procedure. Sixth, we could not perform risk-adjusted CUSUM analysis because of the small sample size. In a previous study, a risk-adjusted CUSUM methodology was used to adjust for individual risk and minimize selection bias based on a multivariable logistic regression model [9,11]. However, such models are statistically unstable when the sample size is small [14]. Future large-scale studies are required. Seventh, we postulated that aortic occlusion time is a surrogate marker of success in REBOA procedures. No evidence is available regarding this issue. However, guidelines recommend balloon deflation as soon as possible [4]. Prolonged occlusion time induces ischemic damage and reducing occlusion time may require a well-organized trauma system and proficient staff. For example, prompt detection of the balloon position, early preparation for surgery, or angioembolization may be needed. We hope that this can provide new insight for researchers. Finally, we initially attempted partial REBOA (5 to 10 mL of balloon inflation) and added fluids according to the patient's status. However, unfortunately, our medical records included no records of the inflating fluid in some patients. Thus, we could not distinguish partial from total REBOA. We could not identify even intermittent REBOA due to the limited medical records available.

In conclusion, the performance of the REBOA procedure in terms of mortality and aortic occlusion time improved after the 17th case. CUSUM analysis may be useful for monitoring the procedure when the sample size of the cohort is not sufficient to expect statistical stability. However, further large-scale prospective studies are warranted to confirm the true effect size.

NOTES

Conflicts of interest

The authors have no conflicts of interest to declare.

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None.

Data sharing statement

The data of this article are available from the corresponding author upon reasonable request.

Author contributions

Conceptualization: HC, WSK; Data curation: all authors; Formal analysis: WSK; Methodology: HC, WSK; Project administration: WSK; Visualization: WSK; Writing–original draft: HC, WSK; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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Original Article

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Effect of use and type of helmet on occurrence of traumatic brain injuries in motorcycle riders in Korea: a retrospective cohort study

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Purpose: The purpose of this study was to investigate (1) the association among helmet wearing, incidence rate of traumatic brain injury (TBI), and in-hospital mortality; TBI was diagnosed when the head Abbreviated Injury Scale (AIS) was ≥1, and as severe TBI when head AIS was ≥3; and (2) the association between helmet type and incidence rate of TBI, severe TBI, and in-hospital mortality of motorcycle accidents based on the newly revised Emergency Department-based Injury In-depth Surveillance (EDIIS) data.

Methods: Data collected from EDIIS between January 1, 2020 and December 31, 2020 were analyzed. The final study population comprised 1,910 patients, who were divided into two groups: helmet wearing group and unhelmeted group. In addition, the correlation between helmet type and motorcycle accident was determined in 596 patients who knew the exact type of helmet they wore. A total of 710 patients who wore helmet but did not know the type were excluded from this analysis. Multivariate logistic regression was performed in both the groups to investigate the factors affecting the primary (occurrence of TBIs) and secondary outcomes (severe TBI and in-hospital mortality).

Results: The prevalence of Injury Severity Scores, TBIs, and severe TBIs as well as in-hospital mortality were the highest in the unhelmeted group. Additionally, the results from the group that wore and knew the type of helmet worn indicated that wearing a full-face helmet decreased the incidence of TBIs in comparison to a half-face helmet.

Conclusions: The wearing of a helmet in motorcycle accidents is very important as it plays a role in reducing the occurrence of TBIs and severe TBIs and in-hospital mortality. The use of a full-face helmet lowered the incidence of TBIs.

Keywords: Helmet type; Motorcycle accidents; Traumatic brain injuries; Severe head Abbreviated Injury Scale; Hospital mortality

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INTRODUCTION

The growth of the delivery industry increased due to COVID-19 pandemic in Korea, and the Ministry of Land, Infrastructure and Transport (MOLIT) reported that the number of registered motorcycles in 2020 increased to 2,289,099 units [1]. According to the "Online shopping trends in May 2021," the demand for motorcycles can be estimated through the 62.2% increase in online food delivery services compared to the same period in the previous year [2]. With such rapidly increasing demand for motorcycles, the registration rate and the number of applicants for motor vehicle licenses have also increased significantly. The Korean National Police Agency and the Road Traffic Authority reported that there was a 12% increase in the number of applicants for motorcycle license test, from 54,986 in 2019 to 62,593 in 2020 [3]. With the increase in number of motorcycles, the incidence of motorcycle accidents has also increased. Eltorai et al. [4] reported that motorcycle accidents resulted in more serious injuries than automobiles. Data from the Korea Transportation Safety Authority indicates that head injuries are the main cause of death in road traffic accidents, accounting for 41.3% of all deaths [5]. Studies have shown that the use of helmet can prevent or significantly reduce the severity of injuries in motorcycle accidents, as well as reduce the mortality rate [6,7].

According to the *Motorcycle Safety Guide* provided by the Centers for Disease Control and Prevention (CDC) [8], helmets are classified into the following three types based on their shapes: half helmets, open-face helmets, and full helmets. International studies have proven the efficacy of full-face helmets in preventing a traumatic brain injury (TBI); however, the evidence is limited, with the number of study participants being just over 100 [9,10]. Furthermore, while domestic research have studied the relationship between the use of helmets and motorcycle accidents [4,11], none of the studies have focused on the type of helmet used, the information regarding which can be accessed from the revised Emergency Department-based Injury In-depth Surveillance (EDIIS) data. The objective of our study was to perform a nationwide data analysis to evaluate (1) the association between the use of helmet and the occurrence of TBI and (2) the association between the type of helmet and the occurrence of TBI. For this purpose, we hypothesized that, wearing a helmet will reduce the occurrence of TBI, and among the helmet types, the full-face type would be associated with least TBI, while the open-face type would be linked with the most TBI.

METHODS

Ethics statements

This study was approved by the Korea Disease Control and Prevention Agency (KCDC) and the Institutional Review Board of Pusan National University Hospital (No. 2205-005-114). The need for informed consent was waived by the Institutional Review Board due to the use of de-identified data.

Study design and participants

This was a multicenter retrospective cohort study performed using the Korean EDIIS database. The study was described according to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) statement (https://www.strobe-statement.org/). EDIIS is a nationwide database that comprises data of all injured patients who presented to the emergency department in Korea. The KCDC established EDIIS in 2006 using data collected from five hospitals. Currently, it includes data from 23 participating hospitals all across the country. EDIIS collects data which would aid in developing a national policy for injury prevention and also performs periodic quality control by analyzing errors.

We collected the data of patients registered in EDIIS between January 1, 2020, and December 31, 2020. The exclusion criteria were as follows: age < 15 years (n = 4), death on arrival (n = 1), and patients with missing information regarding helmet (n = 112). A total of 117 patients were excluded after implementing the criteria. The final study population comprised 1,910 patients who were divided into two groups: helmet wearing group and unhelmeted group. In addition, the correlation between helmet type and motorcycle accident was determined in 596 patients, who knew the exact type of helmet they wore. A total of 710 patients who wore a helmet but did not know the type were excluded from this analysis. Since a large number of patients were excluded due to lack of information regarding the type of helmet they wore, the basic characteristics of the group aware of the type of helmet and the group not aware of the type of helmet were analyzed to remove the possible bias.

Data collection and variable definition

The coordinator who collected information for the EDIIS database received regular training at the Coordinator Education and Quality Management Meeting, conducted by the KCDC four times a year. The coordinator collected the information from each patient, primarily via questioning the patient. If a patient

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was unable to provide the information, it was obtained from the patient's guardian or the paramedics (information witnessed directly by the paramedic at the scene and collected by the paramedics from other subjects who witnessed the accident).

The following baseline patient characteristics were extracted from EDIIS: age, sex, alcohol consumption, time of emergency department (ED) arrival, type of road, type of helmet, Injury Severity Score (ISS), head injury, and in-hospital mortality. Elderly was defined as individuals over the age of 65 years. Suspicion for alcohol consumption was noted, but if alcohol intake was unknown, it was classified as unused. ED visit dates were divided based on seasons: spring (March to May), summer (June to August), autumn (September to November), and winter (December to February). The time of ED visit was divided into dawn (00:00–05:59), morning (06:00–11:59), afternoon (12:00–17:59), and night (18:00– 23:59).

The type of helmet was classified into three categories based on their shape: half helmet, open-face helmet, and full helmet. This classification of helmets is used not only by the *Motorcycle Safety Guide* provided by the CDC [8], but also by the United Nations Economic Commission for Europe (UNECE) [12], which is currently used in more than 50 countries and is the world's most popular motorcycle helmet test standard. The KCDC also uses the same helmet classification [13]. The open-face helmet protects the ears, cheeks, and back of the head, but does not cover the area under the chin. The half-face helmet features the same front design as the open-face helmet, but lacks a lowered rear. The full-face helmets offer the maximum protection, protecting the eyes and face with a face shield and providing protection to the chin (Fig. 1). Road type was classified into three categories: alley, highway, and general road (i.e., all roads excluding alleys and highways). Opponent objects were classified into seven categories: pedestrian, two-wheel vehicle, four-wheel small vehicle (i.e., sedan and sport utility vehicle), four-wheel large vehicle (i.e., van, bus, and truck), a fixed object, unknown, and none. Severe injury was defined as an ISS of ≥16 points. TBI was defined when the head Abbreviated Injury Scale (AIS) was ≥1, and severe TBI was defined when head AIS was ≥3 [14]. In-hospital mortality was divided into two groups: alive and expired. The primary outcome was risk factors of TBI, and the secondary outcomes were factors associated with severe TBI and in-hospital mortality.

Statistical analysis

Descriptive statistics were reported as median (interquartile range) for continuous variables according to the normality test using the Kolmogorov-Smirnov test. Categorical variables were expressed as frequencies (percentage).

Intergroup comparisons of baseline characteristics based on the use of helmet (unhelmeted vs. helmeted group) and helmet type (half-face vs. open-face vs. full-face helmet group) were performed. Mann-Whitney U-test or Kruskal-Wallis test were used for continuous variables, while chi-square test or Fisher exact test for categorical variables. In addition, to determine whether there was a bias between unknown and known helmet type groups, the same statistical methods mentioned above were used.

Significant variables in the univariate analysis (i.e., those with $P < 0.10$) were entered into a stepwise backward multivariate logistic regression analysis to determine the independent risk factors of TBI, severe TBI and in-hospital mortality. For each independent risk factor, adjusted odds ratio (aOR) with 95% confidence (CI) were calculated. All statistical analyses were performed using IBM SPSS ver. 22.0 (IBM Corp), and $P < 0.05$ was considered statistically significant.

Fig. 1. The different types of helmets. (A) Full-face helmet, (B) open-face helmet, and (C) half-face helmet.

RESULTS

Comparison of the unhelmeted and helmeted groups

During the study period, 2,027 patients injured as a result of motorcycle accidents were registered in the EDIIS registry. Among the 1,910 patients of the study population, 604 belonged to the unhelmeted group while 1,306 to the helmeted group (Table 1). In the >65 years age group, the ratio of individuals not wearing a helmet was 22.8%, which was significantly higher than 12.6% who wore a helmet. In addition, the proportion of women not wearing a helmet was 15.4%, which was significantly higher than 6.0% of men not wearing a helmet. It was observed that accidents occurred mainly at night in both the groups (32.3% vs. 42.3%, respectively). The ratio of alcohol intake was 18.2% versus 6.1%, which was significantly higher in the unhelmeted group. The most common opponent object observed was a four-wheel small car, and the proportions were 40.9% and 58.1% in the unhelmeted and helmeted group, respectively. The prevalence of ISS ≥16, TBIs, and severe TBIs, as well as in-hospital mortality were highest in the unhelmeted group (22.4%, 37.7%, 19.9%, and 7.5%, respectively).

Logistic regression to predict TBI

Table 2 shows the factors affecting TBIs based on the use or disuse of helmets, using the multivariate logistic regression analysis. In this analysis, the adjusted variables were age ≥65 years, season, admission time, alcohol consumption, opponent object, and the use of a helmet. The analysis showed that the factors affecting TBIs were being elderly (aOR, 1.012; 95% CI, 1.007–1.018) and consumption of alcohol (aOR, 2.643; 95% CI, 1.914–3.650). The incidence of TBIs were lower in winter compared to spring (aOR, 0.627; 95% CI, 0.506–0.862), and the accidents were more common at night than dawn (aOR, 0.756; 95% CI, 0.608–0.941). Wearing a helmet (aOR, 0.544; 95% CI, 0.436–0.678) lowered the incidence of TBIs. The analysis of factors affecting severe TBIs and in-hospital mortality showed that the factors which reduced the incidence of severe TBIs included time of accident, i.e., night compared to dawn (aOR, 0.703; 95% CI, 0.505–0.978); accident site, i.e., an alley compared to a highway (aOR, 0.285; 95% CI, 0.102–0.796); and use of helmet (aOR, 0.307; 95% CI, 0.226–0.419) (Table S1). Being elderly (aOR, 1.021; 95% CI, 1.014–1.028) and drinking alcohol (aOR, 1.692; 95% CI, 1.106–2.589) were more likely to cause severe TBIs. Furthermore, it was observed that in-hospital mortality increased for the elderly (aOR, 1.017; 95% CI,1 .007–1.028) and for four-wheel large vehicle opponent object compared to pedestrians (aOR, 2.518; 95% CI, 1.195–5.305), and decreased for those wearing helmets (aOR, 0.325; 95% CI, 0.203–0.519) (Table S2).

Comparison of patients according to type of helmet in the group with known helmet type

Among the 1,309 patients who wore helmets, 596 were aware of the type of helmet while 710 were not. The 596 patients with clear helmet type were analyzed. Of these, 125, 185, and 286 patients wore half-face, open-face, and full-face helmets, respectively. Type of road and opponent object were the only two meaningful variables in terms of their basic characteristics. Furthermore, it was observed that majority of the accidents occurred on general roads at rates of 98.4%, 91.9%, and 98.6% in the half-face, open-face, and full-face groups, respectively; and four-wheel small vehicles as the opponent objects were responsible for most accidents at rates of 59.2%, 58.9%, and 58.4%, respectively (Table 3).

Logistic regression to predict TBI in the group with known helmet type

Table 4 shows the analysis of factors affecting TBIs in 596 patients who wore a helmet and were aware of the type. The factors that contributed to an increased incidence of TBIs were age above 65 years (aOR, 1.017; 95% CI, 1.005–1.028) and alcohol consumption (aOR, 2.423; 95% CI, 1.036–5.670). On the other hand, a correlation was observed that the incidence of TBIs decreased in the absence of an opponent object compared to when the opponent object were pedestrians (aOR, 0.496; 95% CI, 0.272–0.905) and when wearing a full-face helmet compared to a half-face helmet (aOR, 0.612; 95% CI, 0.396–0.944). Analysis of the factors affecting severity of TBIs and in-hospital mortality in this patient group (n=596) showed that age of the patient and colliding object were the correlating factors (Tables S3, S4).

Comparison of unknown and known helmet groups

To exclude any statistical bias as a result of the missing data, comparison was done between the group that wore helmet of unknown type and group that wore a known type of helmet. No significant differences were observed in terms of the variables, except incidence of TBI. Although the incidence of TBI was significantly higher in the group with unknown helmet type, the incidence rate of TBI was still as low as 28.3%. This could be interpreted as use of helmets prevented TBI, even when the type of helmet was unknown.

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Table 1. Comparison between the unhelmeted and helmeted groups (n=1,910)

Characteristic	Unhelmeted (n=604)	Helmeted (n=1,306)	P-value
Age (yr)	33 (20–63)	37 (26–51)	0.047
≥65			<0.001
No	466 (77.2)	1,141 (87.4)	
Yes	138 (22.8)	165 (12.6)	
Sex			<0.001
Male	511 (84.6)	1,228 (94.0)	
Female	93 (15.4)	78 (6.0)	
Season			0.053
Spring	160 (26.5)	309 (23.7)	
Summer	152 (25.2)	363 (27.8)	
Autumn	172 (28.5)	423 (32.4)	
Winter	120 (19.9)	211 (16.2)	
Admission time			<0.001
Dawn (00:00–05:59)	149 (24.7)	179 (13.7)	
Morning (06:00–11:59)	106 (17.5)	184 (14.1)	
Afternoon (12:00–17:59)	154 (25.5)	391 (29.9)	
Night (18:00–23:59)	195 (32.3)	552 (42.3)	
Alcohol consumption			<0.001
No	494 (81.8)	1,226 (93.9)	
Yes	110 (18.2)	80 (6.1)	
Type of road			0.544
Highway	1 (0.2)	1 (0.1)	
General road	565 (93.9)	1,306 (92.9)	
Alley	32 (5.3)	86 (6.5)	
Unknown	4 (0.7)	6 (0.5)	
Opponent object			<0.001
Pedestrian	3 (0.5)	11 (0.8)	
Two-wheel vehicle	28 (4.6)	82 (6.3)	
Four-wheel small vehicle	247 (40.9)	759 (58.1)	
Four-wheel large vehicle	31 (5.1)	63 (4.8)	
Fixed object	41 (6.8)	58 (4.4)	
Unknown	11 (1.8)	18 (1.4)	
None	243 (40.2)	315 (24.1)	
Injury Severity Score ≥16			<0.001
No	469 (77.6)	1,131 (86.6)	
Yes	135 (22.4)	175 (13.4)	
TBI (head AIS ≥1)			<0.001
No	376 (62.3)	997 (76.3)	
Yes	228 (37.7)	309 (23.7)	
Severe TBI (head AIS ≥3)			<0.001
No	484 (80.1)	1,223 (93.6)	
Yes	120 (19.9)	83 (6.4)	
In-hospital mortality			<0.001
Alive	559 (92.5)	1,274 (97.5)	
Expired	45 (7.5)	32 (2.5)	

Values are presented as median (interquartile range) or number (%).
TBI, traumatic brain injury; AIS, Abbreviated Injury Scale.

Table 2. Logistic regression to predict traumatic brain injuries (n=1,910)

Variable	Adjusted odds ratio	95% Confidence interval	P-value
Age ≥65 yr	1.012	1.006–1.017	<0.001
Season			
Spring	Reference		
Summer	1.152	0.862–1.541	0.339
Autumn	1.314	0.994–1.735	0.055
Winter	0.627	0.497–0.887	0.002
Admission time			
Dawn (00:00–05:59)	Reference		
Morning (06:00–11:59)	0.934	0.652–1.340	0.712
Afternoon (12:00–17:59)	0.967	0.697–1.343	0.843
Night (18:00–23:59)	0.756	0.608–0.941	0.012
Alcohol consumption			
No	Reference		
Yes	2.643	1.914–3.650	<0.001
Opponent object			
Pedestrian	Reference		
Two-wheel vehicle	0.371	0.188–1.280	0.116
Four-wheel small vehicle	0.596	0.190–1.869	0.375
Four-wheel large vehicle	0.758	0.225–2.558	0.655
Fixed object	0.749	0.223–2.517	0.641
Unknown	4.624	2.099–0.188	0.001
None	0.676	0.531–0.859	0.001
Use of helmet			
No	Reference		
Yes	0.544	0.436–0.678	<0.001

Variables included in multiple logistic regression: age ≥65 years, season, admission time, alcohol consumption, opponent object, and use of helmet.

DISCUSSION

This study aimed to identify the relationship between the use of helmets, occurrence of TBIs and severe TBIs, and in-hospital mortality in motorcycle accidents. The study also aimed to determine whether different types of helmets affected the occurrence of TBIs and severe TBIs and in-hospital mortality. Our study did not directly evaluate the injury-preventing function of helmets like the experiments conducted under uniform conditions, rather, retrospectively analyzed the EDIIS data. We observed that wearing a helmet reduced the occurrence of TBIs and severe TBIs and in-hospital mortality, which was consistent with the findings of other studies [6,7], which indicated that helmets mitigated head injuries in motorcycle accidents. Liu et al. [7] reported that wearing helmet decreased head injuries and mortality by 69% and 42%, respectively. These findings were very similar to our results, which showed that wearing a helmet reduced the incidence of TBIs (aOR, 0.544; 95% CI, 0.436–0.678) and in-hospital mortality (aOR, 0.325; 95% CI, 0.203–0.519).

Our study showed reduced incidence of TBI in the full-face helmet group. This was consistent with the findings of Tabary et al. [9]. However, the P-value in our study was 0.027, which was significant compared to the very limited evidence used in the aforementioned study. In addition, the report by Tabary et al. [9] showed that wider the area covered by the helmet including the face, lower was the degree of damage. We agree with the fact that the position of helmet at the time of the accident is an important factor for TBIs [15]. One study reported that protection of chin is an important differentiating factor between full-face helmets and other helmet types [16]. This study by Richter et al. [16] reported a high prevalence of damage to the chin guard region. Additionally, Otte [17] identified the distribution of impact locations on motorcycle helmets for all types of collisions and found that the rate reached 34.6% for the chin guard. On this basis, the *Motorcy-*

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Table 3. Comparison of patients according to type of helmet in the group with known helmet type (n=596)

Characteristic	Helmet group			P-value
	Half-face (n=125)	Open-face (n=185)	Full-face (n=286)	
Age (yr)	39.0 (24.3–57.0)	35.0 (25.0–52.0)	37.5 (26.0–49.8)	0.743
≥65				0.201
No	101 (80.8)	162 (87.6)	248 (86.7)	
Yes	24 (19.2)	23 (12.4)	38 (13.3)	
Sex				0.825
Male	118 (94.4)	177 (95.7)	272 (95.1)	
Female	7 (5.6)	8 (4.3)	14 (4.9)	
Season				0.042
Spring	29 (23.2)	36 (19.5)	87 (30.4)	
Summer	36 (28.8)	56 (30.3)	69 (24.1)	
Autumn	31 (24.8)	59 (31.9)	63 (22.0)	
Winter	29 (23.2)	34 (18.4)	67 (23.4)	
Admission time				0.900
Dawn (00:00–05:59)	17 (13.6)	27 (14.6)	39 (13.6)	
Morning (06:00–11:59)	18 (14.4)	24 (13.0)	33 (11.5)	
Afternoon (12:00–17:59)	36 (28.8)	48 (25.9)	90 (31.5)	
Night (18:00–23:59)	54 (43.2)	86 (46.5)	124 (43.4)	
Alcohol consumption				0.094
No	119 (95.2)	171 (92.4)	277 (96.9)	
Yes	6 (4.8)	14 (7.6)	9 (3.1)	
Type of road				<0.001
Highway	0	0	0	
General road	123 (98.4)	170 (91.9)	282 (98.6)	
Alley	2 (1.6)	15 (8.1)	4 (1.4)	
Unknown	0	0	0	
Opponent object				<0.001
Pedestrian	0	3 (1.6)	4 (1.4)	
Two-wheel vehicle	14 (11.2)	9 (4.9)	29 (10.1)	
Four-wheel small vehicle	74 (59.2)	109 (58.9)	167 (58.4)	
Four-wheel large vehicle	7 (5.6)	10 (5.4)	17 (5.9)	
Fixed object	2 (1.6)	13 (7.0)	11 (3.8)	
Unknown	1 (0.8)	0	2 (0.7)	
None	27 (21.6)	41 (22.2)	56 (19.6)	
Injury Severity Score ≥16				0.462
No	110 (88.0)	156 (84.3)	238 (83.2)	
Yes	15 (12.0)	29 (15.7)	48 (16.8)	
TBI (head AIS ≥1)				0.056
No	100 (80.0)	143 (77.3)	245 (85.7)	
Yes	25 (20.0)	42 (22.7)	41 (14.3)	
Severe TBI (head AIS ≥3)				0.924
No	117 (93.6)	175 (94.6)	268 (93.7)	
Yes	8 (6.4)	10 (5.4)	18 (6.3)	
In-hospital mortality				0.057
Alive	125 (100)	179 (96.8)	275 (96.2)	
Expired	0	6 (1.0)	11 (3.8)	

Values are presented as median (interquartile range) or number (%).
TBI, traumatic brain injury; AIS, Abbreviated Injury Scale.

Table 4. Logistic regression to predict traumatic brain injuries in the group with known helmet type (n=596)

Variable	Adjusted odds ratio	95% Confidence interval	P-value
Age ≥65 yr	1.017	1.005–1.028	0.004
Alcohol consumption			
No	Reference		
Yes	2.423	1.036–5.670	0.041
Opponent object			
Pedestrian	Reference		
Two-wheel vehicle	0.517	0.084–3.176	0.477
Four-wheel small vehicle	0.519	0.098–2.772	0.440
Four-wheel large vehicle	0.551	0.086–3.546	0.531
Fixed object	0.337	0.047–2.440	0.282
Unknown	1.453	0.077–27.248	0.803
None	0.496	0.272–0.905	0.022
Type of helmet			
Half-face	Reference		
Open-face	1.243	0.707–2.182	0.450
Full-face	0.612	0.396–0.944	0.027

Variables included in multiple logistic regression: age ≥65 years, sex, season, admission time, alcohol consumption, opponent object, type of road, and type of helmet.

cle Safety Guide provided by the CDC emphasizes the importance of full-face helmets. Similarly, Tabary et al. [9] also reported that full-face type helmets remained fixed in the most intact position at the scene after the accident, and this benefit had the most significant effect on mortality in motorcycle traffic accidents. This fact is also supported by findings on the relationship between helmet loss during accident and fatal injury [16]. The UN-ECE regulation [12], currently used in more than 50 countries and the world's most popular motorcycle helmet test standard, provides safety regulations for helmet users. However, the usefulness of this certification is debated as it does not test for penetration and has no test for chin guards [18]. Motorcyclists who purchase helmets should be made aware that only full-face helmets achieve their true function, that is ensuring safety. The Eastern Association for the Surgery of Trauma (EAST) Guidelines Committee Injury Prevention Task Force of the United States conducted a study on the effectiveness of full-face helmets to develop practice management guidelines for the use of motorcycle helmets [19]. This meta-analysis was published in 2022, which concluded that full-face helmets prevented TBIs and recommended their use in motorcyclists [19]. Although the full-face helmet is not a specific advanced case, it was found that if the helmet law was repealed in the United States, the use of helmets decreased significantly, and consequently death and TBI increased [6]. Conversely, the use of helmets has been found to increase with the enactment of the helmet wearing law, and it is expected that the incidence of TBI would decrease with promulgation of laws regarding the use of full-face helmets.

Interestingly, with respect to sex, the current study found a higher proportion of unhelmeted female patients (93 of 171, 29.4% vs. 511 of 1,739, 54.4%) (Table 1). Although the reason for this disparity remains unknown, these findings highlight the need to increase the awareness and use of helmets in women. Meanwhile, although several studies found that alcohol use was an influencing factor for mortality or severe injury in motorcycle traffic accidents [20,21], our result indicated that alcohol consumption was a risk factor for the occurrence of TBIs and severe TBIs. Jeong et al. [11] reported that alcohol consumption was associated with high risk of TBI because of the tendency to not to wear a helmet when intoxicated. However, our results support that the use of correct type of helmet, rather than alcohol intake itself, reduced injuries and affected the severity of injury. Future research are needed to establish the direct effect of alcohol consumption on the severity of injury.

This study had some limitations. First, the possibility of bias could not be ruled out owing to the retrospective study design. Second, although the EDIIS is a nationwide system, there may have been a bias in patient recruitment since the participating medical institutions were relatively high-level emergency departments. Third, the missing data in the group that wore unknown type of helmet exceeded the number in the group that wore accurate type of helmet. However, to compensate for the statistical

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Table 5. Comparison between the unknown and known type of helmet groups (n=1,306)

Characteristic	Helmet type		P-value
	Unknown (n=710)	Known (n=596)	
Age (yr)	36 (26–50)	37 (26–52)	0.449
≥65			0.112
No	630 (88.7)	511 (85.7)	
Yes	80 (11.3)	85 (14.3)	
Sex			0.129
Male	661 (93.1)	567 (95.1)	
Female	49 (6.9)	29 (4.9)	
Season			<0.001
Spring	157 (22.1)	152 (25.5)	
Summer	202 (28.5)	161 (27.0)	
Autumn	270 (38.0)	153 (25.7)	
Winter	81 (11.4)	130 (21.8)	
Admission time			0.381
Dawn (00:00–05:59)	96 (13.5)	83 (13.9))	
Morning (06:00–11:59)	109 (15.4)	75 (12.6)	
Afternoon (12:00–17:59)	217 (30.6)	174 (29.2)	
Night (18:00–23:59)	288 (40.6)	264 (44.3)	
Alcohol consumption			0.084
No	659 (92.8)	567 (95.1)	
Yes	51 (7.2)	29 (4.9)	
Type of road			<0.001
Highway	1 (0.1)	0	
General road	638 (89.9)	575 (96.5)	
Alley	65 (9.1)	21 (3.5)	
Unknown	6 (0.9)	0	
Opponent object			<0.001
Pedestrian	4 (0.6)	7 (1.2)	
Two-wheel vehicle	30 (4.2)	52 (8.7)	
Four-wheel small vehicle	409 (57.6)	350 (58.7)	
Four-wheel large vehicle	29 (4.1)	34 (5.7)	
Fixed object	32 (4.5)	26 (4.4)	
Unknown	15 (2.1)	3 (0.5)	
None	191 (26.9)	124 (20.8)	
Injury Severity Score ≥16			0.051
No	627 (88.3)	504 (84.6)	
Yes	83 (11.7)	92 (15.4)	
TBI (head AIS ≥1)			<0.001
No	509 (71.7)	488 (81.9)	
Yes	201 (28.3)	108 (18.1)	
Severe TBI (head AIS ≥3)			0.733
No	663 (93.4)	560 (94.0)	
Yes	47 (6.6)	36 (6.0)	
In-hospital mortality			0.473
Alive	695 (97.9)	579 (97.1)	
Expired	15 (2.1)	17 (2.9)	

Values are presented as median (interquartile range) or number (%).
TBI, traumatic brain injury; AIS, Abbreviated Injury Scale.

bias resulting from this difference, we performed an analysis, the description of which is presented separately in Table 5. Fourth, the number of variables for each type of helmet was small, although the number of patients included in our study was much higher compared to foreign studies. Finally, since the predefined variables of EDIIS lack specificity for evaluation of all important factors, our findings may have limited generalizability and validity. Future studies encompassing more hospitals of all levels and more detailed patient information would help address these limitations and provide information that is more representative of the entire Korean population.

In conclusion, the use of a helmet is very important as it plays a significant role in reducing the occurrence of TBIs and severe TBIs and in-hospital mortality in motorcycle accidents. Although the study did not rank the types of helmets for better protection, we found that the use of a full-face helmet lowered the incidence of TBIs. It is recommended that in future studies, ranking by type of helmet be established with an increased number of variables for each type of helmet, which would be helpful in supplementing education and laws for motorcyclists.

SUPPLEMENTARY MATERIALS

Table S1. Logistic regression to predict severe traumatic brain injuries (n = 1,910)
Table S2. Logistic regression to predict in-hospital mortality (n = 1,910)
Table S3. Logistic regression to predict severe traumatic brain injuries (n = 596)
Table S4. Logistic regression to predict in-hospital mortality (n = 596)
Supplementary materials are available from https://doi.org/10.20408/jti.2022.0029.

NOTES

Conflicts of interest
The authors have no conflicts of interest to declare.

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Data sharing statement
The data of this article are available from the corresponding author upon reasonable request.

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Author contributions
Conceptualization: YC, SRY; Data curation: SS; Formal analysis: SWP; Funding acquisition: YC; Methodology: SJC; Writing–original draft: SS, YC, SWP; Writing–review & editing: IJW, WTY, SJC, SRY. All authors read and approved the final manuscript.

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Thoracolumbar spine fracture patterns, etiologies, and treatment modalities in Jordan

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Purpose: Spine fractures are a significant cause of long-term disability and socioeconomic burden. The incidence of spine fractures tends to increase with age, decreased bone density, and fall risk. In this study, we evaluated thoracolumbar fractures at a tertiary hospital in Jordan regarding their frequency, etiology, patterns, and treatment modalities.

Methods: The clinical and radiological records of 469 patients with thoracolumbar fractures admitted to King Hussein Medical City from July 2018 to August 2022 were evaluated regarding patients' age, sex, mechanism of injury, fracture level and pattern, and treatment modalities.

Results: The mean age of patients was 51.24±20.22 years, and men represented 52.3%. Compression injuries accounted for 97.2% of thoracolumbar fractures, and the thoracolumbar junction was the most common fracture location. Falling from the ground level was the most common mechanism and accounted for half of the injuries. Associated neurological injuries were identified in 3.8% of patients and were more common in younger patients. Pathological fractures were found in 12.4% and were more prevalent among elderly patients and women.

Conclusions: Traffic accidents and falling from height were the most common causes of spine fractures in patients younger than 40. However, 70% of spine fractures in women were caused by simple falls, reflecting the high prevalence of osteoporosis among women and the elderly. Therefore, traffic and work safety measures, as well as home safety measures and osteoporosis treatment for the elderly, should be recommended to reduce the risk of spine fractures.

Keywords: Fractures; Jordan; Thoracolumbar junction; Spine

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INTRODUCTION

Spine fractures are a significant cause of long-term disability and socioeconomic burden [1,2]. The incidence of spine fractures tends to increase with age, decreased bone density, and fall risk. However, increasing road traffic accidents have led to a higher frequency of spine injuries in young people [3,4].

Spinal injuries can result from injury to bony structures and the surrounding ligaments [5]. The involvement of the spinal cord may lead to devastating injuries [6]. Thoracolumbar fracture classification systems are used to facilitate effective communication between spine surgeons, guide treatment, and help pre-

dict the prognosis. An ideal classification system should be simple, comprehensive, reliable, and reproducible with predictive outcomes. Most of the existing classifications have certain advantages and disadvantages. Denis three-column spine model, proposed in 1989, was subsequently used to develop the AO classification of spinal injuries, which includes three categories: compression fracture (group A), distraction injury (group B), and translational injury or rotational injury (group C), and the severity and the need for surgery increase from group A to C [7–9].

Thoracolumbar junction fractures (T10 to L2) are the most common spinal column injuries because of the large amount of biomechanical stress involving this region due to the transition from the less mobile thoracic spine to the dynamic lumbar spine [10]. In this review, we evaluated the frequency, etiology, patterns, and treatment of thoracolumbar fractures at a tertiary hospital in Jordan.

METHODS

Ethics statements

This study was approved by the Human Research Ethics Committee of Royal Medical Services (No. 23/2022). The requirement for informed consent was waived due to the retrospective nature of the study.

Study design

This retrospective study reviewed the clinical and radiological records of all thoracolumbar fractures admitted to King Hussein Medical City (Amman, Jordan) from July 2018 to August 2022. King Hussein Medical City is a referral center for all districts and health sectors in the kingdom. In total, 469 thoracolumbar patients with fractures were enrolled in this study, their sociodemographic data were extracted from their records, and their radiographs were reviewed using a picture archiving and communication system to analyze the fractures' locations and patterns.

The patients' age, sex, mechanism of injury, level of fracture, fracture pattern, and treatment modalities were obtained. The AO classification system was used to classify fractures into type A (compression injuries, including wedge, burst, spinous, and transverse process fractures), type B (distraction injuries, as represented by Chance fractures), and type C (torsional injuries, which result in fracture-dislocation).

Treatment was classified as conservative, kyphoplasty, vertebroplasty, and fusion. The mechanism of injury was classified into simple falls (from ground level), falls from height, road traffic accidents, and others. Age groups were classified into 18 to 40, 40 to 64, and older than 65 years. Pediatric patients (younger than 18 years) were excluded from the study.

Statistical analysis

The mean and standard deviation were used to describe the continuously measured variables and the median and interquartile range for continuous variables with skewness. The frequency and percentage were used to describe the categorically measured variables. Multiple-response dichotomy analysis was applied to describe multiple-choice variables. The Kolmogorov-Smirnov test was used to assess the statistical normality assumption for metric variables. The bivariate chi-square test of association was used to assess the correlations between categorical variables. However, the continuity-corrected chi-square and the likelihood ratio chi-square test of association were used when the statistical count assumption was violated in some contingency tables with fewer than expected counts for the 2×2 and 2-way tables. IBM SPSS ver. 21 (IBM Corp) was used for the statistical data analysis. The alpha significance level was set at 0.050.

RESULTS

The records of 469 patients were retrospectively reviewed. The mean age of the patients was 51.24 ± 20.22 years, and male patients represented 52.7% of the sample (Table 1). Compression fractures accounted for most thoracolumbar injuries (97.2%), and wedge and burst fractures were the most common form of compression fractures, accounting for 52.2% and 41.4%, respectively. Distraction and translational injuries represented 2.8% of all injuries. However, associated neurological lesions were identified in 3.8% of patients, and pathologies were found in 12.4%. Injuries mainly occurred in the lumbar spine (83.6%). However, 90% of fractures occurred in the thoracolumbar junction (Fig. 1).

Falls from the ground level were the most common mechanism, accounting for half of the injuries, while falling from height and road traffic accidents caused 26.7% and 21.3% of fractures, respectively. Most patients (58.0%) were treated surgically, mainly by surgical fusion and kyphoplasty. However, conservative treatment was the treatment for 42.0% of patients.

When comparing the incidence of thoracolumbar fractures between different sexes and ages, more than 50% of thoracolumbar spine fractures in female patients occurred in patients older than 65 years. In contrast, about half of fractures in male patients were observed in patients under the age of 40 years. Additionally, injuries involving higher thoracic spine levels (especially T6 to T9) were significantly associated with younger age groups. Neverthe-

Table 1. Descriptive analysis of the patients and their fractures (n=469)

Variable	No (%)
Sex	
Female	222 (47.3)
Male	247 (52.7)
Age (yr)	
≤39	162 (34.5)
40–64	144 (30.7)
≥65	163 (34.8)
Fracture classification and pattern	
Compression injury	456 (97.2)
Wedge	245 (52.2)
Burst	194 (41.4)
Transverse process	15 (3.2)
Spinous process	2 (0.4)
Distraction injury (Chance)	5 (1.1)
Translational injury (fracture dislocation)	8 (1.7)
Pathological fracture	58 (12.4)
Associated neurological injury	18 (3.8)
Mechanism of injury	
Simple fall	233 (49.7)
Fall from height	125 (26.7)
Road traffic accident	100 (21.3)
Others	11 (2.3)
Received treatment	
Conservative	197 (42.0)
Fusion surgery	151 (32.2)
Kyphoplasty	105 (22.4)
Vertebroplasty	16 (3.4)

less, there was no significant difference in lumbar fractures in the different age groups (Figs. 2, 3).

Compression injuries were the most common pattern across all age groups. Additionally, pathological fractures were more prevalent among the elderly and female patients, and associated neurological injuries were more likely in younger patients. Young patients were more likely to have experienced high-energy injury mechanisms such as falls from heights and road traffic accidents. However, spinal fractures in elderly patients were due to simple falls. Most spine fractures in the younger age group mandated fusion surgery, unlike elderly patients, whose fractures were mostly treated by kyphoplasty (Table 2).

DISCUSSION

Epidemiological studies on spinal fractures are lacking in Jordan; thus, this study analyzed thoracolumbar fracture patients admitted to the spine unit in King Hussein Medical City. The results of this study improve our understanding of the incidence of spinal fractures in Jordan, helping to identify the needs of our healthcare system and suggesting guidelines for protective measures.

The first 10 thoracic vertebrae are connected by ribs to the sternum anteriorly; therefore, the thoracic spine is less mobile than the lumbar spine due to the stability provided by the thoracic cage. In contrast, the thoracolumbar region (T10 to L2) and lumbar region are flexible, and the transition from a less mobile

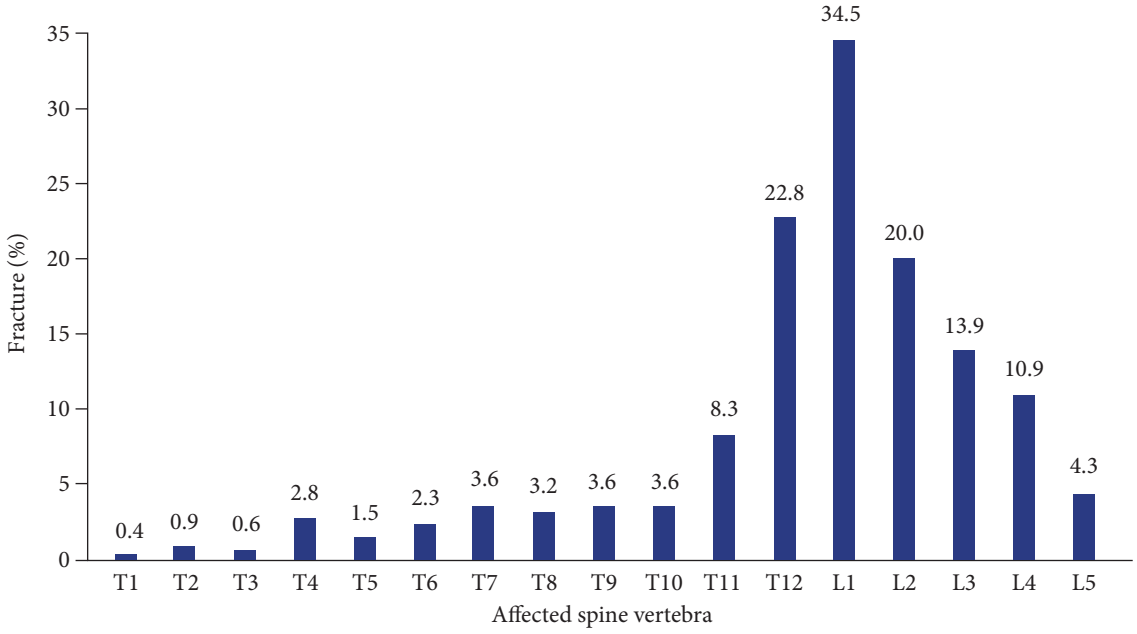

Fig. 1. The distribution of thoracolumbar fractures. The numbers represent the percentage of each vertebra fracture.

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Sex (%)		P-value
Male	Female	
0.8	0	0.529
1.6	0	0.161
1.2	0	0.286
3.6	1.8	0.225
1.6	1.4	>0.999
2.4	2.3	>0.999
4.5	2.7	0.311
3.2	3.2	>0.999
5.7	1.4	0.013[a]
4.0	3.2	0.604
8.1	8.6	0.857
17.0	29.3	0.002[a]
35.2	33.8	0.747
21.5	18.5	0.419
14.6	13.1	0.636
11.3	10.4	0.735
4.9	3.6	0.502

Fig. 2. Thoracolumbar fracture distribution among both sexes. The numbers represent the percentage of each vertebral fracture within the same sex. [a]Statistically significant difference.

Age (yr) (%)			P-value
≤39	40–64	≥65	
0.6	0.7	0	0.432
1.9	0.7	0	0.118
1.2	0.7	0	0.246
4.3	2.1	1.8	0.349
2.5	1.4	0.6	0.370
4.9	1.4	0.6	0.026
6.2	4.2	0.6	0.011[a]
6.8	1.4	1.2	0.008[a]
6.2	3.5	1.2	0.048
5.6	4.2	1.2	0.075
8.6	9.0	7.4	0.853
23.5	20.8	23.9	0.787
35.2	36.1	32.5	0.785
17.9	20.8	21.5	0.692
16.0	11.1	14.1	0.456
10.5	9.0	12.9	0.546
5.6	2.1	4.9	0.286

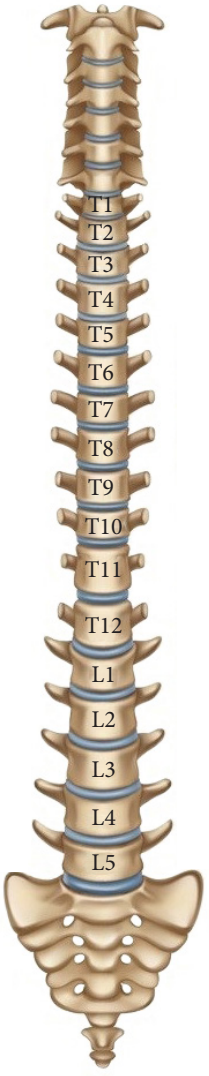

Fig. 3. Thoracolumbar fracture distribution among different age groups. The numbers represent the percentage of each vertebral fracture within the same age category. [a]Statistically significant difference.

thoracic cage to the lumbar spine explains the high frequency of traumatic spinal injuries and degenerative changes in this region. The spinal cord ends at L1 to L2. Therefore, fractures associated with neurological injuries above this level result in upper motor neuron manifestations and lower motor neuron presentations at a lower level [11–13].

Many factors play an important role in fracture patterns, such as the mechanism of injury, the age of patients, and preexisting bone pathology. Spine fractures occur mainly with high-energy injuries such as falls and road traffic accidents. Pathological fractures and osteoporotic fractures might happen with minor trauma [14,15].

When comparing our results with similar studies from other countries in the region—specifically, Saudi Arabia [16] and the United Arab Emirates (UAE) [17]—we found a higher mean age of the patients (51.24 ± 20.22 years) than was reported in the Saudi study (36.9 ± 16.2 years) or the UAE study (37.5 ± 12.5 years). Similarly, in our study, male and female patients were affected nearly equally. However, male patients outnumbered female patients by four times in the Saudi study and nine times in the UAE study. We explain this difference in age and sex as resulting from the large number of expatriate workers in the Gulf area, most of whom are young men. Falling from height was the leading cause of spine injuries in Jordan, while traffic accidents were the most common cause in the Saudi Arabia and UAE studies.

Simple falls were the most common mechanism of spine frac-

Table 2. Bivariate comparison between patients' age groups and sex and spine fractures

Variable	Age (yr)				Sex		
	≤39 (n=162)	40–64 (n=144)	≥65 (n=163)	P-value	Female (n=222)	Male (n=247)	P-value
Fracture classification and pattern				0.018			0.804
Compression injury	152 (93.8)	141 (97.9)	163 (100)		217 (97.7)	239 (96.8)	
Distraction injury	4 (2.5)	1 (0.7)	0		2 (0.9)	3 (1.2)	
Translational injury	6 (3.7)	2 (1.4)	0		3 (1.4)	5 (2.0)	
Fracture pattern				<0.001			0.031
Wedge	78 (48.1)	72 (50.0)	95 (58.3)		115 (51.8)	130 (52.6)	
Burst	62 (38.3)	64 (44.4)	68 (41.7)		100 (45.0)	94 (38.1)	
Transverse process	10 (6.2)	5 (3.5)	0		2 (0.9)	13 (5.3)	
Spinous process	2 (1.2)	0	0		0	2 (0.8)	
Chance	4 (2.5)	1 (0.7)	0		2 (0.9)	3 (1.2)	
Fracture dislocation	6 (3.7)	2 (1.4)	0		3 (1.4)	5 (2.0)	
Pathological fracture	1 (0.6)	9 (6.2)	48 (29.4)	<0.001	45 (20.3)	13 (5.3)	<0.001
Neurological injury	13 (8.0)	3 (2.1)	2 (1.2)	0.003	6 (2.7)	12 (4.9)	0.225
Mechanism of injury				<0.001			<0.001
Simple fall	21 (13.0)	68 (47.2)	144 (88.3)		157 (70.7)	76 (30.8)	
Fall from height	66 (40.7)	44 (30.6)	15 (9.2)		44 (19.8)	81 (32.8)	
Road traffic accident	70 (43.2)	26 (18.1)	4 (2.5)		17 (7.7)	83 (33.6)	
Others	5 (3.1)	6 (4.2)	0		4 (1.8)	7 (2.8)	
Received treatment				<0.001			<0.001
Conservative	71 (43.8)	63 (43.8)	63 (38.7)		82 (36.9)	115 (46.6)	
Fusion surgery	89 (54.3)	54 (37.5)	9 (5.5)		56 (25.2)	95 (38.5)	
Kyphoplasty	3 (1.9)	20 (13.9)	82 (50.3)		74 (33.3)	31 (12.6)	
Vertebroplasty	0	7 (4.9)	9 (5.5)		10 (4.5)	6 (2.4)	

Values are presented as number (%).

ture in patients older than 40 years. However, it was responsible for 47.2% of injuries in the middle age group and 88.3% for those older than 65 years. In contrast, road traffic accidents were the most common mechanism in young patients, followed by falls from height, and male patients are more prone to such mechanisms.

Compression injuries are the most common pattern across all age groups and in both sexes. However, the low frequency of minor fractures, such as transverse and spinous process fractures, is explained by the fact that our center is a referral center to which patients whose fractures need surgical intervention or even bracing are referred. In contrast, fractures that did not need such treatment received treatment at the local hospitals distributed throughout Jordan.

Thoracolumbar fractures were associated with neurological injuries in 3.8% of patients in our study, with no significant difference between the sexes. However, patients younger than 40 were more predisposed to neurological injuries, which is explained by the fact that injuries in this age group are more likely to be due to high-energy injuries such as road traffic accidents and falls from height. Otom et al. [18] retrospectively reviewed 151 patients in Jordan with traumatic spinal cord injuries during 1988–1993 and concluded that the estimated annual incidence was 18 per million population; male patients represented the majority with a percentage of 85.4%, and the mean age was 33 years. Two-thirds of patients developed paraplegia, and the remaining third developed quadriplegia. Motor vehicle accidents were the commonest cause of traumatic spinal injury, followed by bullet injuries.

Pathological spine fractures accounted for 12.4% of our cases and were more notable in female patients and patients older than 65. However, this percentage would be higher if insufficiency fractures were included. In this study, we defined a fracture as pathological if there were pathological deposits to the spine or radiological reports of pathological fracture. However, some reports counted insufficiency fractures as pathological, although most of these fractures are not classified in the radiological reports as pathological. Therefore, this percentage does not represent the actual prevalence of all pathological fractures, and the lack of sufficient data precludes a detailed analysis of pathological spine fractures.

The prevalence of osteoporotic vertebral fractures steadily increases with advancing age. Although most fractures heal well,

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up to 30% of fractures can develop painful nonunion, progressive kyphosis, and neurological deficits. However, such patients will benefit from percutaneous interventions such as vertebroplasty and kyphoplasty, while unstable fractures and associated neurological deficits are candidates for spinal fusion [19,20].

Thoracolumbar spine fractures can be treated either nonoperatively or operatively, depending on the extent of bony injury, neurological involvement, and posterior ligamentous complex integrity. Most thoracolumbar fractures are stable and treated nonoperatively with a molded brace or hyperextension cast that allows early mobility [21,22]. In our sample, 42% received conservative treatment by bed rest and orthosis; one-third underwent surgical fixation, and 25% received vertebroplasty or kyphoplasty treatment. Young male patients received fusion surgery more often because their high-energy injuries resulted in unstable spine fractures, while female patients more frequently underwent kyphoplasty, which is explained by their higher osteoporotic risk.

Vertebroplasty or kyphoplasty are minimally invasive vertebral cement augmentation techniques that give an alternative solution to prolonged bed rest or invasive spine surgery. Pain relief occurs due to fracture stabilization and thermal and chemical ablation of nerve endings [23,24].

The advantage of surgical treatment is that it fastens rehabilitation and early mobilization and allows restoration of surgical alignment of the spine. Surgical intervention allows spinal canal decompression and thus can restore neurological function [25–27]. Surgery carries the risk of blood loss and infection. Rechtine et al. [28] reported a 10% infection rate. Siebenga et al. [29] compared the outcome between a group treated nonoperatively with 5 days of bed rest followed by 3 months of a Jewett brace and another group treated surgically with short-segment posterior pedicle screw fixation and found higher scores in the surgically treated group after 4 years of follow-up.

The main drawback of our study is the retrospective design, and the lack of adequate documentation of the injury mechanism prevented a detailed analysis of the etiology. Grouping the mechanism of injury into broad categories, such as simple falls and falls from a height, makes it challenging to identify the exact causes of the injury and determine future preventive measures. The lack of data regarding spine pathology precludes a detailed analysis of this issue.

In conclusion, traffic accidents and falling from heights were the commonest causes of spine fractures in patients younger than 40 years. However, 70% of spine fractures in female patients were caused by simple falls, reflecting the high prevalence of osteoporosis among female and elderly patients. Therefore, traffic and work safety measures should be enforced to reduce the risk of spine fractures in young patients, and home safety measures and osteoporosis treatment should be provided for elderly patients.

NOTES

Conflicts of interest
The authors have no conflicts of interest to declare.

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None.

Data sharing statement
The data of this article are available from the corresponding author upon reasonable request.

Author contributions
Conceptualization: AA; Data curation: SA, MBM, MA, AAA; Formal analysis: AA; Methodology: AA; Project administration: AA; Visualization: all authors; Writing–original draft: AA; Writing–review & editing: AA. All authors read and approved the final manuscript.

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Experience of surgical treatments for abdominal inferior vena cava injuries in a regional trauma center in Korea

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Purpose: Inferior vena cava (IVC) injuries are a rare type of traumatic abdominal injuries that are challenging to treat and have a very high mortality rate. This study described our experience with the surgical treatment of traumatic IVC injuries, and we investigated the demographics, clinical profiles, and surgical outcomes of cases at a regional trauma center.

Methods: Among the 16 patients who were treated for a traumatic IVC injury between January 2014 and March 2022, 14 underwent surgery. The surgical outcomes included overall mortality and 24-hour mortality, and we investigated the factors associated with these surgical outcomes. The 14 patients were divided into two groups according to the location of the IVC injury (retrohepatic IVC or higher vs. subhepatic IVC), and differences between the two groups were analyzed.

Results: A body mass index (BMI) >23.0 kg/m^2 (P=0.046), an elevated serum lactate level (P=0.043), and a shorter operation time (P=0.016) were associated with overall mortality. A higher BMI (P=0.050), higher serum lactate level (P=0.004), shorter operation time (P=0.005), and an injury at the retrohepatic IVC or higher level (P=0.031) were associated with 24-hour mortality. Younger age (P=0.028), higher BMI (P=0.005), more acidic pH, higher lactatemia (P=0.012), a higher hemoglobin level (P=0.012), and shorter door-to-operating room time (P=0.028) were associated with injury at the retrohepatic IVC or higher level. Patients with subhepatic IVC injuries had a high rate of direct repair (75.0%) and a significantly lower 24-hour mortality rate (37.5%, P=0.031).

Conclusions: Subhepatic IVC injuries are easy to access and are usually expected to treat with a direct repair method. Injuries at the retrohepatic IVC or higher level are difficult to treat surgically and require a systematic and multidisciplinary treatment strategy.

Keywords: Inferior vena cava; Wounds and injuries; Operative surgical procedures

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INTRODUCTION

Traumatic inferior vena cava (IVC) injuries are rare among traumatic abdominal injuries, accounting for fewer than 5% of penetrating injuries and 0.5% of blunt trauma injuries [1]. However, they are often fatal, with prehospital and in-hospital mortality rates of 30% to 50% and 20% to 66%, respectively [2].

There are various methods for treating traumatic IVC injuries,

including surgery, vascular grafting, and even close monitoring, depending on the injury level and patient stability. Although IVC repair is the mainstay treatment, in cases where repair is challenging because of massive bleeding, difficult access to the injured site, or notable patient instability, ligation is a treatment option [3]. An atriocaval shunt can also be used to repair the retrohepatic IVC segment [4]. This variety of treatment methods illustrates the lack of consensus or guidelines, and survival rates have not significantly improved over time [5].

Currently, a higher level of injury, blunt trauma, and a lower Glasgow Coma Scale (GCS) score are associated with worse outcomes of traumatic IVC injuries [3,6–8]. However, relatively few cases of IVC injuries have been studied to identify the prognostic factors.

IVC injuries often require emergency treatment, and it can be difficult to collect data in those urgent situations. Moreover, IVC injuries are rare and information is scarce. In Korea, where the availability of authorized trauma centers is relatively recent, there have been few studies on traumatic IVC injuries, and most are case reports. Therefore, this study aimed to describe our experience with the surgical treatment of traumatic IVC injuries and to investigate the demographics, clinical profiles, and surgical outcomes of cases at a regional trauma center.

METHODS

Ethics statements

This study was reviewed and approved by the Institutional Review Board Dankook University Hospital (No. DKUH 2022-11-034). The requirement for informed consent was waived by the Institutional Review Board because this was a retrospective study and only anonymized data were used.

Description of participants

The medical records of patients admitted to a single regional trauma center for traumatic IVC injuries between January 2014 and March 2022 were retrospectively reviewed. Nineteen patients with IVC injuries were identified. Among them, one patient had an IVC contusion only, one patient had an unnamed vessel branch injured near the IVC, and one patient was transferred from another hospital after already undergoing repair. Thus, 16 patients were enrolled after the three above-mentioned patients were excluded. Of these 16 patients, two underwent medical treatment without surgery. Finally, 14 patients were enrolled for the analysis of surgical outcomes (Fig. 1). The surgical outcomes included overall mortality and 24-hour mortality. We aimed to identify the factors associated with these surgical outcomes and the differences between patients with injuries at the retrohepatic IVC or higher level and those with injuries at the subhepatic IVC level.

Data collection

Data regarding patient demographics, injury levels, initial clinical characteristics, initial laboratory values, treatments, and surgical outcomes were collected. The demographics included age, sex, body mass index (BMI), injury mechanism, cause of injury, prehospital time, Injury Severity Score (ISS), and Abbreviated Injury Scale for each body part. Initial clinical characteristics included systolic blood pressure (SBP), heart rate per minute, mean arterial pressure (MAP), and GCS score. Initial laboratory values included pH, partial pressure of arterial oxygen, serum lactate level, hemoglobin, and international normalized ratio. Treatment data included cardiopulmonary resuscitation (CPR) in the emergency room (ER), door-to-operating room (DTO) time, main treatment methods (direct repair, ligation, atriocaval shunt, observation, and others), amount of red blood cells (RBCs) transfused within the first 24 hours, and operation time. "Others" in the main treatment methods included procedures to stop bleeding such as gauze packing, direct manual compression, and resuscitative endovascular balloon occlusion of the aorta.

If the patient was intubated on arrival, the GCS verbal score was calculated using a linear regression model as follows [9]:

$$\text{Derived verbal score} = -0.3756 + \text{motor score} \times (0.5713) + \text{eye score} \times (0.4233)$$

The abdominal IVC was anatomically divided into five segments as follows: (1) suprahepatic IVC, from the upper margin of the hepatic veins to the lower margin of the diaphragm; (2) retrohe-

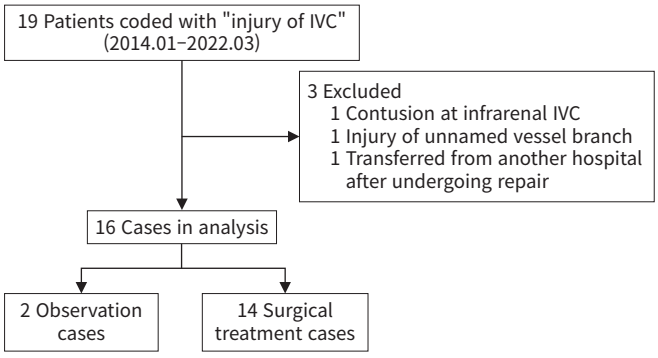

Fig. 1. Patient selection flow chart in a study of patients with traumatic inferior vena cava (IVC) injuries.

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patic IVC, which is covered by the liver; (3) suprarenal IVC, from the upper margin of the renal vessels to the lower margin of the liver; (4) juxtarenal IVC, between the bilateral renal vessels; and (5) infrarenal IVC, from the bifurcation of the common iliac veins to the lower margin of the renal vessels (Fig. 2). In this study, subhepatic IVC included the IVC segments below the retrohepatic IVC.

Statistical analysis

Categorial variables were analyzed using the Fisher exact test and continuous variables were analyzed using the Mann-Whitney U-test. Continuous variables were expressed as median values (interquartile range, IQR). Statistical significance was set at $P < 0.05$. Statistical analysis was conducted using R ver. 4.2.0 (R Foundation for Statistical Computing).

RESULTS

Demographics

Of the 16 patients who had traumatic IVC injury, 10 (62.5%) were male and 15 (93.8%) had blunt trauma. The most common cause of traumatic IVC injury was a car-driver traffic accident (six patients, 37.5%), followed by falls (three patients, 18.8%). The median patient age was 48 years (IQR, 40–68 years), BMI was 23.4 kg/m^2 (IQR, 21.0–26.1 kg/m^2), prehospital time was 92.5 minutes (IQR, 54.0–158.0 minutes), and ISS was 34 (IQR, 25–43) (Table 1). The most common injury level was the retrohepatic IVC (six patients, 37.5%), followed by the infrarenal IVC (five patients, 31.3%), suprarenal IVC (two patients, 12.5%), juxtarenal IVC (two patients, 12.5%), and suprahepatic IVC (one patient, 6.3%) (Fig. 2).

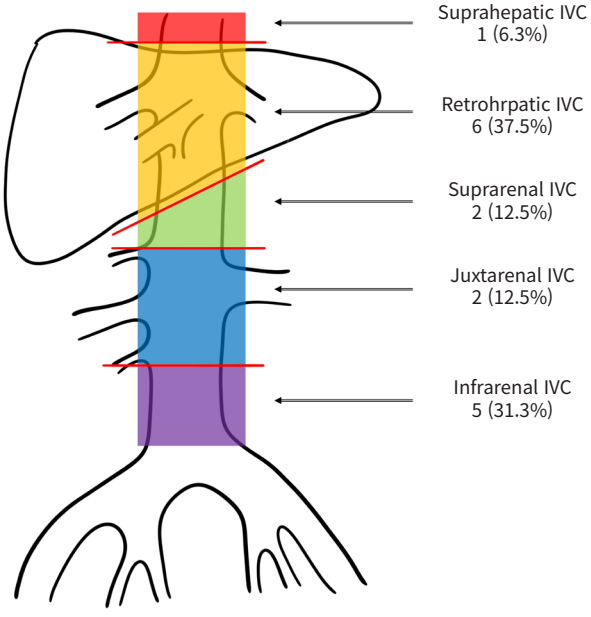

Fig. 2. Anatomical levels of the inferior vena cava (IVC), distinguished by colors and frequency (percentage) of injuries in this study: red, suprahepatic IVC; orange, retrohepatic IVC; green, suprarenal IVC; blue, juxtarenal IVC; purple, infrarenal IVC.

Clinical characteristics and initial laboratory findings

During admission, the median SBP and MAP values were 86.5 mmHg (IQR, 71.8–120.8 mmHg) and 60.5 mmHg (IQR, 54.7–85.3 mmHg), respectively. Patients had a moderate loss of consciousness (median GCS, 10; IQR, 6–15). The initial laboratory data showed acidosis (median pH, 7.31; IQR, 7.24–7.37) with hyperlactatemia (median lactate, 4.3 mmol/L; IQR, 2.2–7.5 mmol/L) (Table 1).

Treatment and surgical outcomes

Of the 16 patients studied, eight (50.0%) underwent direct repair, two (12.5%) were closely monitored (observation), one (6.3%) underwent ligation, and one (6.3%) underwent an atriocaval shunt. Furthermore, four patients (25.0%) underwent other damage control surgery, and three (18.8%) underwent CPR in the ER. The median DTO time was 72.5 minutes (IQR, 55.8–109.8 minutes) and the median number of RBC units transfused within the first 24 hours was 29.0 (IQR, 19.8–40.3). Of the two patients who were closely monitored, one had a pericaval hematoma at the infrarenal IVC level and received only an injection of tranexamic acid and fluid therapy because the hemodynamics were stable. The other patient was hypotensive on arrival and had extravasation at the retrohepatic IVC level. However, the hemodynamics became stable after an initial transfusion of 2 units of RBCs. The patient was then closely monitored during hospitalization and received additional transfusions (14 units of RBCs, 7 units of fresh-frozen plasma, and 30 units of platelet concentrate) and injections of tranexamic acid. Both patients that were closely monitored, eventually survived. Of the 14 patients who underwent surgery, 11 (78.6%) did not survive, nine of whom (64.3%) died within 24 hours of admission (Table 1).

Survivors who underwent damage control surgery

The five survivors who underwent surgical treatment for traumatic IVC injury are presented in Table 2. All patients were injured at the subhepatic IVC level and successfully underwent direct repairs (venorrhaphy) in the first operation. Three patients were discharged alive and the remaining two died. One patient

Table 1. Overall patient characteristics, treatment, and surgical outcomes

Variable	Value (n=16)
Male sex	10 (62.5)
Age (yr)	48 (40–68)
Body mass index (kg/m^2) (n=14)[a]	23.4 (21.0–26.1)
Prehospital time (min)	92.5 (54.0–158.0)
Injury mechanism (blunt)	15 (93.8)
Cause of injury	
In-car TA	6 (37.5)
Motorcycle TA	2 (12.5)
Pedestrian TA	2 (12.5)
Fall	3 (18.8)
Crash injury	2 (12.5)
Stab wound	1 (6.3)
Injury Severity Score	34 (25–43)
Abbreviated Injury Scale	
Head and neck	0 (0–0)
Chest	3 (2–3)
Abdominopelvic	4 (4–5)
Extremities and pelvis	0 (0–3)
Systolic blood pressure (mmHg)	86.5 (71.8–120.8)
Mean arterial pressure (mmHg)	60.5 (54.7–85.3)
Heart rate (beats/min)	96.0 (76.5–115.0)
Glasgow Coma Scale	10 (6–15)
pH	7.31 (7.24–7.37)
PaO_2 (mmHg)	119.5 (60.8–209.3)
Lactate (mmol/L)	4.3 (2.2–7.5)
Hemoglobin (g/dL)	11.8 (9.0–13.1)
International normalized ratio (n=15)[b]	1.22 (1.08–1.37)
CPR in the ER	3 (18.8)
DTO time (min)	72.5 (55.8–109.8)
Treatment method	
Direct repair	8 (50.0)
Ligation	1 (6.3)
Atriocaval shunt	1 (6.3)
Others[c]	4 (25.0)
Observation[d]	2 (12.5)
Operation time (min)	100.0 (80.5–157.5)
Transfused RBC within 24 hr (unit)	29.0 (19.8–40.3)
Surgical outcome (n=14)	
Overall mortality	11 (78.6)
24-hr Mortality	9 (64.3)

Values are presented as median (interquartile range) or number (%).
TA, traffic accident; PaO_2, partial pressure of arterial oxygen; CPR, cardiopulmonary resuscitation; ER, emergency room; DTO, door-to-operating room; RBC, red blood cell.
[a]Values of two patients were not available. [b]Value of one patient was not available. [c]Gauze packing, manual compression, and resuscitative endovascular balloon occlusion of the aorta. [d]Medical treatment with close monitoring.

died of severe brain injury on hospital day 11, and the other died of septic shock with pneumonia on hospital day 12.

Table 2. Clinical profiles of five patients survived after damage control surgery

Case no.	Age (yr)	Sex	BMI (kg/m^2)	IVC injury level	Injury mechanism	Prehospital time (min)	ISS	GCS	SBP (mmHg)	Lactate (mmol/L)	CPR in the ER	Operation time (min)	Treatment	HD (day)	Status
1	40	Male	22.0	Suprarenal	Crash	191	42	15	135	2.4	No	160	Venorrhaphy, diaphragm repair, perihepatic packing, TAC	19	Alive
2	74	Female	20.8	Juxtarenal	Pedestrian TA	51	30	15	73	2.3	No	200	Venorrhaphy, nephrectomy, perihepatic packing, TAC	34	Alive
3	41	Female	19.1	Infrarenal	Stab injury	23	25	6	59	2.0	No	264	Venorrhaphy, hemicolectomy with enterostomy	35	Alive
4	68	Female	21.5	Infrarenal	Car driver TA	70	43	6	140	1.3	No	117	Venorrhaphy, craniectomy	11	Dead
5	57	Male	23.3	Suprarenal	Car driver TA	55	25	6	71	4.2	No	160	Venorrhaphy, nephrectomy	12	Dead

BMI, body mass index; IVC, inferior vena cava; ISS, Injury Severity Score; GCS, Glasgow Coma Scale; SBP, systolic blood pressure; CPR, cardiopulmonary resuscitation; ER, emergency room; HD, hospital day; TAC, temporary abdominal closure; TA, traffic accident.

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Variables associated with surgical outcomes

A BMI >23.0 kg/m^2 (P=0.046), a higher serum lactate level (P=0.043), and a shorter operation time (P=0.016) were significantly associated with overall mortality (Table 3). A higher BMI (P=0.050), higher serum lactate level (P=0.004), shorter operation time (P=0.005), and injury at the retrohepatic IVC or higher level (P=0.031) were significantly associated with 24-hour mortality in the univariate analysis (Table 3).

Comparison according to the injury level of the IVC

Younger age (P=0.028), higher BMI (P=0.005), more acidic pH (P=0.028) with higher lactatemia (P=0.012), higher hemoglo-

Table 3. Comparison between survivor and nonsurvivor groups following surgical treatment

Variable	Overall mortality		P-value	24-hr Mortality		P-value
	Survival (n=3)	Death (n=11)		Survival (n=5)	Death (n=9)	
Male sex	1 (33.3)	7 (63.6)	0.539	2 (40.0)	6 (66.7)	0.580
Age (yr)	41.0 (40.5–57.5)	48.0 (41.0–68.5)	0.815	57 (41–68)	47 (40–69)	0.841
Body mass index (kg/m^2)	20.8 (20.0–21.4)	26.1 (23.3–26.1)	0.094	21.5 (20.8–22.0)	26.1 (25.4–27.7)	0.050
≥23.0	0	7 (63.6)	0.046	1 (20.0)	6 (66.7)	0.072
Prehospital time (min)	51.0 (37.0–121.0)	93.0 (55.0–146.0)	0.436	55.0 (51.0–70.0)	130.0 (55.0–147.0)	0.317
Injury mechanism (blunt)	2 (66.7)	11 (100)	0.214	4 (80.0)	9 (100)	0.357
Injury Severity Score	30 (28–36)	34 (25–43)	0.635	30 (25–42)	34 (25–43)	0.735
Abbreviated Injury Scale						
Head and neck	0 (0–0)	0 (0–0)	0.523	0 (0–0)	0 (0–0)	0.662
Chest	3 (3–4)	3 (2–3)	0.665	3 (3–3)	3 (0–3)	0.504
Abdominopelvic	5 (5–5)	4 (4–5)	0.352	4 (4–5)	4 (4–5)	0.885
Extremities and pelvis	0 (0–0)	0 (0–3)	0.197	0 (0–0)	2 (0–3)	0.058
Systolic blood pressure (mmHg)	73.0 (66.0–104.0)	82.0 (71.0–112.5)	>0.999	107.0 (73.0–131.0)	78.0 (68.0–94.0)	0.350
Mean arterial pressure (mmHg)	59.7 (52.3–79.3)	61.3 (54.0–75.5)	>0.999	67.7 (59.7–99.0)	56.0 (52.7–64.0)	0.286
Heart rate (beats/min)	82.0 (82.0–95.5)	102.0 (71.5–131.0)	0.755	82.0 (82.0–109.0)	102.0 (72.0–130.0)	0.894
Glasgow Coma Scale	15 (11–15)	9 (6–13)	0.423	6 (6–15)	10 (7–15)	0.891
pH	7.37 (7.34–7.39)	7.27 (7.14–7.34)	0.119	7.37 (7.31–7.40)	7.27 (7.12–7.31)	0.061
PaO_2 (mmHg)	194.0 (125.0–239.5)	80.0 (60.5–209.5)	0.815	56.0 (56.0–194.0)	82.0 (76.0–210.0)	0.229
Lactate (mmol/L)	2.3 (2.2–2.4)	5.2 (4.3–9.9)	0.043	2.3 (2.0–2.4)	7.3 (4.9–11.6)	0.004
Hemoglobin (g/dL)	10.5 (9.5–10.7)	11.9 (8.9–13.1)	0.350	10.5 (8.5–10.8)	13.0 (9.0–13.1)	0.182
International normalized ratio	1.05 (0.99–1.14)	1.24 (1.13–1.43)	0.127	1.19 (1.05–1.22)	1.25 (1.11–1.51)	0.163
CPR in ER	0	3 (27.3)	>0.999	0	3 (33.3)	0.258
DTO time (min)	69.0 (68.0–99.0)	76.0 (51.0–101.5)	0.696	76.0 (69.0–129.0)	67.0 (50.0–85.0)	0.181
Treatment method			0.692			0.119
Direct repair	3 (100)	5 (45.5)		5 (100)	3 (33.3)	
Ligation	0	1 (9.1)		0	1 (11.1)	
Atriocaval shunt	0	1 (9.1)		0	1 (11.1)	
Others[a)]	0	4 (36.4)		0	4 (44.4)	
Operation time (min)	200.0 (180.0–232.0)	90.0 (80.0–111.0)	0.016	160.0 (160.0–200.0)	82.0 (80.0–95.0)	0.005
Transfused RBC within 24 hr (unit)	40.0 (35.0–40.5)	28.0 (1.5–40.5)	0.456	36.0 (30.0–40.0)	28.0 (22.0–45.0)	0.797
IVC injury level			0.368			0.091
Suprahepatic	0	1 (9.1)		0	1 (11.1)	
Retrohepatic	0	5 (45.5)		0	5 (55.6)	
Suprarenal	1 (33.3)	1 (9.1)		2 (40.0)	0	
Juxtarenal	1 (33.3)	1 (9.1)		1 (20.0)	1 (11.1)	
Infrarenal	1 (33.3)	3 (27.3)		2 (40.0)	2 (22.2)	
Level (retrohepatic or higher)	0	6 (54.5)	0.209	0	6 (66.7)	0.031

Values are presented as number (%) or median (interquartile range).
PaO_2, partial pressure of arterial oxygen; CPR, cardiopulmonary resuscitation; ER, emergency room; DTO, door-to-operating room; RBC, red blood cell; IVC, inferior vena cava.
[a)]Gauze packing, manual compression, and resuscitative endovascular balloon occlusion of the aorta.

bin level (P = 0.012), and shorter DTO time (P = 0.028) were significantly associated with injury at the retrohepatic IVC or higher level (Table 4). Although not statistically significant, the MAP was lower (P = 0.081) in patients with an injury at the retrohepatic IVC or higher level, and CPR in the ER was performed more frequently in these patients (P = 0.055). All patients with injuries at the retrohepatic IVC or higher level who underwent surgical treatment died within 24 hours of admission. In contrast, patients with subhepatic IVC injuries had a high rate of direct repair (75.0%) and a significantly low 24-hour mortality rate (37.5%, P = 0.031) (Table 4).

DISCUSSION

In this study, the overall and 24-hour mortality rates after surgery were 78.6% and 64.3%, respectively. These outcomes are slightly worse than those noted in previous studies, where the overall mortality rates ranged between 20% and 70% [5,8,10–14]. The worse outcomes in this study are probably because 13 of the 14 patients who underwent surgery had blunt trauma, which is a known risk factor for mortality in traumatic IVC injury [7]. Of the nine deaths within 24 hours of admission, seven developed cardiac arrest due to massive bleeding during the operation and did not recover. For the remaining two deceased patients, the op-

Table 4. Comparison according to the injury level of IVC

Variable	Retrohepatic IVC or higher (n = 6)	Subhepatic IVC (n = 8)	P-value
Surgical outcome			
Overall mortality	6 (100)	5 (62.5)	0.209
24-hr Mortality	6 (100)	3 (37.5)	0.031
Male sex	5 (83.3)	3 (37.5)	0.138
Age (yr)	41 (33–46)	69 (53–75)	0.028
Body mass index (kg/m^2)	26.1 (26.1–28.5)	21.1 (19.6–21.9)	0.005
Prehospital time (min)	74.0 (47.5–120.8)	108.5 (54.0–198.3)	0.366
Injury mechanism (blunt)	6 (100)	7 (87.5)	>0.999
Injury Severity Score	43 (36–43)	28 (25–36)	0.101
Abbreviated Injury Scale			
Head and neck	0 (0–0)	0 (0–1)	0.244
Chest	3 (3–3)	3 (2–3)	0.518
Abdominopelvic	5 (4–5)	4 (4–4)	0.326
Extremities and pelvis	2 (0–3)	0 (0–1)	0.285
Systolic blood pressure (mmHg)	76.0 (18.5–81.0)	100.5 (71.8–121.3)	0.272
Mean arterial pressure (mmHg)	54.0 (13.2–59.8)	65.8 (58.8–99.9)	0.081
Heart rate (beats/min)	101.0 (60.3–108.0)	95.5 (79.5–130.5)	0.747
Glasgow Coma Scale	9 (4–14)	9 (6–15)	0.740
pH	7.14 (7.08–7.24)	7.34 (7.31–7.38)	0.028
PaO_2 (mmHg)	81.0 (77.0–178.0)	127.0 (56.0–228.0)	0.651
Lactate (mmol/L)	9.9 (5.7–13.1)	3.3 (2.2–4.5)	0.011
Hemoglobin (g/dL)	13.1 (13.0–14.1)	9.7 (8.0–11.0)	0.011
International normalized ratio	1.25 (1.10–1.25)	1.21 (1.10–1.30)	0.942
CPR in ER	3 (50.0)	0	0.055
DTO time (min)	51.0 (47.8–63.3)	80.5 (74.3–120.8)	0.028
Treatment method			0.277
Direct repair	2 (33.3)	6 (75.0)	
Ligation	0	1 (12.5)	
Atriocaval shunt	1 (16.7)	0	
Others[a)]	3 (50.0)	1 (12.5)	
Operation time (min)	92.5 (82.5–102.5)	138.5 (81.5–170.0)	0.244
Transfused RBC within 24 hr (unit)	36.0 (18.8–48.8)	32.5 (26.5–37.0)	0.852

Values are presented as number (%) or median (interquartile range).
IVC, inferior vena cava; PaO_2, partial pressure of arterial oxygen; CPR, cardiopulmonary resuscitation; ER, emergency room; DTO, door-to-operating room; RBC, red blood cell.
[a)]Gauze packing, manual compression, and resuscitative endovascular balloon occlusion of the aorta.

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erations ended with uncontrolled bleeding. Therefore, 24-hour mortality in this study indicated a failure of damage control.

Several prognostic factors associated with traumatic IVC injury have been reported. According to previous studies, a higher IVC injury level was a prognostic factor for mortality [3,8]. A recent meta-analysis revealed that blunt trauma and injury at the suprarenal or higher IVC level were prognostic factors for mortality in traumatic IVC injury [7]. It is difficult to expose the retrohepatic IVC segment as the liver is attached to the anterior surface of the IVC, and the major hepatic veins connect to this level; therefore, the mortality rate associated with a retrohepatic IVC injury can be as high as 90% [3]. Furthermore, in this study, compared to patients with injury at the subhepatic IVC, those with injury at the retrohepatic IVC or higher level showed worse 24-hour mortality rates in the univariate analysis. In a study of 16 cases, multiple logistic regression analysis revealed lower GCS scores to be an independent factor for mortality [6]. We found that higher BMI and serum lactate levels were associated with mortality. Obesity has been reported as an independent risk factor for mortality in blunt trauma patients because the kinetic energy applied to the patient is in proportion to the mass; thus, obesity may increase the energy and cause more severe injury [15]. A higher initial serum lactate level has been associated with higher injury severity and can predict massive hemorrhage in trauma patients [16]. However, because the currently available studies and this study have all had small sample sizes, further studies with a large population are required to confirm that these are prognostic factors for traumatic IVC injury.

The surgical treatments for IVC injuries vary depending on the location of the injury. In general, the first step is to expose the injured IVC segment and apply direct compression to the proximal and distal parts of the segment [1]. Direct repair can then be attempted following proximal and distal control of the injured IVC. However, when repair is difficult due to massive bleeding, ligation can be performed more quickly and easily for damage control [2]. In a study using data from the United States (2007 to 2014), excluding other-vessel injuries and severe extraperitoneal injuries, there was no difference in mortality between ligation and repair, and ligation was not an independent factor for mortality [17]. A recent meta-analysis showed that, compared with repair, ligation was associated with higher mortality. However, there was no significant difference in mortality rates for infrarenal IVC injuries [7]. Therefore, ligation appears to be a safe treatment option, particularly in infrarenal injuries. Nevertheless, we were unable to save a patient with an infrarenal IVC injury despite using ligation. For a retrohepatic IVC injury, liver mobilization may be required to expose the segment, but massive hemorrhage from the injury site can occur with this procedure [5]. Therefore, in a retrohepatic IVC injury, without active bleeding or with only a contained hematoma, perihepatic gauze packing without mobilization should be performed [1]. However, if packing fails to control the bleeding, direct repair of the injured site may be the only way to do so. Total hepatic vascular occlusion or an atriocaval shunt can be used to achieve a clear operative field during repair. Since subhepatic and suprahepatic IVC clamping for total hepatic vascular occlusion also blocks venous return, it may cause cardiac arrest. Therefore, additional aortic clamping at the supraceliac level or a venovenous bypass may be required, although outcomes have been reported to be poor [18,19]. Alternatively, an atriocaval shunt facilitates volume resuscitation during repair by isolating the injury site and maintaining venous return through a shunt using an endotracheal tube or a chest tube. As such, it can be used in a retrohepatic IVC injury with active bleeding, a large injury site, and extreme hemodynamic instability [4,5,20]. However, the reported outcomes of using an atriocaval shunt have also been unsatisfactory due to the severity of retrohepatic IVC injuries, the complexity of the procedure, the approach to the thorax, and delays in the decision to apply the procedure [4,20]. Richardson [21] reported a mortality rate of 88% in 412 patients with atriocaval shunts. We had one case of retrohepatic IVC injury for whom total hepatic vascular occlusion and an atriocaval shunt were ineffective. The patient was a 24-year-old man who was crushed by 2,000 kg of building material. Although venorrhaphy for a retrohepatic IVC injury was performed with total hepatic vascular occlusion, bleeding through an extended supradiaphragmatic IVC injury continued. By switching to an atriocaval shunt, the extended IVC injury was confirmed and venorrhaphy was successfully performed. Unfortunately, the patient did not survive because the delay in deciding to apply the atriocaval shunt resulted in significant blood loss (57 units of RBC were transfused during the operation). However, this case confirmed that an atriocaval shunt could be a better damage control tool than total hepatic vascular occlusion for primary repair of a retrohepatic IVC or higher level injury in terms of securing the operative field during massive bleeding.

There were some limitations to this study. First, it was a retrospective study; therefore, important variables affecting surgical outcomes may have been missed. Moreover, data extracted from a review of medical records are not very reliable. Second, this was a single-center study, making it difficult to generalize the results to the overall population of patients with traumatic IVC injuries. Third, the statistical power of this study was weak because the

sample size was small (14 to 16 patients).

Subhepatic IVC injuries, which are easy to access, can be usually treated with a direct repair method. A systematic and multidisciplinary treatment strategy is required to deal with injuries at the retrohepatic IVC or higher level that are difficult to treat surgically. Since IVC injuries that require surgical treatment are rare, simulation training may be necessary to master the surgical skills needed for the complex damage control techniques (e.g., atriocaval shunt or ligation) and to understand their correct indications. This study described 14 cases in which surgical treatment was performed for IVC injury over a period of 9 years at a single institution. For a more comprehensive analysis, further studies are needed with larger populations and the participation of multiple centers.

NOTES

Conflicts of interest
The authors have no conflicts of interest to declare.

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The data of this article are available from the corresponding author upon reasonable request.

Author contributions
Conceptualization: all authors; Data curation: all authors; Formal analysis: all authors; Investigation: all authors; Methodology: all authors; Project administration: DHK; Visualization: all authors; Writing–original draft: all authors; Writing–review & editing: DHK. All authors read and approved the final manuscript.

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The practicality of interleukin-6 in prognosis of blunt chest trauma in Korea: a retrospective study

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Purpose: There are many studies on the practicality of interleukin-6 (IL-6) as a prognostic predictor in patients with multiple severe traumas. However, few studies focus on the practicality of IL-6 in patients with chest trauma. So, this study investigated whether IL-6 is effective as a prognostic factor in patients with blunt chest trauma.

Methods: A total of 44 blunt chest trauma patients who visited the regional trauma center from July to December 2021 were included in this retrospective study. Blood IL-6 levels were measured immediately after emergency room admittance (IL-6 E) and 24 hours after trauma (IL-6 24). To determine whether IL-6 levels can predict the clinical course and prognosis of patients with blunt chest trauma, the correlation between IL-6 (IL-6 E and IL-6 24) and the trauma score system, Injury Severity Score, Thoracic Trauma Severity Score, and Pulmonary Contusion Score, intensive care unit (ICU) stay period, and total hospitalization period were analyzed.

Results: IL-6 E showed a good correlation with Injury Severity Score (P=0.505), Thoracic Trauma Severity Score (P=0.597), Pulmonary Contusion Score (P=0.493), ICU stay period (P=0.762), and total hospitalization period (P=0.662). However, IL-6 24 had a relatively low correlation compared to IL-6 E. Therefore, IL-6 E showed useful results for predicting the prognosis of patients with blunt chest trauma.

Conclusions: Early plasma IL-6 levels (IL-6 E) can predict the injury severity of blunt chest trauma, length of ICU stay, and total hospitalization period.

Keywords: Interleukin-6; Thoracic injury; Injury Severity Score

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INTRODUCTION

The Injury Severity Score (ISS), New Injury Severity Score (NISS), Revised Trauma Score (RTS), Trauma and Injury Severity Scale (TRISS), and Glasgow Coma Scale are widely used in evaluating trauma severity and are designed to predict the progress and prognosis of acute severe trauma patients [1]. In a study by Orhon et al. [2], the ISS, NISS, RTS, and TRISS were useful for predicting trauma patients' mortality. The NISS, RTS, and TRISS were also significantly correlated with intensive care unit (ICU) treatment period, and the TRISS was highly correlated with mechanical ventilation time in trauma ICU treatment patients [2].

The systemic inflammatory immune response in acute blunt trauma patients is an important pathophysiological mechanism for tissue damage, and the amplified inflammatory response can cause multiple organ failure syndromes [3]. Tumor necrosis factor-α (TNF-α) and interleukin-6 (IL-6) are well known as the major cytokines that cause such systemic inflammatory reactions [3]. When multiple organ failure occurs in trauma patients, the duration of ICU treatment and the period of artificial ventilator treatment are prolonged, which increases the long-term mortality and the risk of functional disability [4–7]. Other studies have reported that increased IL-6 and IL-8 levels and reduced IL-4 levels in the early stage of trauma can cause systemic inflammatory response syndromes, acute respiratory distress syndrome, and multiorgan failure syndrome, which can increase morbidity and mortality [8].

To determine whether the IL-6 level in the blood was effective for prognosis in early trauma patients, Qiao et al. [9] performed a meta-analysis of studies evaluating IL-6 levels and the prognosis of trauma patients. As a result, the blood IL-6 level tested within 24 hours after trauma was effective in predicting posttraumatic complications, especially the occurrence of multiple organ failure syndromes [9]. Gebhard et al. [10] periodically measured the blood IL-6 levels in the first 24 hours after trauma in severe trauma patients and found they were correlated with the ISS.

Thoracic trauma is associated with 60% of severe multiple trauma patients and has a 20% to 25% mortality rate [11]. Depending on the mechanism of injury, chest trauma is divided into blunt and penetrating wounds, and blunt injuries account for about 70% [11]. The proportion of blunt thoracic injuries is about 15% of all trauma patients, and when accompanied by pulmonary contusions, 10% to 15% mortality is observed depending on the accompanying damage [11].

In the past, there have been many studies showing that IL-6 levels in the blood are effective in predicting the prognosis of patients with multiple traumas caused by acute blunt injuries [9]. However, there have been few studies on IL-6 in blunt chest trauma. In a study of 208 patients who visited a level I trauma center, Taniguchi et al. [12] showed that IL-6 levels in the blood tested immediately after arrival in the emergency room were correlated with the duration of ICU treatment and the Abbreviated Injury Scale (AIS) in the chest, abdomen, and musculoskeletal system. Other studies have shown that IL-6 and surfactant protein-D levels were associated with complications in patients with multiple rib fractures and lung contusion with blunt chest injuries [13].

Therefore, the purpose of this study was to investigate whether the initial IL-6 level in blunt chest trauma patients was effective as a predictor of progress and prognosis. In blunt chest trauma patients who visited the trauma center, the IL-6 values were collected immediately after emergency room admittance (IL-6 E) and 24 hours after trauma (IL-6 24). Statistical analysis was conducted to determine whether the IL-6 values were correlated with the ISS, Thoracic Trauma Severity Score (TTSS), Pulmonary Contusion Score (PCS), ICU treatment period, and total hospitalization period.

METHODS

Ethics statements

The study was approved by the Institutional of Review Board of Cheju Halla General Hospital (No. 2002-L05-01). This study is a retrospective study of patient medical records. Hence, written informed consent was not needed.

Research subject

Among the trauma patients who visited the regional trauma center from July 1 to December 31, 2021, those with acute blunt chest injury were identified, and their medical records were reviewed retrospectively. Patients with traumatic brain and spinal cord injuries, musculoskeletal injury of AIS 3 or higher, and abdominal injuries requiring surgery were excluded. For all patients with chest injuries who visited the regional trauma center, a basic blood IL-6 test was performed at the time of the emergency room visit and 24 hours after the injury. After reviewing the medical records, patients with missing test results and who visited the emergency room for more than 3 hours after trauma were excluded from the study. A total of 44 patients were selected for the study, excluding patients with inflammatory diseases and malignant tumors as underlying diseases and patients who underwent cardiopulmonary resuscitation.

Measure and definition

The medical records of the included patients were reviewed for IL-6 E and IL-6 24, and the ISS, PCS, and TTSS values of each patient were calculated. Then, the number of days of treatment in the ICU (ICU stay) and the total number of days in the hospital (total hospitalization period) were calculated for each patient.

The level of IL-6 in the blood was tested by electrochemiluminescence immunoassay analysis using the Cobas e 411 equipment (Hitachi, Tokyo, Japan) at the Department of Laboratory Medicine at Cheju Halla General Hospital, and the results were reported within 60 minutes after requesting the test.

The ISS is an anatomically-based consensus severity score sys-

tem standardized by the Association for the Advancement of Automotive Medicine and the International Trauma Association. This scoring system divides the body into six parts to obtain the AIS value for each part, and the squares of the AIS values for the three most severe parts are summed.

The PCS was devised by Kim et al. [14] using chest computed tomography (CT). In this grading method, both lungs were divided into quadrants, and the right upper and middle lobes were included in one lobe, and the right lower, left upper, and lower left lobes were separate quadrants each. Each lobe was given 0 to 3 points for the degree of lung contusion on the chest CT, and the scores of each lobe were summed up (0–12 points total) to obtain the PCS. The combined score was determined as follows: 0 to 2 as mild, 3 to 5 as moderate, and 6 to 12 as severe [14].

The TTSS was described by Pape et al. [15]. Compared to the AIS or Lung Injury Scale, the TTSS is a system that is more suitable for thoracic trauma patients [15]. The TTSS consists of five items, the PaO2/FiO2 ratio, number of rib fractures, grade of lung contusion, pleural involvement, and patient's age. The sum of the scores of the five items ranges from a minimum of zero points and a maximum of 25 points [15].

Statistical analysis

IBM SPSS ver. 20.0 (IBM Corp) was used for the statistical analysis of the collected data. The IL-6 E, IL-6 24, ISS, PCS, TTSS, ICU stay, and total hospitalization period were calculated, and descriptive statistics were performed. A bivariate correlation analysis was performed to determine whether there was a correlation between each variable. A multivariate linear regression analysis was performed to test the causality between IL-6 and treatment outcomes (ICU stay and total hospitalization period). A Pearson's correlation was used, and a P-value less than 0.05 was defined as statically significant. The variance inflation factor was used to evaluate multicollinearity.

RESULTS

A total of 44 blunt chest trauma patients were selected for the study. The average age of the patients was 59.3 ± 15.8 years old, and the male to female ratio was 1.44:1. The average ISS was 14.4 ± 8.0, TTSS was 8.6 ± 3.7, and PCS was 2.7 ± 2.3. The IL-6 E value of the patient group 474.7 ± 745.9 pmol/L, and the IL-6 24 value was268.0 ± 531.6 pmol/L, showing a larger standard deviation than the average value (Table 1, Figs. 1, 2).

Only the blunt chest injury was present in 24 patients (55.6%). Eight patients (17.8%) had orthopedic fractures, two patients (4.4%) had orthopedic fractures and spleen injuries, three patients (6.7%) had facial bone fractures, three patients (6.7%) had vertebral fractures, two patients (4.4%) had liver injuries, one patient (2.2%) had a pelvic bone fracture, and one patient (2.2%) had a skull fracture (Table 2).

To determine whether an IL-6 test can predict the clinical course and prognosis of patients with blunt chest trauma, the correlation between IL-6 (IL-6 E, IL-6 24) and the trauma score system, ICU stay period, and total hospitalization period was analyzed (Table 3).

IL-6 E levels showed a high correlation with the ISS, TTSS (Table 3, Figs. 3, 4), and PCS, which can predict the patient`s prognosis. IL-6 E levels were also highly correlated with the ICU stay and total hospitalization periods, which are determined by the patient`s treatment result (Table 3, Figs. 5, 6). IL-6 24 levels were correlated with the TTSS, ICU stay, and total hospitalization period but had no correlation with the ISS and PCS. A multivariable linear regression analysis was performed with IL-6 E levels, the ISS, and the TTSS as independent variables to confirm the causality of IL-6 E levels with the ICU stay and total hospitalization period (Table 4).

The causality of IL-6 E levels was well explained with the ICU stay (standardized β coefficient, 0.424; $P < 0.001$) and with total hospitalization periods (standardized β coefficient, 0.345; $P < 0.010$). The variance inflation factors among the ISS, TTSS, and IL-6 E levels were under 10.

DISCUSSION

In this study, the level of IL-6 tested immediately after visiting the

Table 1. Basic characteristics of patient and result of study (n=44)

Characteristic	Value
Sex ratio	1.44:1
Age (yr)	59.3±15.8
Injury Severity Score	14.4±8.0
Thoracic Trauma Severity Score	8.6±3.7
Pulmonary Contusion Score	2.7±2.3
Intensive care unit stay (day)	1.8±3.5
Total hospitalization period (day)	24.2±16.1
IL-6 E (pmol/L)	474.7±745.9
IL-6 24 (pmol/L)	268.0±531.6

Values are presented as mean±standard deviation, unless otherwise indicated.
IL-6 E, interleukin-6 levels measured immediately after the emergency room admittance; IL-6 24, interleukin-6 levels measured at 24 hours after trauma.

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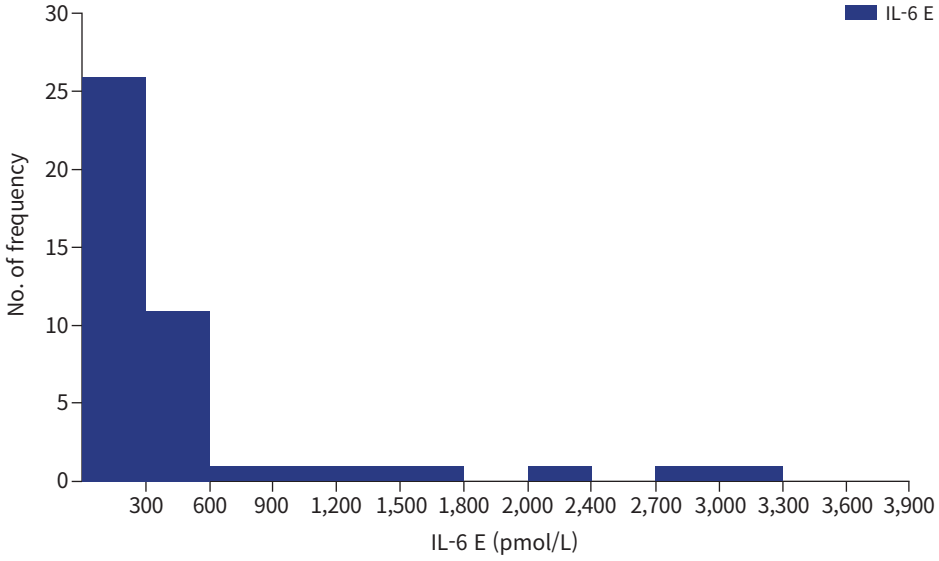

Fig. 1. Interleukin-6 levels measured immediately after the emergency room admittance (IL-6 E; n=44). SD, standard deviation.

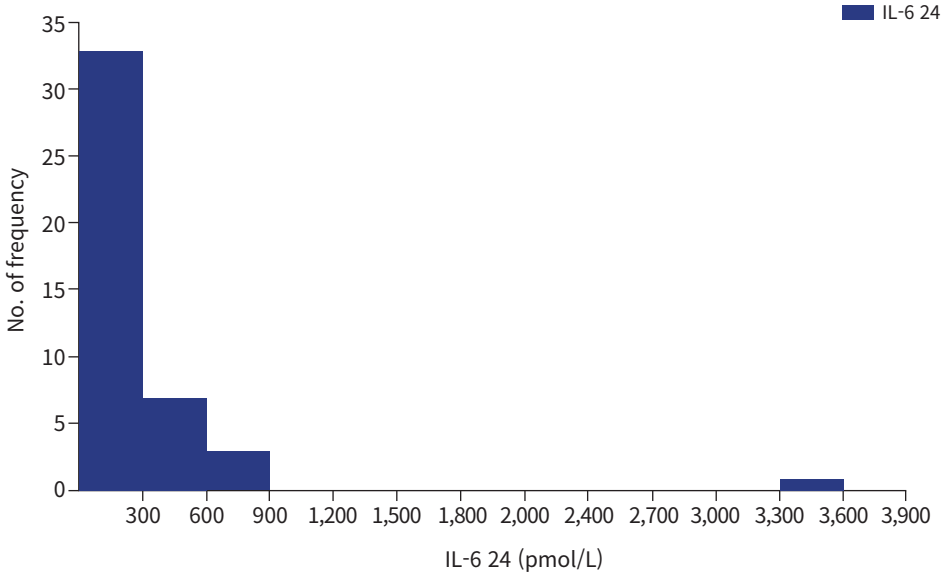

Fig. 2. Interleukin-6 levels measured at 24 hours after trauma (IL-6 24; n=44). SD, standard deviation.

emergency room of a patient with a blunt chest injury was found to be correlated with various indicators related to chest injuries, such as the ISS, TTSS, and PCS. In addition, it was found that there was a correlation between IL-6 E levels and the duration of ICU stay and the total hospitalization periods. IL-6 24 levels were correlated with the TTSS, ICU stay, and total hospitalization periods.

In several previous studies, blood IL-6 levels tested within 24 hours in multiple trauma patients were reported to have a high correlation with the trauma severity score (correlation coefficient, 0.46–0.61) [10,12,16]. In this study, which focused on patients with chest trauma, only the IL-6 E level was correlated with the ISS (correlation coefficient, 0.505), and not the IL-6 24 level. Also, in this study, the IL-6 E level showed a good correlation with the TTSS (0.597) and PCS (0.493), whereas IL-6 24 level showed a correlation with only the TTSS (0.398). These results show that the IL-6 E level is more valuable than the IL-6 24 level in predicting the severity of the initial chest trauma.

A number of studies have evaluated the association between an increase in serum IL-6 levels and multiple organ failure syndromes in trauma patients [17–19]. Frink et al. [19] analyzed the association between the levels of TNF-α, IL-6, IL-8, and IL-10 in

Table 2. Associated injury (n=44)

Associated injury	No. (%)
Thorax injury only	24 (54.5)
Fracture of extremity	8 (18.2)
Fracture of extremity and spleen injury	2 (4.5)
Facial bone fracture	3 (6.8)
Fracture of spine	3 (6.8)
Liver injury	2 (4.5)
Pelvic bone fracture	1 (2.3)
Simple skull fracture	1 (2.3)

Table 3. Correlation between IL-6 and injury scores and treatments outcomes

Variable	IL-6 E (n=44)	IL-6 24 (n=44)
ISS		
Pearson correlation	0.505**	0.117
P-value	<0.001	0.45
TTSS		
Pearson correlation	0.597**	0.398**
P-value	<0.001	0.007
PCS		
Pearson correlation	0.493**	0.28
P-value	0.001	0.065
ICU stay		
Pearson correlation	0.762**	0.556**
P-value	<0.001	<0.001
Total hospitalization period		
Pearson correlation	0.662**	0.389**
P-value	<0.001	0.009

IL-6, interleukin-6; IL-6 E, interleukin-6 levels measured immediately after the emergency room admittance; IL-6 24, interleukin-6 levels measured at 24 hours after trauma; ISS, Injury Severity Score; TTSS, Thoracic Trauma Severity Score; PCS, Pulmonary Contusion Score; ICU, intensive care unit.
**P<0.01.

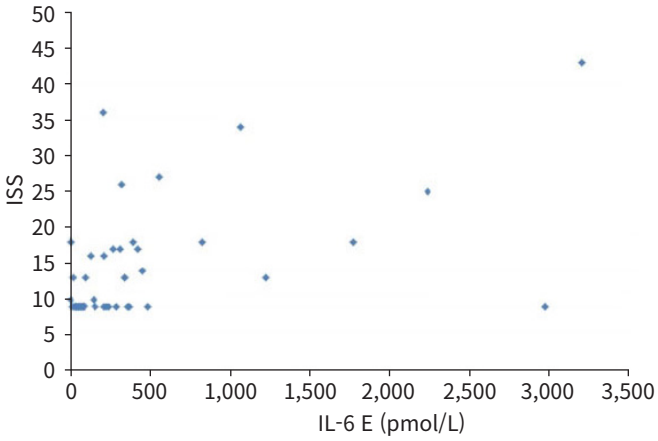

Fig. 3. Scatterplot between Injury Severity Score (ISS) and interleukin-6 levels measured immediately after the emergency room admittance (IL-6 E).

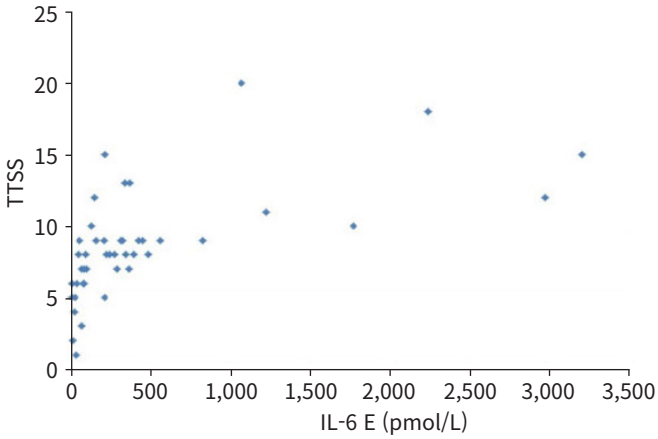

Fig. 4. Scatterplot between Thoracic Trauma Severity Score (TTSS) and interleukin-6 levels measured immediately after the emergency room admittance (IL-6 E).

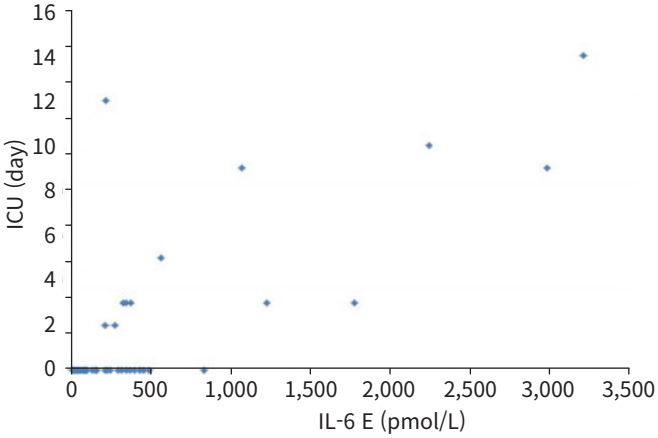

Fig. 5. Scatterplot between intensive care unit (ICU) stay and interleukin-6 levels measured immediately after the emergency room admittance (IL-6 E).

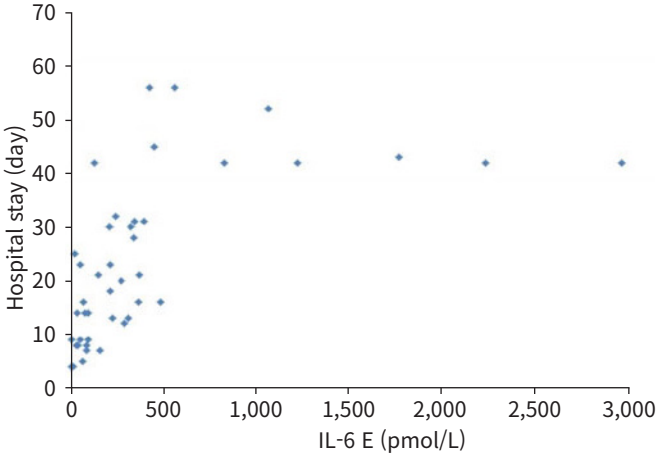

Fig. 6. Scatterplot between total hospitalization periods and interleukin-6 levels measured immediately after the emergency room admittance (IL-6 E).

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Table 4. Multivariable linear regression analysis

Variable	β	Standardized β	P-value
Intensive care unit stay			
ISS	0.091	0.208	0.040
TTSS	0.369	0.391	0.001
IL-6 E	0.007	0.424	<0.001
Total hospitalization period			
ISS	0.771	0.387	0.003
TTSS	0.871	0.203	0.128
IL-6 E	0.027	0.345	0.010

ISS, Injury Severity Score; TTSS, Thoracic Trauma Severity Score; IL-6 E, interleukin-6 levels measured immediately after the emergency room admittance.

the blood of early trauma patients and the occurrence of multiple organ failure syndrome. The researchers reported that IL-6 was the most useful predictor of multiple organ failure [19]. Similarly, Jastrow et al. [17] and Cuschieri et al. [18] reported that the area under the curve (AUC) value of the correlation between blood IL-6 levels was high in predicting multiorgan dysfunction syndrome in the early stage of trauma (Jastrow et al. [17]: n = 48; blood IL-6 levels 4–8 hours after admission to the ICU; AUC, 0.816; Cuschieri et al. [18]: n = 79; blood IL-6 levels over 12 hours; AUC, 0.749; 95% confidence interval, 0.643–0.855). The occurrence of multiorgan dysfunction syndrome in patients with multiple trauma due to blunt injury prolongs the patients' ICU treatment period and increases the incidence of complications [4,5]. In a study by Taniguchi et al. [12], the ICU treatment period was prolonged, and the mortality rate increased 28 days after hospitalization in a group of multiple blunt trauma patients with increased serum IL-6 E levels. This study on patients with blunt chest trauma showed a correlation between the increase in IL-6 E and IL-6 24 levels and the length of treatment in the ICU and total hospitalization period. This result is similar to the previous studies conducted on multiple trauma patients.

According to past studies, blood IL-6 levels in patients with acute multiple trauma begin to rise immediately after injury and reach a peak within 6 hours after trauma [8,10]. Other studies investigated the association between the level of IL-6 in the blood within 4 to 12 hours after arriving at the emergency room, the trauma severity score, and the patient's clinical course and reported that blood IL-6 levels are useful for determining patient prognosis [8,10,19]. However, based on the results of these studies, the IL-6 levels obtained 4 to 12 hours after arrival at the hospital do not predict the severity and clinical course. According to the statistics of the regional trauma center, for most trauma patients, diagnosis and immediate necessary surgical and/or interventional procedures and the severity and clinical prognosis are completed within 4 to 12 hours after trauma [20]. Thus, the results of this study confirm that IL-6 E levels correlate well with the trauma scoring system, and patient treatment outcomes show that IL-6 E levels are valuable as a diagnostic aid to help determine the treatment direction and predict the course of treatment for acute chest trauma patients.

This study has two limitations. First, although blunt chest trauma was the main injury, there is a possibility that IL-6 levels may be affected depending on the accompanying injuries to other body parts. Second, IL-6 levels continuously change over time after trauma. Therefore, the time it takes for each patient to arrive at the emergency room after trauma can affect the test results and cause statistical errors.

In patients with acute blunt thoracic trauma, higher the level of blood IL-6 E level correlate with the severity of the trauma and lung damage, and the duration of ICU treatment and hospitalization are likely to increase. Therefore, patients with high IL-6 E levels need more active observation and treatment to prevent trauma complications.

NOTES

Conflicts of interest

The authors have no conflicts of interest to declare.

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Data sharing statement

The data of this article are available from the corresponding author upon reasonable request.

Author contributions

Conceptualization: JWO; Data curation: JWO, TYL; Formal analysis: MC; Writing–original draft: JWO; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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Changes in incidence and severity of commercial motorcycle accidents due to the use of delivery service platforms in Korea: a retrospective cohort study

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Purpose: Recently, a sharp increase in the use of delivery services has led to an increase in motorcycle accidents. This study aimed to identify the characteristics of the commercial motorcycle injured patients and factors related to the severity during the past 10 years.

Methods: Patients (15–64 years old) who visited the emergency department with commercial motorcycle accidents injury registered in the Korean Emergency Department-based Injury In-depth Surveillance (2011–2020) database, were included. All included cases were categorized into two groups according to the period: group 1 (2011–2015) and group 2 (2016–2020). General characteristics and the factors associated with severity were investigated.

Results: Among 8,123 emergency department visits, patients in group 1 were 3,071, and patients in group 2 were 5,052. The odds for severity were affected by patients age (odds ratio [OR], 1.008; 95% confidence interval [CI], 1.004–1.013), and overnight/morning (00:00–12:00; OR, 1.243; 95% CI, 1.091–1.415). The odds for severity were higher in head and neck injury (OR, 8.357; 95% CI, 7.410–9.424) and torso injury (OR, 4.122; 95% CI, 3.610–4.708). The odds for the severity of accidents based on excess mortality ratio-adjusted Injury Severity Score (EMR-ISS) after 2015 were significant (OR, 1.491; 95% CI, 1.318–1.687). Hospitalization in the intensive care unit and death were associated with accidents after 2015 (OR, 2.593; 95% CI, 2.120–3.170).

Conclusions: Commercial motorcycle accidents have increased significantly over the past decade. There were statistical differences in severity based on EMR-ISS and the hospitalization in intensive care unit and death.

Keywords: Motorcycles; Wounds and injuries; Injury Severity Score; Traffic accidents

INTRODUCTION

Korea is a country with one of the most advanced food delivery cultures in the world, which has been growing the development of a delivery service market in recent years [1]. These delivery services generally use motorcycles for deliveries [2].

Motorcycles move on two wheels, and as a result, they tend have higher accident rates and severities due to difficulty in maintaining balance, as compared to four-wheeled vehicles. Moreover, the structure of a motorcycle does not protect the driver upon impact, and thus, wearing equipment may affect severity. Because of such characteristics of motorcycles, motorcycle accidents have 34 times higher mortality rate and more than eight times higher incidence than regular automobile accidents [3,4].

According to a survey conducted by the Market Research Bureau of Korea Consumer Agency, the number of users since the introduction of delivery app platforms in 2010 has increased sharply from 870,000 in 2013 to 10.46 million in 2015 and 25 million in 2018 [5]. In the past, individual stores had their own delivery service; however, in recent years, there has been an increase in the number of delivery workers called "riders" who are managed by delivery platforms [6]. With such increasing trends in delivery services, motorcycle traffic accidents are also increasing. According to the Korea Road Traffic Authority, the number of motorcycle traffic accidents has increased recently, from 16,357 cases in 2012 to 20,898 cases in 2019 [7]. The severity of motorcycle accidents may vary depending on the speed, time of accident, and violation of traffic laws [8,9]. Meanwhile, active use of delivery services has created competition among the riders, and as a result, speeding and reckless driving in violation of laws are believed to affect the severity of accidents, which would also bring changes to the sites of injury. Moreover, such exponential growth in large platforms has also led to systematic management of individually operated motorcycle delivery businesses and gradual improvement in safety systems. In particular, regular safety education and recommendation for wearing proper equipment are being implemented through industrial safety and health guidelines [10].

Although there is an increasing trend in commercial motorcycle accidents due to the growth of delivery services, studies on this topic are still lacking. There are concerns that this increase in accidents is not just a temporary phenomenon and could become a serious problem with the accelerating expansion of a platform-based economy. This study investigated if the severity of accidents can be lowered by changes in driver awareness and rider management and safety education provided by platforms. Accordingly, the study aimed to identify whether there are changes in the incidence of commercial motorcycle accidents, severity of accidents, and sites of injury. For this objective, the authors investigated the 10-year trend in the incidence of commercial motorcycle accidents, changes in severity, and related factors.

METHODS

Ethics statements

The study was approved by the Institutional Review Board of Gachon University Gil Medical Center and received a waiver for participant consent form (No. GBIRB2022-102).

Study design

This study is a retrospective cohort study based on a chart review. This study used data from the Emergency Department-based Injury In-depth Surveillance (EDIIS), a part of the hospital-based injury surveillance system of Korea Disease Control and Prevention Agency (KDCA).

The study data was collected from the EDIIS registry and patients' medical records. The EDIIS was established by the KDCA in 2006. The number of participating hospitals in this surveillance has increased from five to 23 hospitals nationwide. A trained coordinator at each hospital registers the data for 246 variables in the KDCA online system, including patient demographics, injury-related profiles, prehospital records, diagnosis, disposition, and outcomes. The KDCA manages the quality of the input data through periodic error analyses.

The study retrospectively investigated patients who were admitted to an emergency department (ED) for a commercial motorcycle accident between January 2011 and December 2020. Upon confirmation of a sharp increase in the number of delivery app users since 2015, 10-year data were analyzed after dividing the period as before (group 1, 2011–2015) and after (group 2, 2016–2020) 2015. Data from a total 8,857 patients were collected for the study period, and of these, data from those aged ≥16 years, who can legally obtain a driving license for motorized bicycle, were used in the study. After excluding 12 patients with re-

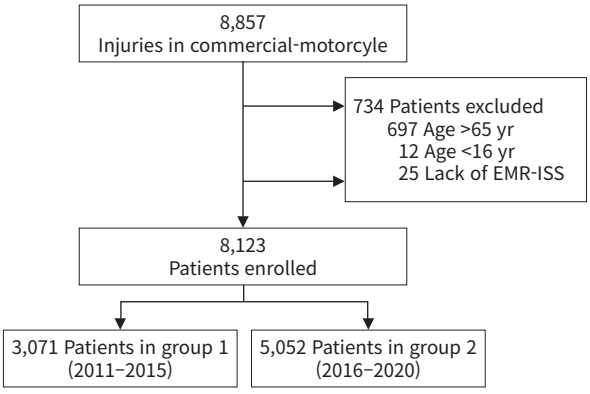

Fig. 1. Flow diagram of the patient selection and exclusion process. EMR-ISS, excess mortality ratio-adjusted Injury Severity Score.

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cording error and aged < 16 years, 25 patients with missing raw data, and 697 patients aged ≥ 65 years since economically active population is up to age of 64 years, data of 8,123 patients were used in the study (Fig. 1).

The general characteristics of the patients were identified through their age, sex, site of injury, time of injury, and with or without surgery. The time of injury was divided into two time periods considering the delivery service time: afternoon/ evening (working hours, 12:00–23:59) and overnight/morning (non-working hours, 00:00–11:59). The severity of injury was assessed using the excess mortality ratio-adjusted Injury Severity Score (EMR-ISS). EMR-ISS is derived using the S or T code in the International Classification of Diseases (ICD). Each diagnosis is graded on a scale of 1 to 5 points and the three codes with the highest scores, regardless of the body part, are scored and added: EMR-ISS = (first highest EMR grade)^2 + (second highest EMR grade)^2 + (third highest EMR grade)^2. The EMR-ISS was classified into four categories: mild (1 ≤ EMR-ISS ≤ 8), moderate (9 ≤ EMR-ISS ≤ 24), severe (25 ≤ EMR-ISS ≤ 74), and critical (EMR-ISS ≥ 75 or death). In this study, the scores were divided into two groups with 15 points as the cutoff. Whether the patients were wearing a helmet was determined and the treatment outcomes were classified as discharged to home, transferred to another hospital, admitted to general ward, admitted to intensive care unit (ICU), and death. Among the classified patients, those admitted to ICU and patients who died were classified as severe patients for reassessment of severity that was not assessed by EMR-ISS.

The site of injury was classified using ICD-10 code S according to the diagnosis based on the injury data investigated from patients who visited an ED. Codes consisted of S01–S19 for head and neck injury, S20–S39 for torso injury, S40–S69 for upper limb injury, and S70–S99 for lower limb injury.

For the statistical analyses, each variable was expressed as frequency and percentage. Continuous variables were expressed as mean and standard deviation or median and quartile, as needed. Categorical data were analyzed using chi-square test and continuous variables were analyzed using t-test. In addition, multivariate logistic regression analysis was performed to determine factors related to severe injury. Statistical significance was set to $P < 0.05$. Data were collected using a Microsoft Excel database (Microsoft Corp) and statistical analyses were performed using IBM SPSS ver. 23.0 (IBM Corp).

RESULTS

After classifying into group 1 and group 2, the demographic characteristics of patients who were admitted to our ED for commercial motorcycle accidents during the 10-year period were identified (Table 1). With respect to sex, the percentage of male patients was significantly higher with 95.1% (n = 2,921) and 97.0% (n = 4,901) in groups 1 and 2, respectively.

The mean age was similar with 36.01 ± 14.33 and 36.10 ± 13.27 years in groups 1 and 2, respectively. Meanwhile, the number of patients who were wearing a helmet at the time of accident increased from 1,682 in group 1 (54.7%) to 4,108 in group 2 (81.3%).

The time of accident was investigated by dividing the time into two groups in consideration of when delivery services are mostly used. Time was divided in peak hours and other hours. The number of accidents that occurred during 12:00 to 23:59 and 00:00 to 11:59 were 2,287 (74.5%) and 784 cases (25.5%), respectively, in group 1, and 3,876 (76.7%) and 1,176 cases (23.3%), respectively, in group 2.

Based on EMR-ISS, which was used as a scale for assessing the severity of injury, group 1 had 2,079 mild cases (67.7%) and 992 severe cases (32.3%), while group 2 had 3,073 mild cases (60.8%) and 1,979 severe cases (39.2%). Of these, the number of patients requiring surgery increased from 236 in group 1 (7.7%) to 721 in group 2 (14.3%).

In group 1, 2,007 patients (65.3%) were discharged to home from ED, 182 patients (5.9%) were transferred to another hospital, 669 patients (21.8%) were admitted to the general ward, 190 patients (6.2%) were admitted to ICU, and 23 patients (0.7%) died in the ED. In group 2, 3,294 patients (65.2%) were discharged to home from ED, 252 patients (5.0%) were transferred to another hospital, 868 patients (17.2%) were admitted to the general ward, 602 patients (11.9%) were admitted to ICU, and 36 patients (0.7%) died.

Multivariate logistic regression analysis was performed to identify the factors that increase the severity of commercial motorcycle accidents (Table 2). Statistical analysis was performed using variables that showed statistical significance in univariate logistic regression analysis and other variables that the researchers believed must be included. Of these, sex did not show a statistically significant difference. The severity tended to increase by 1.008 times as age increased by one year (95% confidence interval [CI], 1.004–1.013). The severity of injury was 1.243 times higher during overnight/morning, as compared to afternoon/evening (95% CI, 1.091–1.415).

Severity increased by 1.491 times in group 2, as compared to group 1 (95% CI, 1.318–1.687). With respect to the site of injury, severity was 8.357 times higher for head and neck injury (95%

Table 1. Characteristics of commercial motorcycle accidents that visited ED in 10 years

Characteristic	Group 1[a] (n=3,071)	Group 2[b] (n=5,052)	P-value
Sex			<0.001
Male	2,921 (95.1)	4,901 (97.0)	
Female	150 (4.9)	151 (3.0)	
Age (yr)	36.01±14.33	36.10±13.27	<0.001
Helmet use	1,682 (54.8)	4,108 (81.3)	<0.001
Time of the accident			0.064
12:00–23:59	2,287 (74.5)	3,876 (76.7)	
00:00–11:59	784 (25.5)	1,176 (23.3)	
EMR-ISS			<0.001
Mild (<15)	2,079 (67.7)	3,073 (60.8)	
Severe (≥15)	992 (32.3)	1,979 (39.2)	
Operation case	236 (7.7)	721 (14.3)	<0.001
ED result			<0.001
Discharge	2,007 (65.4)	3,294 (65.2)	
To ward	669 (21.8)	868 (17.2)	
To intensive care unit	190 (6.2)	602 (11.9)	
Transfer	182 (5.9)	252 (5.0)	
Death	23 (0.7)	36 (0.7)	
Injury			
Head and neck	1,150 (37.4)	1,764 (34.9)	0.021
Torso	607 (19.8)	1,278 (25.3)	<0.001
Upper limb	848 (27.6)	1,800 (35.6)	<0.001
Lower limb	1,209 (39.4)	2,451 (48.5)	<0.001

Values are presented as number (%) or mean ± standard deviation.
ED, emergency department; EMR-ISS, excess mortality ratio-adjusted Injury Severity Score.
[a]Accidents from 2011 to 2015; [b]Accidents from 2016 to 2020.

Table 2. Multivariate logistic regression analysis of factors contributing to the severity of injury associated with commercial motorcycle accidents

Variable	Odds ratio	95% Confidence interval	P-value
Sex	1.013	0.751–1.365	0.933
Age	1.008	1.004–1.013	<0.001
Time			
00:00–11:59	1.243	1.091–1.415	0.001
12:00–23:59	Reference		
No helmet use	1.476	1.284–1.696	<0.001
Injury			
Head and neck	8.357	7.410–9.424	<0.001
Torso	4.122	3.610–4.708	<0.001
Upper limb	1.657	1.470–1.867	<0.001
Lower limb	1.466	1.303–1.648	<0.001
Group 2[a]	1.491	1.318–1.687	<0.001

[a]Accidents from 2016 to 2020.

CI, 7.410–9.424) and 4.122 times higher for torso injury (95% CI, 3.610–4.708).

Multivariate logistic regression analysis was performed to identify the factors leading to ICU admission and death in commercial motorcycle accident cases (Table 3). With respect to age, based on the age of 16 years, increase in age by 1 year caused ICU

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Table 3. Multivariate logistic regression analysis of factors contributing to the intensive care unit and death associated with commercial motorcycle accidents

Variable	Odds ratio	95% Confidence interval	P-value
Sex	1.190	0.771–1.838	0.432
Age	1.012	1.006–1.018	<0.001
Time			
00:00–11:59	1.102	0.913–1.329	0.311
12:00–23:59	Reference		
No helmet use	2.100	1.739–2.535	<0.001
Injury			
Head and neck injury	1.428	1.206–1.690	<0.001
Torso injury	1.818	1.537–2.165	<0.001
Upper limb injury	0.302	0.243–0.376	<0.001
Lower limb injury	0.291	0.239–0.354	<0.001
Group 2[a)]	2.593	2.120–3.170	<0.001

[a)]Accidents from 2016 to 2020.

admission or death to increase by 1.012 times (95% CI, 1.006–1.018). ICU admission or death increased by 2.593 times in group 2, as compared to group 1 (95% CI, 2.120–3.170).

DISCUSSION

Since 2000, single-person households have become a common household type, increasing sharply from 15.5% in 2000 to 23.9% in 2010; this proportion is expected to increase to 31.3% in 2025 [11]. With the increase in single-person households, the frequency of delivery service use has also increased, while food delivery culture has increased over twofold due to coronavirus disease 2019, thus becoming a global service industry [12]. Since the introduction of delivery platforms, the number of its users has increased sharply, and consequently, the commercial use of motorcycles has also increased. This study, which used injury data of ED patients, also confirmed such increase in the past 10 years (Fig. 2). There have not been many studies investigating the increase in delivery service use and changes in motorcycle accidents in the past 10 years. Byun et al. [13] reported on the general characteristics of commercial motorcycle accident victims, including their sex, age, time of accident, work background, and site of injury, for the period till 2015; however, they did not identify the changing trends in motorcycle accidents.

The comparison of the severity of accidents before and after 2015 using EMR-ISS revealed significant results. It is possible that result of increased speeding and traffic law violations due to intensifying competition in commercial motorcycles. Despite the efforts of delivery platforms to prevent accidents, results contrary to our initial expectations were derived. Accordingly, we determined that the policies implemented by delivery service platforms have not been successful.

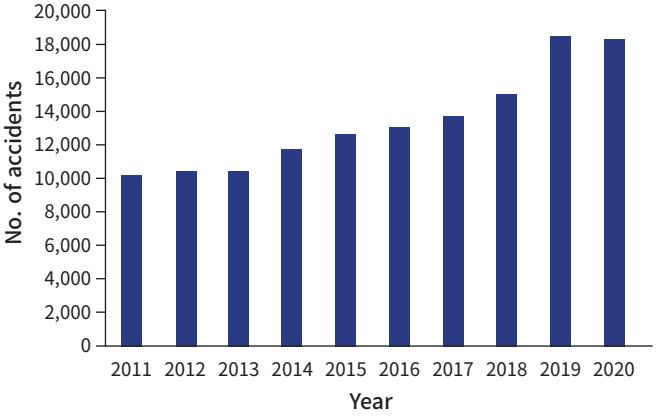

Fig. 2. Number of commercial motorcycle accidents in 10 years.

EMR-ISS can be a suitable tool for identifying severity from large-scale data [14]. However, although ISS may indicate the severity of anatomical injury, it has the limitations of not reflecting physiological indicators and not representing severity in anatomical sites in cases involving multiple injuries [15]. Accordingly, the authors of this study recognized the limitations of using EMR-ISS. When a motorcycle accident patient admitted to ED must immediately undergo surgery to treat the most urgent injuries, problems in other areas could be diagnosed or detected later on, and problems not diagnosed in ED are not reflected in the score. The data used in this study identified EMR-ISS of patients admitted to ED, and this score system, which uses three different scores, has limitations in reflecting the severity of patients' inju-

ries. Accordingly, ICU admission and death were investigated as another scale for assessment of severity (Table 3). Such standard was applied because there may be sites of injury not detected during the process of identifying severity based on diagnosis and the physiological condition of the patient may not be fully accounted for. Statistical data that can differentiate patients admitted to ICU as an indicator of the anatomical and physiological conditions of the patient can be meaningful. In this study, both the EMR-ISS and ICU admissions showed significant increases, but the ICU hospitalization results showed a high odds ratio. The authors considered these results that hospitalization decisions for trauma patients are not objective because they depend on the physician's opinion.

Wearing a helmet in a motorcycle accident affects ICU admission, consciousness at admission, and mortality rate, while its importance continues to be emphasized [16]. Logistic regression analyses in this study showed that the percentage of severe patients did not change significantly in groups 1 and 2, but wearing a helmet reduced the severity. With the development of the delivery service industry, the need to manage motorcycle riders has emerged and the rate of wearing a helmet is increasing due to active management (Fig. 3). However, the fact that the percentage of severe patients has not changed requires further examination. Such results demonstrate the importance of having full-body protective equipment, as well as wearing a helmet, in a motorcycle accident. While the need for full-body protective equipment and clothing in motorcycle accidents is being emphasized, there are advances in protective equipment for different parts of the body. de Rome et al. [17] conducted a study in 2011 on hospitalization rate and sites of injury according to wearing equipment other than helmet. Injury risk was compared by jackets, gloves, pants, and boots for different parts of the body and the results showed decrease of 0.77, 0.55, 0.61, and 0.55 times, respectively [17]. Therefore, studies on protective equipment other than helmet should continue in the future.

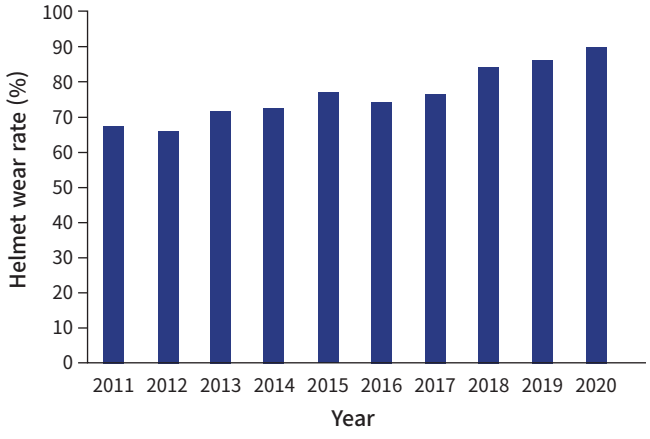

Fig. 3. Helmet wear rates in 10 years.

A 2016 study by Xiong et al. [18] reported that accidents occurring during 00:00 to 06:00 increased in severity by 2.45 times. As shown in Table 1, the findings in this study showed that the number of accidents during the afternoon was higher by approximately three times or more than at other times. However, the results in Tables 2 and 3 show that severity was higher in accidents that occurred during overnight hours, rather than in the afternoon, with higher number of cases. During overnight hours, competition among riders may be more severe due to fewer delivery cases, and accidents with more severe injuries occur as riders travel at higher speeds on empty roads. During overnight hours, driving through dark areas with poor lighting and frequent traffic violations, such as speeding, signal violations, and lane violations, may have affected the severity of accidents. Although the number of accident cases may be low, medical and policy plans must be established in consideration of physical and economic damages caused by an accident and its severity.

This study had some limitations. First, while advancement of delivery platforms may have influenced motorcycle accidents, the time point of such advancement is unclear. Second, this study investigated only patients who were admitted to ED, and not all admitted patients. Therefore, there is a lack of statistics on patients who died at the scene of the accident or were transferred from another hospital. Lastly, underlying diseases may have affected the prognosis and treatment outcomes of accident victims. However, despite such limitations, the significance of this study was that it used a considerable amount of data accumulated over 10 years to examine the trends. Additionally, the findings of the study can be helpful for future studies on commercial motorcycle accidents.

Since a sharp increase in the use of delivery services, motorcycle accidents have increased. There was increased severity based on EMR-ISS and severity based on ICU admission and death. Safety management and education by large platforms and implementation of systematic upgrades by the government can gradually improve the results with respect to commercial motorcycle accidents in the future. With the increasing development of the platform-based delivery industry, further investigation and studies are needed on factors that affect severity of accidents.

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NOTES

Conflicts of interest

Seung Hwan Lee serves on the Editorial Board of *Journal of Trauma and Injury*, but was not involved in the peer reviewer selection, evaluation, or decision process of this article. The authors have no other conflicts of interest to declare.

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None.

Data sharing statement

The data of this article are available from the corresponding author upon reasonable request.

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Author contributions

Conceptualization: SHL, JHJ, SYH; Methodology: DM, SHL, JHJ, JSC; Data curation: DM, JYC; Formal analysis: JSC, JW, JHJ; Writing–original draft: DM, JHJ; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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Case Report

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Submental intubation using laparoscopic trocar in zygomaticomaxillary complex fracture surgery in Korea: a case report

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Submental intubation is an effective alternative technique for airway management in patients with maxillofacial trauma. Compared with tracheostomy, it is less invasive, but has risks associated with potential airway compromise such as hypoxia due to tube obstruction, collapse, and kinking. To shorten procedure time and ensure a reinforced tube lumen, we used a laparoscopic trocar as a new device for submental intubation. A 54-year-old male patient sustained a zygomaticomaxillary complex fracture and was scheduled to undergo open reduction and internal fixation. We performed intraoral intubation and made a small 1-cm incision at the submandibular midline. After dissection of the tissue from the incision site, a reinforced tube was passed using a 12-mm laparoscopic trocar. The procedure took about 5 minutes, and apnea time from disconnecting the breathing circuit and passing through the internal lumen of the trocar until it was reconnected to the ventilator was 1 minute 5 seconds. Using a laparoscopic trocar for submental intubation can reduce the time required for dissection, prevent luminal occlusion complications due to soft tissues or blood clots in the endotracheal tube, and decrease soft tissue damage.

Keywords: Airway management; Maxillofacial injuries; Intratracheal intubation; Surgical instruments; Case reports

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INTRODUCTION

Submental intubation is a technique wherein the endotracheal tube protrudes through the anterior floor of the mouth, not through the mouth opening, which allows free intraoperative access to the oral cavity and nasal pyramid without compromising the airway in patients with skull base trauma. The reason for performing submental intubation is that facial trauma patients may also have a fracture at the base of the skull, and it is important to determine dental malocclusion during oral surgery. In addition, nasotracheal intubation is not possible in patients with basilar fracture, and in zygomaxillary complex fracture surgery, the surgeon and anesthesiologist share the intraoral space, making it difficult to manage the airway through the mouth during surgery [1]. Therefore, after securing an airway by orotracheal intubation, airway management is performed through submandibular intu-

bation or tracheostomy. Submental intubation can be used for short-term airway control as an alternative to tracheostomy but with minimal complications [2].

Although it has been modified in various ways since it was first proposed by Altemir [3] in 1986, no published modification or specific type of reinforced tubing has been universally demonstrated to be superior. Since then, other complementary techniques using the tracheostomy kit have been proposed, but even this method could not prevent blockage of the internal lumen of the endotracheal tube by blood clot and soft tissue and caused trauma to surrounding soft tissue [4–6]. Various efforts have been introduced to reduce or address complications that occur in the process of exteriorization [7–9].

The proposed method using a laparoscopic trocar is part of that effort. This is a method that can be easily and simply mounted without blood clots and soft tissues entering the endotracheal tube, while also reducing the soft tissue trauma that occurs during the exteriorization process.

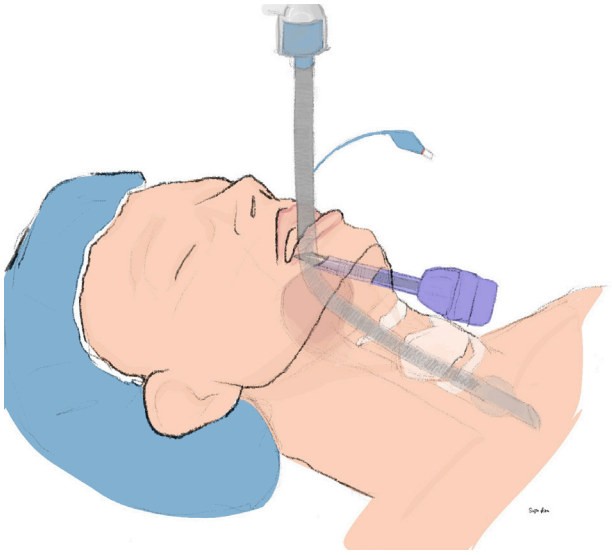

Fig. 1. The conventional tube is changed by reinforced tube and a skin incision and soft tissue dissection were performed. A laparoscopic trocar was inserted from the skin to the mouth floor. Illustration by Sujin Kim.

CASE REPORT

A 54-year-old male patient sustained a zygomaticomaxillary complex fracture after a 5-m fall. The patient was scheduled to undergo open reduction and internal fixation and intermaxillary fixation including a closed reduction for nasal bone fracture.

Instead of nasal intubation or tracheostomy, we decided to perform submental intubation using a 12-mm laparoscopic trocar. Before the procedure, we checked that the reinforced endotracheal tube (internal diameter, 7.0 mm) passed through the trocar's internal lumen. The connector part of the reinforced tube was removed.

Then, the tube change was performed using a videoscope with a reinforced tube prepared from the conventional tube the patient had received. Subsequently, the oral and maxillofacial surgeon placed an incision of about 1 cm in the submental space and dissected it with Kelley forceps to reach the mouth floor (Figs. 1, 2). Upon dilation of the open penetrating site from the skin to the mouth floor, a laparoscopic trocar was inserted from the skin to the mouth floor. After confirming that the tip of the trocar has passed through to the mouth floor, the trocar stylet was removed, and the Kelly forceps was inserted through the trocar.

First, the pilot balloon was passed into the trocar lumen and then the end of the reinforced tube with the connector removed was inserted into the trocar lumen (Figs. 3, 4). The reinforced tube was withdrawn toward the skin incision, and a connector

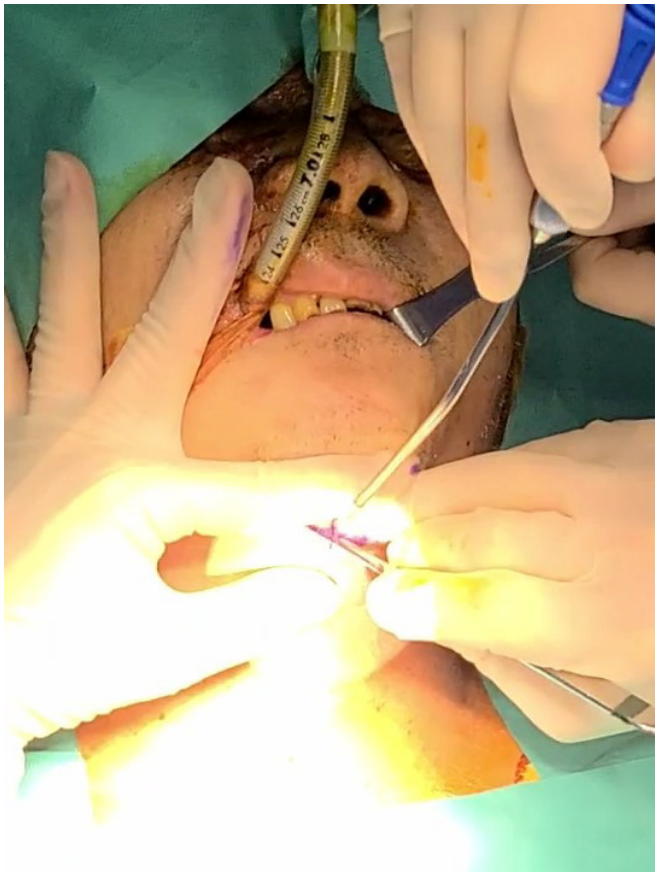

Fig. 2. After checking the mandible and midline, a surgeon makes a skin incision. The patient provided written informed consent for publication of the research details and clinical images.

and a breathing circuit were connected for ventilation. The airway pressure of the ventilator was checked for signs of blockage due to blood clots or soft tissue in the tube lumen. The tube depth was confirmed through capnography and auscultation, and after checking the patient's ventilation, the tube was fixed with a skin suture (Fig. 5). The patient's apnea time from disconnecting the breathing circuit and passing through the internal lumen of the trocar until it was reconnected to the ventilator was 1 minute 5 seconds. After surgery, the reinforced tube is pulled back into the oral cavity and the incision is sutured (Fig. 6).

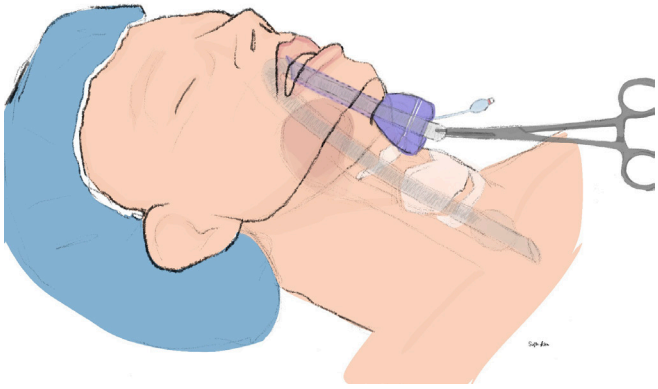

Fig. 3. After the trocar stylet was removed, and the Kelly forceps was inserted through the trocar. The pilot balloon was passed into the trocar lumen, and then the end of the reinforced tube with the connector removed was inserted into the trocar lumen. Illustration by Sujin Kim.

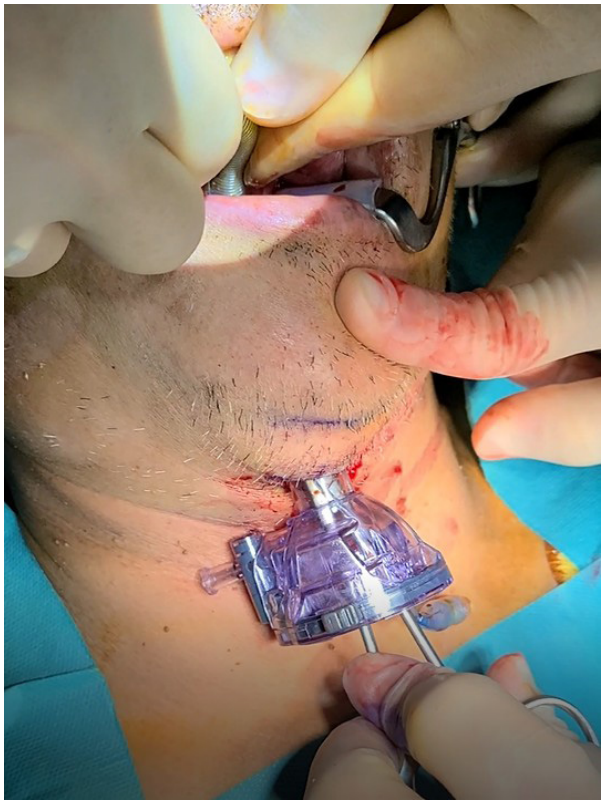

Fig. 4. A 12-mm trocar is placed from the skin to the mouth floor, and the end of the reinforced endotracheal tube is inserted into the trocar lumen in the mouth. The patient provided written informed consent for publication of the research details and clinical images.

Ethics statements

This case was conducted with the approval of the Institutional Review Board of Wonju Severance Christian Hospital (No. CR322318). The patient provided written informed consent for publication of the research details and clinical images.

DISCUSSION

Submental intubation has been an effective alternative technique for airway management in patients with maxillofacial trauma

Fig. 5. A surgeon stabilizes the reinforced endotracheal tube with skin suture. The patient provided written informed consent for publication of the research details and clinical images.

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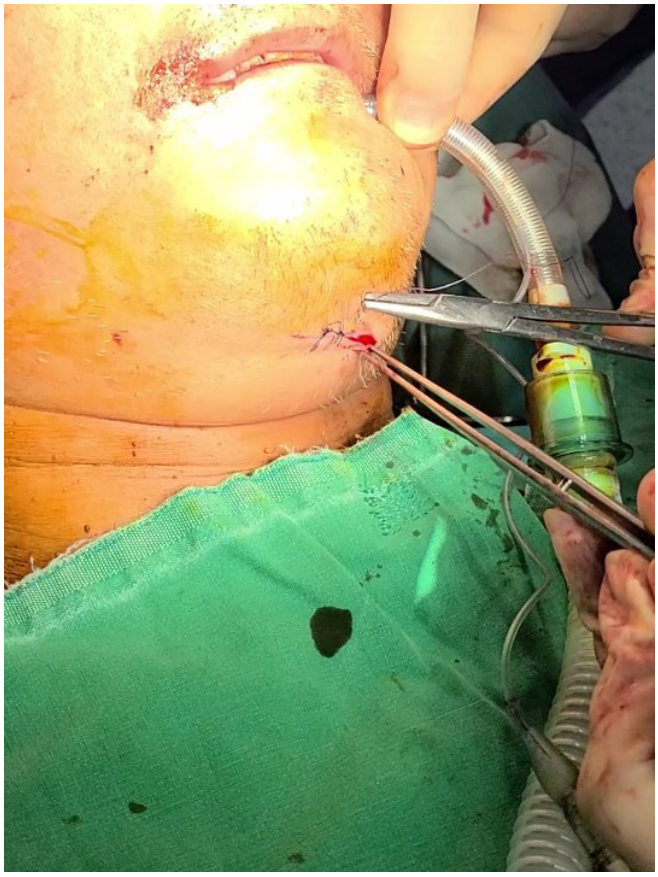

Fig. 6. After surgery, the reinforced tube is disconnected, and the end of the tube is pulled into the oral cavity. The reinforced tube is reconnected with the ventilator, and the submental incision is sutured. The patient provided written informed consent for publication of the research details and clinical images.

since first published in 1986 [3]. Compared with tracheostomy, this method facilitates airway management in patients with skull base fracture during zygomaticomaxillary complex fracture surgery. Tracheostomy also facilitates airway management but is more invasive and has complications such as surgical emphysema, tracheal erosion, hemorrhage, dysphagia, decannulation, and scarring [2,10].

The complication associated with submental intubation is potential airway compromise. Obstruction, collapse, kinking, or displacement of endotracheal tube could lead to fatal hypoxia. Other complications include potential risk of skin infection, abscess in the mouth floor, and injury of the marginal mandibular and lingual nerves and of salivary glands [1,11]. A reinforced tube is used to prevent kinking and collapse of the endotracheal tube. Displacement of the endotracheal tube is prevented by stabilizing through skin sutures as the last step. Obstruction by blood clot or soft tissue interferes with the procedure and increases the risk of hypoxia due to apnea when an endotracheal tube is disconnected from the breathing circuit and passes through the mouth floor.

In previous studies using conventional methods, the mean time to complete the procedure was about 10 minutes [12], on the other hand, our procedure required only 5 minutes. In particular, the apnea time was about 1 minute 5 seconds, because it was the first trial using a trocar, but it is thought that this time can be shortened to about 30 to 40 seconds if physicians become skilled. A laparoscopic trocar through small incision (< 2 cm) easily and quickly passes through the mouth floor and minimizes blunt trauma to surrounding tissues. Also, the probability of occlusion is low because the stylet retains its inner diameter while passing through the mouth floor. Compared with the conventional method, using a laparoscopic trocar can reduce the time required for dissection, as well as prevent luminal occlusion complications due to soft tissues or blood clots in the endotracheal tube; less surrounding tissue damage is also a benefit.

Recently, a case of submental intubation using a laparoscopic trocar like this case has been reported [13]. It is similar in methods and tools, However, in the previous case, only skin incision was performed before the passage of the laparoscopic trocar, and dissection occurred by the laparoscopic trocar stylet that passed through the bottom of the mouth. On the other hand, in our case, a laparoscopic trocar probe passes through the gap after a slight dissection of the soft tissue with forceps after skin incision. This can further reduce the soft tissue damage caused by the stylet in the previous case.

One point requiring emphasis during this procedure is sufficient space for passage between the reinforced tube and the trocar. We used a reinforced tube with an inner diameter of 7.0 mm and a 12-mm trocar, which is common use in laparoscopic surgery. Since these tools are generally used in the operating room, a trocar during submandibular intubation in patients undergoing zygomaticomaxillary complex fracture surgery is easy, safe, quick, and may cause minimal complications.

In conclusion, submental intubation is an alternative technique for airway management in maxillofacial trauma. Using a laparoscopic trocar can reduce the time required for dissection, as well as prevent luminal occlusion complications due to soft tissues or blood clots in the endotracheal tube; less soft tissue damage is another benefit. Since no definitive approach of submental intubation has been established, a large-scale study comparing existing methods including the trocar is required.

NOTES

Conflicts of interest
The authors have no conflicts of interest to declare.

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Not applicable.

Author contributions
Conceptualization: HD, CL, HKL; Data curation: HD, HDH, HH, SK; Supervision: HKL, SK; Writing–original draft: HD, HDH, HH; Writing–review & editing: CL, HKL, SK. All authors read and approved the final manuscript.

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Case Report

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Sphenoid sinus foreign body following airbag deployment in the United States: a case report

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We report a unique case of penetrating foreign bodies following a motor vehicle accident with airbag deployment. The patient presented with evidence of facial trauma and was found to have three retained foreign bodies on imaging. Notably, one foreign body was within the sphenoid sinus. This foreign body was removed uneventfully through endoscopic sinus surgery. The patient was doing well at follow-up visits. We concluded that the foreign bodies were steering wheel accessories, which detached upon airbag deployment and penetrated the patient's face. This case report is intended to inform the public regarding the dangers of placing accessories on a steering wheel.

Keywords: Sphenoid sinus; Nasal surgical procedures; Foreign bodies; Craniocerebral trauma; Case reports

INTRODUCTION

Sinonasal foreign bodies are rare, but concerning due to nearby critical structures, including the orbit, optic nerves, internal carotid arteries, brain, and cavernous sinus. Due to the proximity of these structures, sinonasal foreign bodies can result in significant complications. Within the orbit, traumatic foreign body injury can result in visual disturbance, diplopia, ophthalmoplegia, or infectious complications, whereas sinonasal complications may include nasal obstruction, sinusitis, smell disturbance, cerebrospinal fluid rhinorrhea, life-threatening hemorrhage, or stroke.

Several traumatic cases of traumatic sinonasal foreign bodies have been reported. Most commonly, injuries involving high-velocity trauma, such as firearms [1–3], ballistic projectiles [4], and high falls [5,6], increase the risk of penetrating foreign bodies. However, even falls from standing height impart enough force to result in sinus penetration [7,8]. Foreign body entry wounds frequently involve the nasal cavity [2,3,5,8] and orbit [1,6,7]. These foreign bodies are typically less than a centimeter in all dimensions. For cylindrical objects, at least one two-dimensional face of less than 1 cm^2 is typical, such as a wooden stick [6,8] or pen [5]. We report a case of a sphenoid sinus foreign body resulting from airbag deployment during a motor vehicle accident (MVA).

CASE REPORT

The patient was a 31-year-old female without any relevant medical history brought to our emergency department following a head-on MVA with airbag deployment. She was alert and only complained of pain along her lower face and minor epistaxis. Her only obvious injuries were two small puncture wounds over her chin and right mandible. Due to the nature of the accident, a full-body computed tomography scan was obtained, which demon-

strated metallic densities within the facial soft tissues and within the right posterior ethmoid and sphenoid sinus, abutting the paraclival carotid artery (Fig. 1). The appearance of the foreign body on imaging was similar to what would be expected from a screw. Given the proximity of the foreign body to the carotid artery a computed tomography angiogram was obtained that did not identify any major vascular injury (Fig. 2).

In preparation for endoscopic removal of the foreign body, the neurointerventional radiology team was consulted in the unlikely event of an unexpected injury to the carotid artery. Interestingly, it was recognized that the foreign body had entered through the left nasal cavity, traversed the head of the left inferior turbinate, penetrated through the septum, and entered the right posterior ethmoid and sphenoid sinus (Figs. 3, 4). The approach began with resection of the right middle turbinate, which would give wide access to the sphenoid in the event of excessive bleeding. A standard maxillary antrostomy and ethmoidectomy were then performed. The sphenoid sinus was then entered along its medial aspect to avoid any manipulation of the foreign body. Careful lateral dissection then exposed the distal aspect of the foreign body lodged in the clival recess of the sphenoid sinus. The proximal aspect of the foreign body was then exposed along the lamina papyracea after some edematous mucosa was removed. The foreign body was then removed with Takahashi forceps without any adverse event. No skull base injury or major neurovascular injury was encountered during the approach or removal.

At the patient's latest follow-up, 1 month after surgery, she had some synechiae in the left nasal cavity, which were lysed. This was in the area where the foreign body penetrated the septum. Otherwise, she had resolving edema of the maxillary sinus, but had no long-lasting effects from the injury.

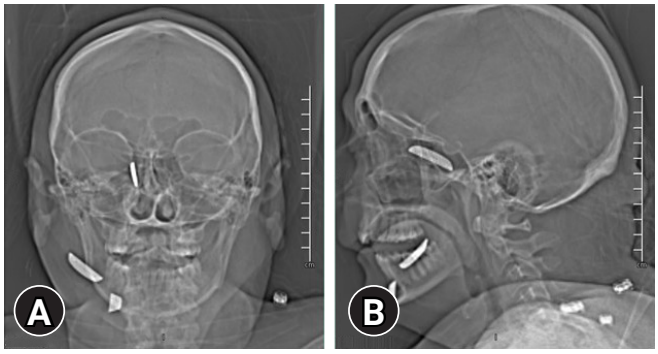

Fig. 1. Scout x-ray showing location of foreign bodies. (A) Anteroposterior and (B) lateral X-ray demonstrating the location of the foreign bodies in the facial soft tissue and right sphenoid sinus.

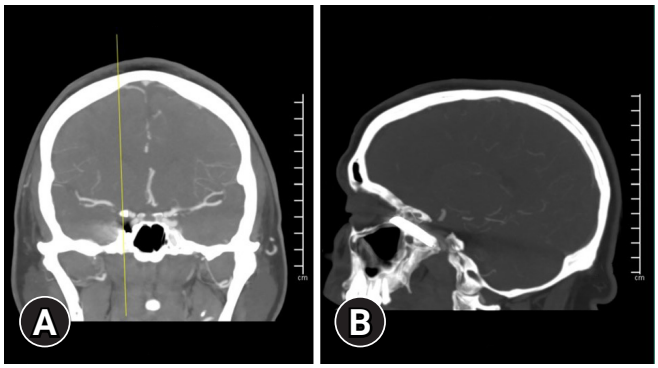

Fig. 2. Coronal and sagittal images from a computed tomography angiogram. (A) Coronal image showing the location of the foreign body in lateral sphenoid sinus (yellow line) and proximity to the cavernous carotid artery. (B) Sagittal image showing the proximity of the foreign body to the cavernous carotid artery.

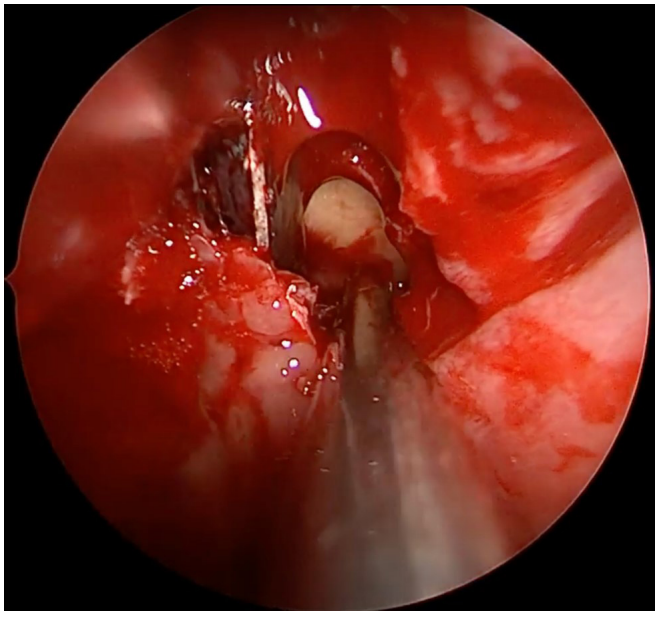

Fig. 3. Intraoperative view of the foreign body projecting inferiorly within the lateral aspect of the right sphenoid sinus.

Fig. 4. Foreign bodies following removal.

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Ethics statements

Written informed consent for publication of the research details and clinical images was obtained from the patient.

DISCUSSION

MVAs are the most common cause of serious facial trauma [9]. Standard safety features, such as seatbelts and airbags, significantly reduce facial trauma [10], but have limitations at high speeds [11] and are associated with their own injuries. Injuries related to airbag deployment mostly affect the face (42%), with minor burns and abrasions being typical [12]. Serious cases of penetrating injury attributed to airbag deployment have been reported [13,14], and in the past decade, several automobile fatalities were directly attributed to defective airbags.

In November 2014, the US National Highway Traffic Safety Administration ordered a nationwide recall of Takata airbags, affecting 34 million vehicles on US roads, the largest automobile recall in history. The recalled airbags contained a defective inflator, which resulted in either slow airbag deployment or, more dangerously, explosion of the inflator. To date in the United States, 19 deaths have been attributed to these airbags, including 16 in Honda vehicles (American Honda Motor) according to the Honda company website [15].

The patient in this case was driving a Honda, and had affixed aftermarket accessories to her steering wheel, as pictured in Fig. 5. Whether a defective airbag contributed to her facial injuries is unknown; however, the most likely explanation of her facial injuries is dislodgement of steering wheel accessories during airbag deployment, creating projectiles near the patient's face. Entry through the nasal cavity and ultimate embedment in the sphenoid sinus is highly suggestive of a direct course starting near the steering wheel and demonstrates the force with which airbags deploy. The trajectory of the foreign body through the patient's septum and its terminus within the sphenoid sinus adjacent to critical neurovascular structures makes this case a fortunate close call.

Fig. 5. Foreign bodies arranged within the Honda logo.

In our review of the scientific literature, we found no similar reported cases of injury by steering wheel accessories. However, there has been speculation regarding the dangers of these objects in the lay media. This is based on the logical concern regarding a loosely adhered object over an airbag, which is designed to explode violently. As of this report, these products are widely available to consumers without an associated safety warning. The goal of this report is to bring awareness to the potential danger posed by steering wheel accessories in the event of airbag deployment.

While penetrating sinonasal foreign bodies are rare entities within the trauma community, it is important to keep in mind that they may occur even in the absence of obvious entry wounds. Additionally, consumers should beware that placement of aftermarket products over airbags may turn these benign objects into dangerous projectiles upon airbag deployment.

NOTES

Conflicts of interest

The authors have no conflicts of interest to declare.

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Author contributions

Conceptualization: all authors; Data curation: all authors; Formal analysis: all authors; Methodology: all authors; Project administration: all authors; Visualization: all authors; Writing–original draft: all authors; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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Case Report

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External iliac artery injury with posterior pelvic ring injury in Korea: two case reports

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Pelvic ring injuries associated with external iliac artery injuries are rare and may be life-threatening condition. The most important factors in the managements are the immediate bleeding control and restoration of distal blood flow. We report two cases of pelvic ring injuries with external artery injuries. One case was occlusion of external iliac artery with concomitant rupture of internal iliac artery. The other case was ruptured external iliac artery. Every surgeon must understand the possibility of hidden lesions—for example, arterial rupture and thrombus—and should consider the need for embolization or thrombectomy when treating this type of injury.

Keywords: Pelvic ring injury; Pelvic fracture; Vascular system injuries; External iliac artery; Case reports

INTRODUCTION

In pelvic fractures, hemorrhage originates from the fracture site or owing an injury to the presacral and lumbar venous plexus [1]. Pelvic ring injuries associated with external iliac artery injuries are rare and may arise due to a lacerated or thrombosed on injured artery [2–6]. Injuries to the external iliac artery may be life-threatening. Moreover, vascular injury-induced lower extremity ischemia can worsen the clinical condition and thereby necessitate generalized salvage treatment for the rest of the body. Most surgeons agree that immediate hemostasis and restoration of vascular perfusion constitute crucial interventional strategies for the management of major arterial injuries. This report describes two cases of combined pelvic ring and external iliac artery injuries.

CASE REPORTS

Case 1

A 48-year-old healthy male construction worker who suffered a traumatic injury when he fell while carrying a 100-lb (45.36 kg) cement bag, which caused compression injuries to his inguinal area, was promptly admitted to Inje University Haeundae Paik Hospital. On admission, his mental status was alert; the initial blood pressure was 120/80 mmHg with tachycardia (110 beats/min); and the initial hemoglobin level was 13.5 g/dL (normal range, 12.0–16.0 g/dL). The patient complained of severe back, pelvis, and left heel pain and hypoesthesia, especially in the right lower extremity. On examination, muscular strength in the left lower extremities was intact according to the manual muscle testing scale; on the right side, the ankle dorsiflexion and plantar flexion power was grade 0, and the extensor hallucis longus pow-

er was grade 0. The peripheral pulses were palpable. Voluntary anal contraction was examined, and the anal and bulbocavernosus reflexes were found to be intact. Radiographic imaging showed an Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) C3 pelvic ring injury, which included bilateral sacral fractures, bilateral superior and inferior rami fractures, and right anterior iliac wing fracture; the patient also had a left calcaneal fracture (Fig. 1). A plain radiograph and computed tomography of the lumbosacral spines revealed right L1–L4 transverse process fractures. A computed tomography scan of the patient's abdomen and thorax showed multiple rib fractures, right-sided pneumothorax, and hemoperitoneum.

After the initial resuscitation, closed reduction of the fracture-induced pelvis widening was attempted by applying a pelvic binder, and the patient was shifted to the angiography suite for vascular assessment. Angiography demonstrated contrast extravasation from the right internal iliac artery, for which an intravascular coil was inserted, hemostasis was ensured, and the patient was transferred to the intensive care unit because of unstable vital signs (blood pressure, 90/50 mmHg; heart rate, 71 beats/min) with a hemoglobin level of 8.6 g/dL. The bilateral palpable femoral pulses were palpable; however, the right dorsalis pedis and right posterior tibial artery pulses were nonpalpable. A repeat angiography was conducted for vascular assessment after 40 minutes of the initial angiography (Fig. 2) and demonstrated a filling defect of the right external iliac artery which was not previously observed. A thrombectomy of the right external iliac artery restored the right lower extremity circulation, and fasciotomies of the right thigh and leg were performed to prevent compartment syndrome. The patient transferred back to the intensive care unit for further resuscitation and, 10 days later, underwent reduction and fixation of the posterior pelvic disruption and right iliac wing fracture; the fracture fragments of both sacroiliac joints and the right iliac wing were reduced and fixed using screws. The postoperative course was uneventful, without any complications; an anteroposterior pelvis radiograph that was obtained at the 6-week postoperative follow-up is shown in Fig. 3. The patient was subsequently discharged to a rehabilitation facility. Normal

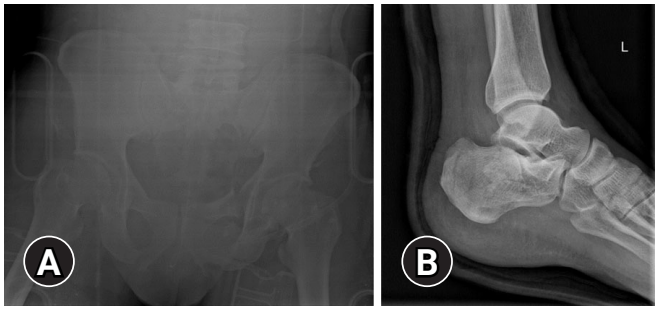

Fig. 1. Anteroposterior pelvic and lateral ankle radiographs showing (A) both sacral fractures, both superior and inferior rami fractures, anterior right iliac wing fracture, and (B) left calcaneal fracture.

Fig. 3. An anteroposterior pelvis radiograph at postoperative 6 weeks.

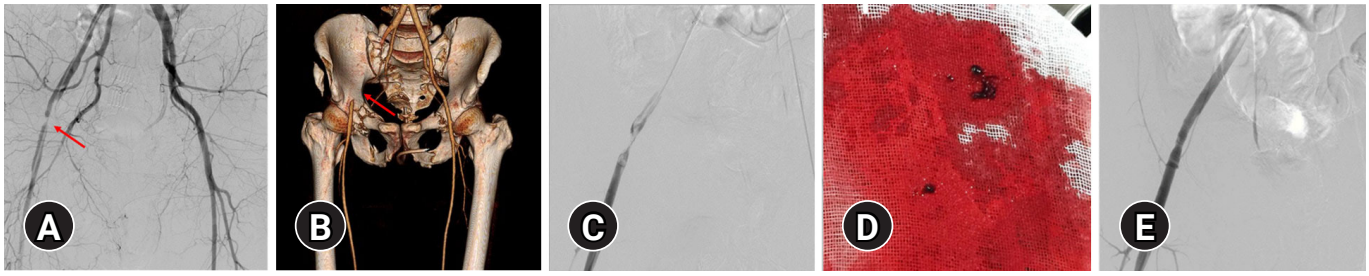

Fig. 2. Angiography of lower extremities. (A, B) An abrupt stoppage of flow was identified in the right external iliac artery (arrows). (C) Balloon angioplasty and thrombectomy were done. (D) The removed thrombus. (E) After the removal of filling defect.

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motor power recovery in the affected extremity was restored within 6 months.

Case 2

A 57-year-old healthy male worker sustained a crush injury under an overturned forklift. He was transferred to and evaluated at a community hospital and was then referred to Inje University Haeundae Paik Hospital. At presentation, the patient had a crushed left thigh and muscle protrusion of the left pelvis from an open wound with active bleeding. On admission, his mental status was alert; the initial blood pressure was 80/50 mmHg and the heart rate was 85 beats/min; and the initial hemoglobin level was 13.8 g/dL. The patient complained of pain in the left pelvis and in both thighs. A radiograph of the pelvis showed AO/OTA C3 pelvic ring injury; left femoral neck, subtrochanteric, and shaft fractures; and a right subtrochanteric femoral fracture (Fig. 4). The patient underwent angiographic vascular assessment in the angiography suite that revealed abrupt flow cessation in the left common iliac artery (Fig. 5). However, 30 minutes after admission, the patient slipped into a semicomatose state with uncheckable blood pressure and bradycardia (50 beats/min). Resuscitation was started with normal saline of 1,000 mL infusion and two packs of universal O group packed red blood cells transfusion. Also, a dopamine infusion (flow rate, 7 mcg/kg/min) was started for resuscitation and increased to 14 mcg/kg/min, but the patient's vital signs remained unstable, and the patient was shifted to the operating room for emergent surgical reduction and external fixation of pelvic fracture and to control hemorrhage. The ruptured left external iliac artery was repaired with a saphenous vein graft and 41 units of packed red blood cells were transfused intraoperatively. Fasciotomies of the left thigh and the left leg were performed to prevent compartment syndrome. Four days later, infection of the fasciotomy site was observed, with a large area of skin necrosis and severe pain of the lower extremity, for which an above-knee amputation and hip disarticulation were consecutively performed. Despite these radical interventions, the infection was not controlled, and the patient died of multiorgan failure and uncontrolled sepsis 34 days after the surgery.

Fig. 4. An anteroposterior pelvis radiograph showing Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) C3 pelvic ring injury, left femoral neck/subtrochanteric fracture, and right intertrochanteric/subtrochanteric/shaft fractures.

Ethics statements

The Institutional Review Board of Inje University Haeundae Paik Hospital waived the need for informed consent due to the retrospective nature of the case reports (No. 2017-08-004).

DISCUSSION

White et al. [7] reported that hemorrhagic pelvic fractures that induce hemodynamic instability have a mortality rate of as much

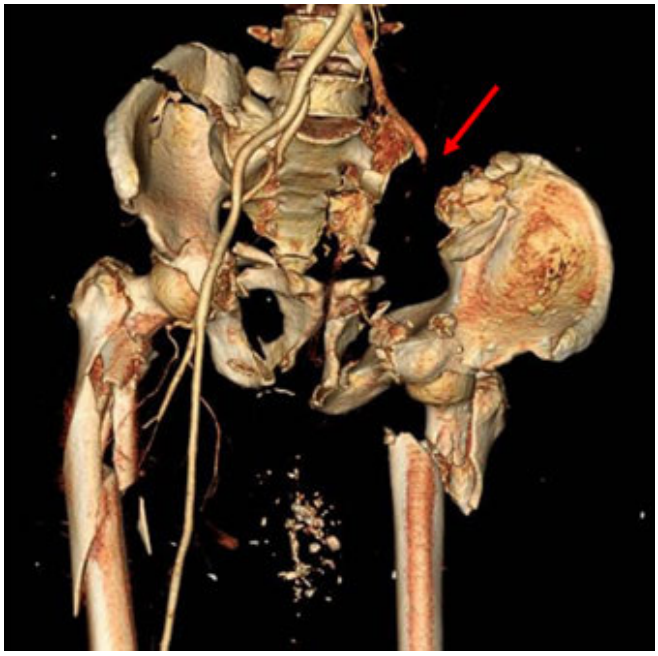

Fig. 5. Angiography of lower extremities. An abrupt stoppage of flow was identified in the left common iliac artery (arrow).

as 40%. Given the high-energy trauma that is needed to disrupt the pelvic ring, associated injuries are common, and mortality is usually a result of uncontrolled hemorrhage from extra-pelvic sources. Large-vessel bleeding secondary to the pelvic ring injury is an important mortality-inducing factor [8].

Most vascular injuries are venous, whereas arterial injuries involve the branches of the internal iliac artery or superior and inferior gluteal arteries [9], which are particularly vulnerable to trauma due to their relationship to the posterior pelvic bones that are disrupted by high-energy trauma. The superior and inferior gluteal arteries and terminal hypogastric branches are vulnerable to injury because of the close anatomic relationship between these arteries and bony structures.

Nonetheless, the external iliac artery is an uncommon source of bleeding in pelvic fractures. Patients at risk of arterial bleeding with continued hemodynamic instability despite resuscitative efforts should undergo immediate angiography and embolization of bleeding pelvic vessels. If this treatment option is unavailable or delayed, or if the patient has other injuries, external fixation and pelvic packing, which can be performed concomitantly with other lifesaving procedures, may be used to further reduce pelvic venous bleeding. For continued hemodynamic lability without an apparent source of blood loss, transcatheter angiographic embolization should be attempted to locate and stop the pelvic arterial bleeding.

Carrillo et al. [2] reported that a 4% incidence of external iliac artery lesions with a pelvic fracture, and, in the absence of autonomous thrombosis, are often life-threatening. The mortality rate associated with iliac artery injuries ranges from 38% to 72% [10,11]. Injuries to the external iliac artery originate from arterial compression over bone in the pelvic ring or from arterial stretching following an injury to the pelvic structures. External iliac artery injury can be detected through a peripheral vascular examination and does not usually demonstrate a delayed pattern. Several reports of unrecognized injuries have been described in the literature [2,12,13], and this type of injury requires prompt surgery to restore vascular perfusion.

The treatment options depend on the kind of pelvic fracture stabilization that is undertaken, and arterial repair or reconstruction can be carried out with a patch or by grafting. In our cases, both patients required external fixation. One patient needed angiographic thrombectomy and intravascular coiling (case 1). The other patient needed arterial repair (case 2). A compartment syndrome in the lower extremity after the artery repair procedure occurred in both patients.

Pelvic ring injuries that are associated with an external artery injury are uncommon, and few cases have been reported in the literature. As in our cases, associated injuries and open fracture can be catastrophic for the patient. Our case reports emphasize the difficulty of treating combined vascular and peripheral nerve injuries, as one hinders the diagnosis of the other. Every surgeon must understand the possibility of hidden lesions—for example, arterial rupture and thrombus—and should consider the need for embolization or thrombectomy when treating this type of injury.

NOTES

Conflicts of interest
The authors have no conflicts of interest to declare.

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Author contributions
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Case Report

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Delayed diagnosis of popliteal artery injury after traumatic knee dislocation in Korea: a case report

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The popliteal artery damage is present to range from 1.6% to 64% of patients with knee dislocation, and it is crucial to evaluate vascular damage even if there are no prominent ischemic changes in the distal area. The injury of the popliteal artery by high-energy forces around the knee caused by a fall or traffic accident is a potentially limb-threatening complication in traumatic knee dislocation. The popliteal artery injury by blunt trauma has a high risk of limb amputation because the initial symptoms can show normal vascular circulation without urgent ischemia or obvious vascular injury signs. Since the collateral branches can delay the symptoms of decisive ischemia or pulseless extremity, the vascular damage is a major cause of limb amputation. In the present study, we describe a rare case of delayed diagnosis of popliteal artery injury after traumatic knee dislocation, requiring urgent limb revascularization surgery. After revascularization of the occluded popliteal artery, graft interposition was performed, and successful restoration was confirmed. This case illustrates that, even if ankle-brachial index >0.9 or equal pedal pulse to the uninjured extremity, serial vascular evaluation is required if there are soft signs such as diminished pulses, neurologic signs, or high-energy damage such as multiple ligament ruptures since delayed diagnosis of artery injury can be the major cause of limb amputation. The clinicians need to regard high-energy trauma such as multiple ligament rupture around the knee as a hard sign, and immediate computed tomography angiography can be helpful for accurate diagnosis and treatment.

Keywords: Popliteal artery; Knee dislocation; Computed tomography angiography; Physical examination; Case reports

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INTRODUCTION

The popliteal artery is vulnerable to blunt trauma, such as knee dislocation or complex fracture of the proximal tibia or distal femur. The popliteal artery injury by blunt trauma has a high risk of limb amputation because the initial symptoms can show nor-

mal vascular circulation without urgent ischemia or obvious vascular injury signs [1]. Since the collateral branches can delay the symptoms of decisive ischemia or pulseless extremity, the vascular damage is a major cause of limb amputation [2]. In the present study, we describe a rare case of delayed diagnosis of popliteal artery injury after traumatic knee dislocation, requiring urgent limb revascularization surgery.

CASE REPORT

A 54-year-old male patient was referred to the emergency department of Gyeongsang National University Hospital (Jinju, Korea) with acute ischemia, such as weak presence of a dorsalis pedis artery pulse, coldness, motor weakness, and sensory loss in the left lower leg, 9 hours after he suffered a knee dislocation by fallen from an embankment.

The patient's history revealed that he promptly presented to the local hospital after knee dislocation. Before local hospital presentation, the dislocated knee was spontaneously reduced. Investigation of the local hospital records revealed that the left lower leg showed that no evidence of acute ischemia and normal dorsalis pedis artery pulse on Doppler ultrasound, but common peroneal nerve injury symptoms including decreased sensation in the top of the foot and unable to hold the foot up on the initial examination. There were no differences in the pulses of the wrist or ankle compared to those in the contralateral uninjured extremity. A plain radiograph had no evidence of fracture of dislocation (Fig. 1). As a positive Lachman test finding, magnetic resonance imaging (MRI) was performed to confirm around knee ligament continuity. There was complete rupture of the bicruciate ligament, and injury of medial collateral ligament (Fig. 2). In addition, there was a lesion suspected of being minor intimal injury, but the overall patency was maintained in the MRI (Fig. 3). As the pedal pulse was equal to the sound side, close observation was performed, and the patient was scheduled to multiple ligaments reconstruction after swelling control. Without serial physical examination and Doppler ultrasound, the clinician discovered ischemic changes such as weakness of pedal pulse and cyanosis of toes, about 7 hours after the injury. The computed tomography angiography (CTA) was immediately performed, which showed complete segmental occlusion of popliteal artery, and fortunately, well developed genicular artery revealing proper collateral flow to the foot (Fig. 4).

For emergency exploration of the popliteal artery, the patient was transferred to our hospital. Immediately, we carried out surgical intervention to salvage the limb, 10 hours after the injury. The popliteal artery was found to be transected with thrombus and the damaged artery was excised. The graft interposition was performed by using a reversed saphenous vein graft with restoration of distal pulses within 12 hours of the injury. Postoperatively, intravenous heparin was administered for 7 days before replacing to prophylactic low molecular weight heparin. Low molecular weight heparin was kept for 7 days. During the period of observation, aspirin was retained. One week after surgery, follow-up CTA revealed successful restoration of the flow without any complication such as postoperative stenosis, thrombotic occlusion (Fig. 5).

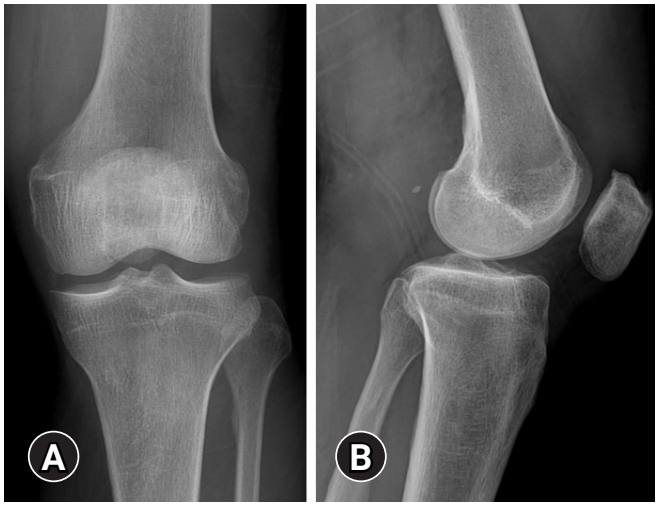

Fig. 1. Initial knee plain radiograph of (A) anteroposterior and (B) lateral. The initial knee X-ray showed no dislocation and bony abnormalities.

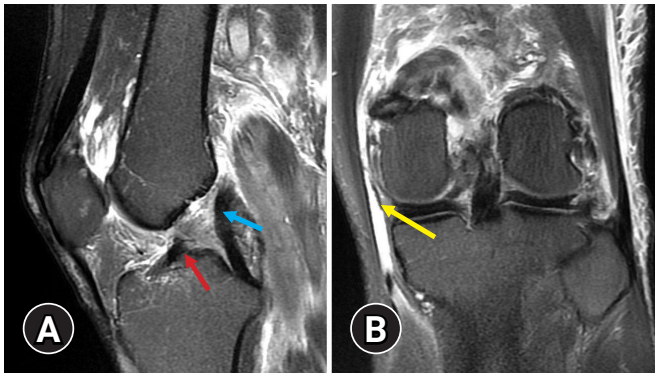

Fig. 2. Knee magnetic resonance imaging of (A) sagittal and (B) coronal views. The knee magnetic resonance imaging showed (A) complete rupture of bicruciate ligaments on the sagittal view (red arrow, anterior cruciate ligament; blue arrow, posterior cruciate ligament) and (B) injury of medial collateral ligament on coronal view (arrow).

Fig. 3. Knee magnetic resonance imaging (popliteal artery) of (A) sagittal and (B, C) coronal views. (A, B) There was a lesion suspected of being minor intimal injury (black circles), but (C) the overall patency of popliteal artery and distal flow (white circle) were maintained in the magnetic resonance imaging.

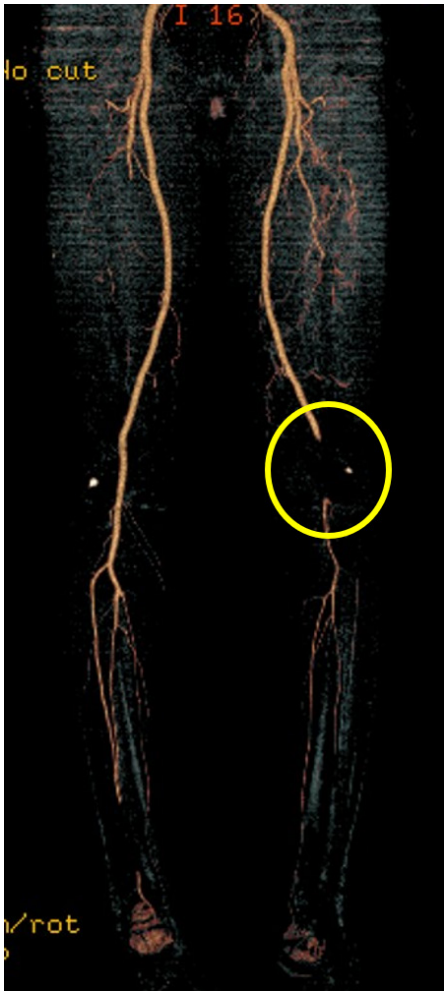

Fig. 4. Lower extremity computed tomography angiography showed complete segmental occlusion of left of popliteal artery (circle).

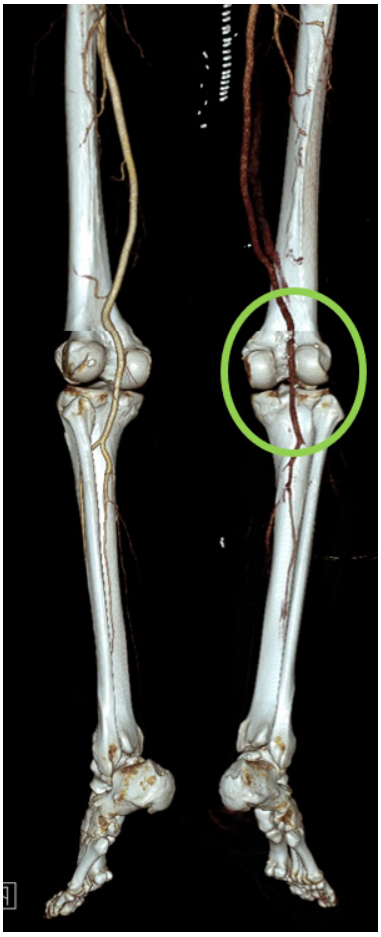

Fig. 5. Lower extremity follow-up computed tomography angiography after vein graft interposition surgery revealed successful restoration of the flow (circle) without any complication such as postoperative stenosis and thrombotic occlusion.

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Ethics statements

The case report was approved by the Institutional Review Board of Gyeongsang National University Hospital (No. GNUH 2022-10-016). The data were collected and analyzed in an ethical manner while protecting the patient`s right to privacy. Informed consent was waived since this was a retrospective study using medical records.

DISCUSSION

In the event of knee dislocation, the popliteal artery is particularly vulnerable to damage due to its anatomical location. At the point of the tendinous hiatus of the adductor magnus, the popliteal artery originates; before separating into the anterior and posterior tibial arteries, the tendinous arch of the soleus muscle anchors it firmly at the popliteal fossa. The artery is thus quite vulnerable to injury because of its position above and below the knee [3]. An irreversible injury could result in the need for amputation above the knee if a vascular injury is not detected and repaired in a timely manner. There are also other complications associated with knee dislocations, such as compartment syndrome, deep vein thrombosis, and most commonly, neurologic damage. The peroneal nerve injury is not a surgical emergency but may result in foot drop and impaired gait if it damages the dorsiflexion of the foot. Furthermore, sensory loss and paresthesia may also occur on portions of the dorsal side of the foot. Dislocations can spontaneously reduce in 50% of cases before they are evaluated, making diagnosis challenging [4]. When treating such patients, clinicians should confirm the history of leg deformity, the mechanism of injury, and any prehospital reduction attempts. Also, clinical assessments should be made to determine if the affected extremity is weak, cool, paresthesia, or bleeding. An evaluation of knee instability including ligamentous injury should be conducted after the reduction. Due to pain or muscular spasm, the initial ligament examination may be limited, which means a normal examination should be interpreted cautiously.

As a tool for assessing limb perfusion, the ankle-brachial index (ABI) is calculated by dividing the systolic blood pressure in the injured extremity by the systolic blood pressure in the uninjured upper extremity. Although the ABI values of >0.9 indicate intact vasculature, monitoring and repeat vascular examinations are recommended to avoid the missed diagnosis [5]. On physical examination, hard signs of arterial injury (pulselessness, rapidly expanding hemorrhage, massive bleeding, or palpable or audible bruit) help to diagnose vascular compromise requiring surgical treatment [6]. For patients without hard signs on physical examination, serial examination by a physician over 24 to 48 hours has proven to be highly sensitive and specific for detecting vascular injury in knee dislocations [3]. Stannard et al. [3] recommended that a surgeon should perform a vascular examination upon admission, 4 to 6 hours after admission, and again 24 and 48 hours later. However, due to the risk of complications (i.e., progression of occlusion or late pseudoaneurysm) associated with missed diagnosis, use of CTA has been recommended when soft signs (diminished pulse, a neurological findings and small nonpulsatile hematoma adjacent to named arteries) of vascular injury are present [7]. In the initial evaluation of this case, there were no hard signs like pulselessness, but only soft signs such as common peroneal nerve palsy at the local hospital. An ABI was not measured, but the same pulse as that of the contralateral side was confirmed. Whenever vascular damage is suspected, serial vascular examinations are required, and CTA is recommended if abnormal findings of ABI or Doppler ultrasound are observed.

An increase in the level of energy in injuries may explain the higher frequency of vascular damage. Especially in cases of high-energy damage such as multiple ligament rupture, vascular damage should be strongly suspected. Since thrombotic occlusion progresses slowly after intimal injury in this rare cases, close observation is necessary when vascular damage is suspected. The best diagnostic method for detecting vascular injuries was under debate in the literature. It is suggested that only patients with abnormal pulses or ABI undergo CTA in patients with knee dislocation [8], in contrast to some studies that recommended routine angiography for all patients [9]. Due to the difficulty of establishing the natural history of minor injuries resulting in healing or occlusion, we agree the "liberal use of angiography" for knee dislocation injuries [10]. The clinicians need to regard high-energy trauma such as multiple ligament rupture around the knee as a hard sign, and immediate CTA can be helpful for accurate diagnosis and treatment.

In summary, knee dislocation can result in vascular injuries, which can be potentially limb-threatening complication. About half of all dislocations can be reduced before arrival, so understanding of injury mechanism and thorough physical examination are essential. The equal pulses do not necessarily exclude vascular injury. In addition, even if ABI of >0.9, serial vascular evaluation is required if there are soft signs such as diminished pulses, neurologic signs, or high-energy damage such as multiple ligament ruptures since delayed diagnosis of artery injury can be the major cause of limb amputation. Traumatic knee dislocation

should be considered as a hard sign and prompt CTA can provide accurate diagnosis of vascular damage.

NOTES

Conflicts of interest
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Case Report

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Management of a traumatic avulsion fracture of the occipital condyle in polytrauma patient in Korea: a case report

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Avulsion fracture of the occipital condyle are rare lesion at craniovertebral junction. It is often related to high-energy traumatic injuries and show diverse clinical presentations. Neurologic deficit and instabilities may justify surgical treatment. However, the integrity of neurovascular structures is undervalued in the current literatures. In this case report, we described a 26-year-old female patient with avulsion fracture of occipital condyle following a traffic accident. On initial presentation, her Glasgow Coma Scale was 8. She presented with fracture compound comminuted depressed, on the left side of her forehead with skull base fracture extending into clivus and occipital condyle. Her left occipital condyle showed avulsion injury with displacement deep into the skull base. On her computed tomography angiography, the displaced occipital condyle compressed on the sigmoid sinus resulting in its obstruction. While she was recovering her consciousness during her stay in the hospital, the lower cranial nerves showed dysfunctions corresponding to Collet-Sicard syndrome. Due to high risk of vascular injury, the patient was conservatively treated for the occipital condyle fracture. On the 4 months postdischarge follow-up, her cranial nerve symptoms practically recovered, and the occipital condyle showed signs of fusion without further displacement. Current literatures focus on neurologic deficit and stability for the surgical decisions. However, it is also important to evaluate the neurovascular integrity to assess the risk of its manipulation as it may result in fatal outcome. This case shows, an unstable avulsion occipital condyle fracture with neurologic deficit can be treated conservatively and show a favorable outcome.

Keywords: Occipital condyle fracture; Avulsion; Computed tomography angiography; Collet-Sicard syndrome; Case reports

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INTRODUCTION

Avulsion fracture of the occipital condyle are rare lesion at craniovertebral junction. It is often related to fatal traumatic craniofacial injuries and in precomputed tomography (pre-CT) era, majority of the cases were detected in postmortem autopsies [1].

The imaging technology has improved dramatically in the recent decades and accordingly, earlier diagnosis and better prognosis of the patients can be anticipated, thanks to high resolution and quality three-dimension CT images.

High impact cranial trauma is often the mechanism leading to occipital condyle fracture (OCF) [2]. Therefore, many clinical symptoms are associated with OCF. Cervical spine fractures and traumatic brain injuries are often accompanied. In a few cases, extra-axial craniocervical hemorrhages may also occur [3]. Furthermore, Collet-Sicard syndrome is common in cases of avulsion fractures of occipital condyle, compressing on cranial nerves IX, X, XI, and XII, which result in hoarseness, dysphagia, and weakness of shoulder muscles [4].

The management of the avulsion or displaced OCFs vary in current literatures. There are reports of conservatively treated displaced OCFs, despite the neurologic symptoms including Collet-Siccard syndrome, which resulted in partial recovery of the neurologic symptoms [5,6]. Conversely, surgical treatments are often favored in patients with neural element compression with or without craniocervical misalignment [3]. However, these previous studies have not described the neurovascular integrity in their management decisions. Extra-axial hemorrhages at the craniocervical junction may result in fatal complications [7]. Therefore, adequate neurovascular evaluation and careful managements are necessary in avulsion OCF patients.

To best of our knowledge, the description of the CT angiography in avulsion OCF lack in current literatures. This case report handles the management decisions that considers the vascular integrity of the avulsion OCF patients.

CASE REPORT

A 26-year-old female patient arrived at the emergency department of the Focused Training Center for Trauma, Korea University Guro Hospital, following a traffic accident with Glasgow Coma Scale of 8. Her vital signs were stable, pupils were 3-mm prompt, and motor function were grossly intact. She did not have a significant medical or family history. The patient was sitting on the backseat of a taxi without fastening the seatbelt. High-speed collision with a guard-rail of a construction site caused her to collide with windshield as reported by the taxi driver, who survived the accident without severe injury. Airbag system did not deploy during the accident. Upon patient inspection, we found 15-cm-deep laceration on the left side of the forehead, raccoon-eye sign, and suspected CSF leakages. Polytrauma CT scan revealed fracture compound comminuted depressed (FCCD) on the left side of the frontal bone (Fig. 1). The fracture line was continuous along the cribriform plate and ethmoid sinuses to the clivus. Bilateral occipital condyle was found, where the left side was more severely affected—accompanying avulsion fracture and depression into skull base corresponding to the type 3 Anderson-Montesano and type 2B Tuli classification (Tables 1, 2, Fig. 1) [14]. Magnetic resonance imaging of the cervical spine revealed a type 1 atlantoaxial subluxation with intact transverse atlantal ligament. Despite the severely affected cervicocranial junction, subaxial cervical vertebrae, and their posterior ligamentous complex remained undamaged. Other findings were craniofacial CT scans were traumatic subarachnoideal hemorrhage at perimesencephalic cistern, subdural hemorrhage along cerebral falx, as well as bilateral frontal cerebral hemorrhagic contusion were noted. Scanty pneumocephalus and blow-out fracture of left orbit were also present. Additionally, mild liver laceration and lung contusion were also found. CT angiography was done for the evaluation neurovascular integrity, which included both arterial and venous phases. No evidence of stenosis or aneurysmal dilatation were found in the craniocervical arteries. However, flow void was observed in the left transverse-sigmoid sinus during the venous phase (Fig. 2).

The patient was admitted to the intensive care unit. The patient was immobilized with Miami brace and mildly sedated as preventing further vascular injury was important. FCCD with CSF leakage were managed with antibiotics administration followed by bifrontal osteoplastic craniectomy. Surgical treatment was not planned for the OCF to conserve the integrity of the sigmoid sinus and prevent devastating intracranial hemorrhage. On the 3rd day of admission, the patient slowly gained consciousness, being able to follow second-step obey command. On 12th admission day, the patient was permitted to drink water on her own and showed no signs of aspiration. However, on the 17th day, the patient developed aspiration signs and the Levine tube was applied. Patient also showed left-sided vocal cord palsy, which was manifested as hoarseness and speech difficulty as she gained consciousness. Left-sided tongue deviation was also observed. The patient was discharged on the 55th hospital day. CT scan prior to discharge showed no further displacement of the occipital condyle.

Miami brace was kept for 4 months after discharge. The patient received injection laryngoplasty in a private hospital 1-month postdischarge. Levine tube was removed within 1 month of discharge, and aspirations or dysphagia gradually im-

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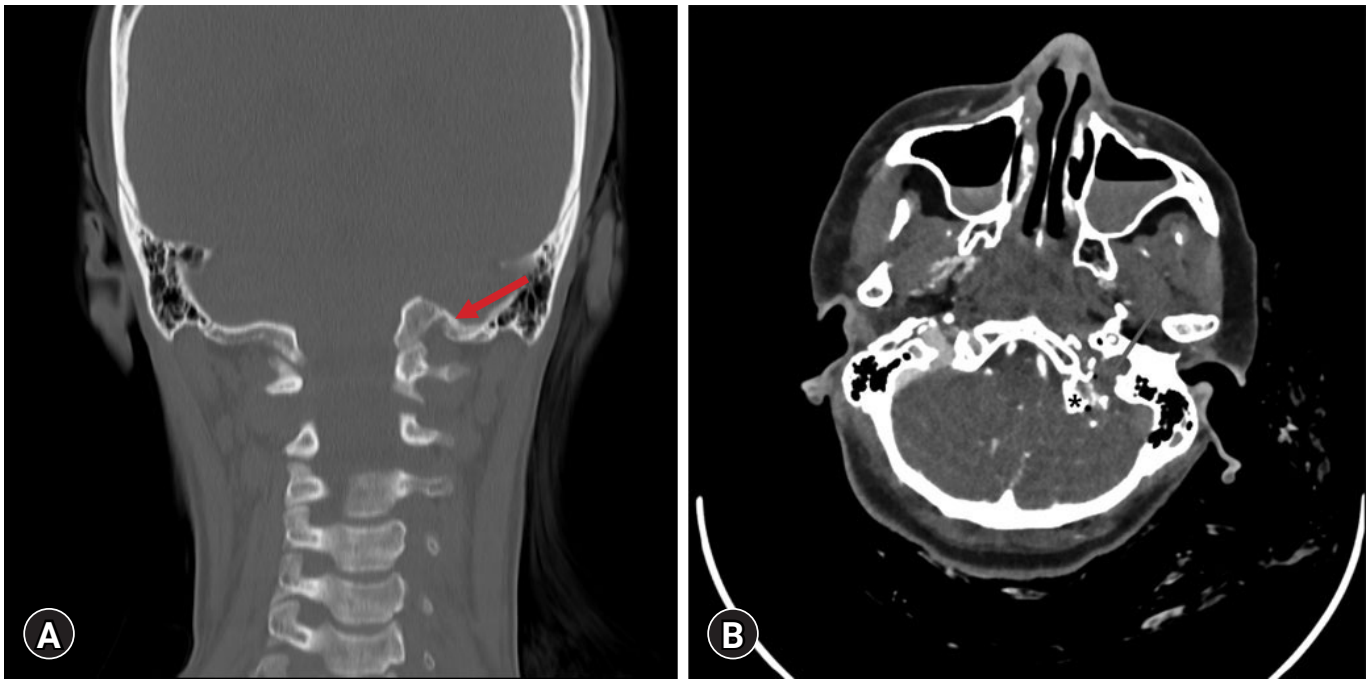

Fig. 1. Avulsion fracture of the occipital condyle. (A) Initial computed tomography image shows displacement of the left occipital condyle deep into the skull base (arrow). (B) Computed tomography image of 4-month follow-up shows fusion of the occipital condyle without further displacement.

Table 1. The Anderson-Montesano classification of occipital condyle fractures

Type	Description	Stability
I	Impacted fracture	Axial stress, stability from the contralateral alar ligament and tectorial membrane
II	Fracture of the base of the skull extending into the condyle	Stability from the intact alar ligament and tectorial membrane
III	Avulsion fracture	Tear of bony attachment of the alar ligament Instability due to associated injuries of the tectorial membrane

Table 2. The Tuli classification of occipital condyle fractures

Type	Description	Stability
I	Not displaced (<2 mm)	Stable
II	Displaced without AOD	Stable
III	Displaced with AOD	Unstable

AOD, atlanto-occipital dislocation.

proved. On the 6th month of the outpatient's follow-up, the patient significantly improved in speech, with less hoarseness. CT scan revealed bony fusion without further displacement of the occipital condyle (Fig. 1).

Ethics statements

The patient provided written informed consent for publication of the research details and clinical images.

DISCUSSION

Avulsion fracture of the occipital condyle is a clinically alarming situation. It often occurs in the setting of polytraumatic injuries of variable mechanisms such as axial compression and/or distraction or lateral skull compression, making it difficult for clinician to manage. Furthermore, it is anatomically located adjacent to many vitally important structures such as medulla oblongata and their neurovascular structures, cranial nerves controlling airways, and cranial venous sinuses [8]. Therefore, varying degrees of clinical symptoms are presented from fatal injuries to clinically dormant situations. Nevertheless, meticulous investigations are necessary for management. In the current literatures, decisions are often made in terms of neurologic deficits and misalignments associated with the injury. Neurologic deficit with concomitant

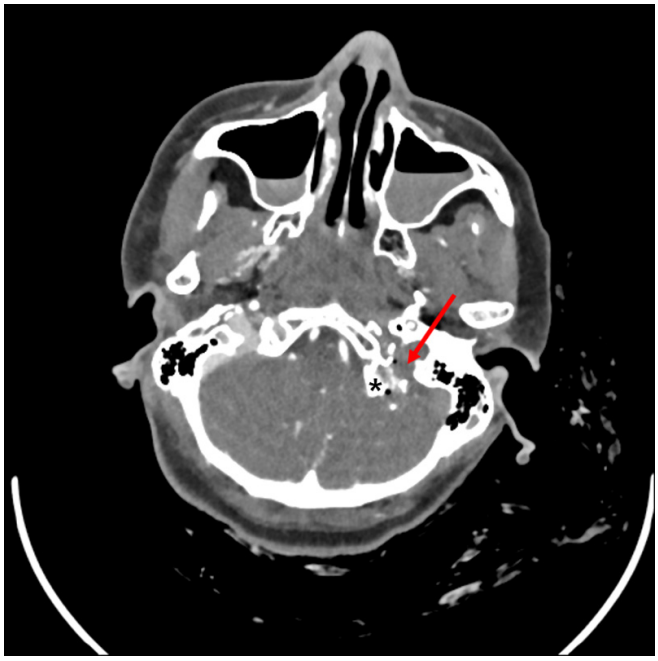

Fig. 2. Cranial computed tomography angiography with venous phase. Left-sided transverse-sigmoid sinus seems obstructed (arrow) with displaced occipital condyle (asterisk).

atlanto-occipital instability is regarded as an indication for surgery [3]. However, neurovascular integrity also plays a great role in this situation as it may result in devastating outcome. Furthermore, surgical treatment often involves the fusion of the occiput and upper cervical vertebrae. This greatly reduces the range of motion in the cervical spine including rotation, flexion and extension, and lateral flexion movements [9]. Additionally, occipital condyle fusion may result in dyspnea and/or dysphagia postoperatively [10].

In this case report, we presented a polytrauma patient with avulsion OCF, who was treated conservatively. The patient was in a minimally conscious state on the 1st week of admission, making it difficult to examine the cranial nerves that are functionally important—dysphagia, dyspnea, and vocal phonation. Immediate polytrauma CT scan showed misalignment of craniocervical junction but no impingement on medulla oblongata or high cervical spinal cord. CT angiography showed obstruction of left-sided transverse-sigmoid sinus due to displacement of left occipital condyle. This situation sets the clinicians in dilemma of making surgical decisions, as injury to this venous sinus may result in unexpected fatal outcome. In this case, we decided to observe the patient by externally fixating the craniocervical junction with Miami brace. The decision was made due to uncertain consciousness and other managements in priority, such as CSF leak and intracranial pressure monitoring. During the admission she slowly gained consciousness and orientations and after the discharge, during the follow-up, the displaced occipital condyle fused in place without further dislocation. The patient also gradually improved in terms of dysphagia and hoarseness. Functional recoveries of unilateral Collet-Sicard syndrome had also been reported with the conservative management by Cirak et al. [11].

Another issue that should be discussed from this case is the obstruction of transverse-sigmoid sinus due to the displaced occipital condyle. Sigmoid sinus drains into internal jugular vein that leaves the cranial vault through jugular foramen, which is located immediately lateral to occipital condyle. Any displacement of occipital condyle may cause obstruction of internal jugular vein or sigmoid sinus. Yet, current reports on avulsion OCFs rarely describe the neurovascular integrity. However, this is an important issue because depending on anatomic variations of torcular Herophili, the consequence can be fatal. Furthermore, the clinical manifestation of obstructed venous drainage is often delayed. Early discharge in patients that are seemingly symptomless may face an irreversible devastating outcome [12]. CT angiography is a convenient image work-up to detect such a lesion. Fortunately, the patient tolerated the acute obstruction of unilateral transverse-sigmoid sinus without developing any sequelae. Nevertheless, we have closely observed her for delayed onset of possible venous infarction of the brain with serial brain CT scans. Currently, the Anderson-Montesano and the Tuli classifications are commonly used mainly to assess the stability of the OCFs [13], but the integrity of the vasculature is incorporated into the classification. For the surgical decision making it is also important to consider vascular work-up in addition to the usual work-up to assess stability, alignment, and neurologic deficit.

To conclude, this case demonstrates a patient with an unstable OCF with neurologic deficit who is conservatively treated due to high risk of vascular damage with obstructed sigmoid sinus. Eventually, the patient practically recovered from Collet-Sicard syndrome, and the occipital condyle fused without further displacement. Therefore, conservative treatment can be a treatment option even in case of unstable and maligned OCF, if high risk of vascular damage is suspected.

NOTES

Conflicts of interest

The authors have no conflicts of interest to declare.

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Case Report

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Delayed open abdomen closure using a combination of acellular dermal matrix and skin graft in Korea: a case report

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Delayed closure of an open abdomen (OA) is a clinically challenging task despite its various modalities. It is substantially more difficult when the duration of OA treatment is prolonged due to a patient's condition. We introduced the management of a patient who had a delayed OA treatment spanning approximately 3 months due to severe abdominal contamination. The 64-year-old male patient had an injured pelvis pressed by a road roller. After visiting a trauma center, the patient initially underwent damage control surgery and OA management; however, early primary abdominal closure failed due to severe peritonitis. After negative pressure wound therapy for several months, an acellular dermal matrix graft followed by a skin graft were successfully used as treatments. A combination of acellular dermal matrix graft, negative pressure wound therapy, and skin graft techniques is a considerable management sequence for patients subjected to delayed OA treatment.

Keywords: Wounds and injuries; Open abdomen techniques; Acellular dermis; Skin transplantation; Case reports

INTRODUCTION

Open abdomen (OA) management is a life-saving strategy for patients with trauma who requires damage control surgery for a severe abdomen injury, such as compartment syndrome, uncontrolled abdominal contamination, and abdominal wall tissue loss [1]. Although OA is a helpful method in the early stages of treatment for patients with trauma, it may result in delayed morbidity from conditions such as incisional hernia, abdominal abscess, and enteroatmospheric fistula (EAF). Therefore, after the initial resuscitation stage, the abdominal wall should be closed at an early stage. The closure rates of OA are archived during the first 7 to 10 days of treatment; however, afterward, the timing of abdominal closure tends to extend to 20–40 days and make poor outcome [2,3].

Primary fascia closure is the best method of OA closure; however, it cannot be performed under many conditions. If it cannot be performed at an early stage, then it is unlikely to be performed at a late stage. As alternatives, various definitive closure methods for a difficult abdomen include bilateral anterior rectus sheath flap, component separation method, abdominal closure method using a mesh, planned ventral hernia, thigh musculocutaneous flap, early planned ventral hernia, and posterior component separation method [4]; however, no conclusion has been reached regarding the most suitable method.

In this case, we performed abdominal wall restoration using an

acellular dermal matrix (ADM) and skin grafts in a patient under long-term OA treatment due to intestinal perforation accompanied by open pelvic fractures and wound infection.

CASE REPORT

A 64-year-old male patient, who had an injured pelvis that was pressed by a small road roller, visited a trauma center. The patient had a blood pressure of 64/32 mmHg, a heart rate of 63 beats/min, and was stupor with a Glasgow Coma Score of 13 (eye, 2; verbal, 5; motor, 6). On physical examination, active bleeding was observed in an open pelvic fracture from the left inguinal to the scrotal area. Massive transfusion, resuscitative endovascular balloon occlusion of the aorta, and pre-peritoneal pelvic packing were performed simultaneously. A radiograph taken at the trauma bay showed a severe pelvic bone fracture (Fig. 1A). The patient was immediately moved to the operating room for emergency surgery.

The surgical findings showed ruptured pelvic floor muscles and a perforated rectum with multiple pelvic arterial injuries. Sigmoid colon hematoma was also identified. Hemostasis was attempted through ligation of bleeding vessels and perforated rectum was closed primarily. Following this, gauze packing was performed for the diffuse oozing. After wound irrigation with warm saline, the operation ended with an OA. Pelvic external fixation was performed by an orthopedic surgery team, followed by a damage control surgery.

A day after the damage control surgery, the patient's vital signs stabilized. Computed tomography scans were performed (Fig. 1B), followed by a second-look operation via a long midline abdominal incision; sigmoid colon segmental resection was performed due to sigmoid colon perforation with multiple mesenteric injuries. Sigmoid colon stump was made without anastomosis due to a severely contaminated abdomen and a high chance of leakage. Colon anastomosis or end colostomy was planned in the third operation, depending on the patient's status. Likewise, the operation ended with an OA because of oozing from the abdominal cavity and severe intestinal swelling.

The third operation was performed on the 3rd day of hospitalization; the OA was closed after the hemostasis of soft tissue bleeding in the pelvis and end-colostomy maturation in the left lower abdomen (Fig. 2A). However, on the 18th day of hospitalization, intestinal necrosis was observed on the colostomy site. The patient went into shock, and emergency surgery was performed. During the surgery, the EAF of the transverse colon and intestinal necrosis of the terminal ileum and cecum were observed, and a total colectomy was performed. Subsequently, an end ileostomy was formed in the right lower abdomen, and the surgery was terminated with an OA because of intraabdominal swelling (Fig. 2B). Abdominal closure was delayed for several weeks due to soft tissue necrosis, coagulopathy, and continued intraabdominal sepsis.

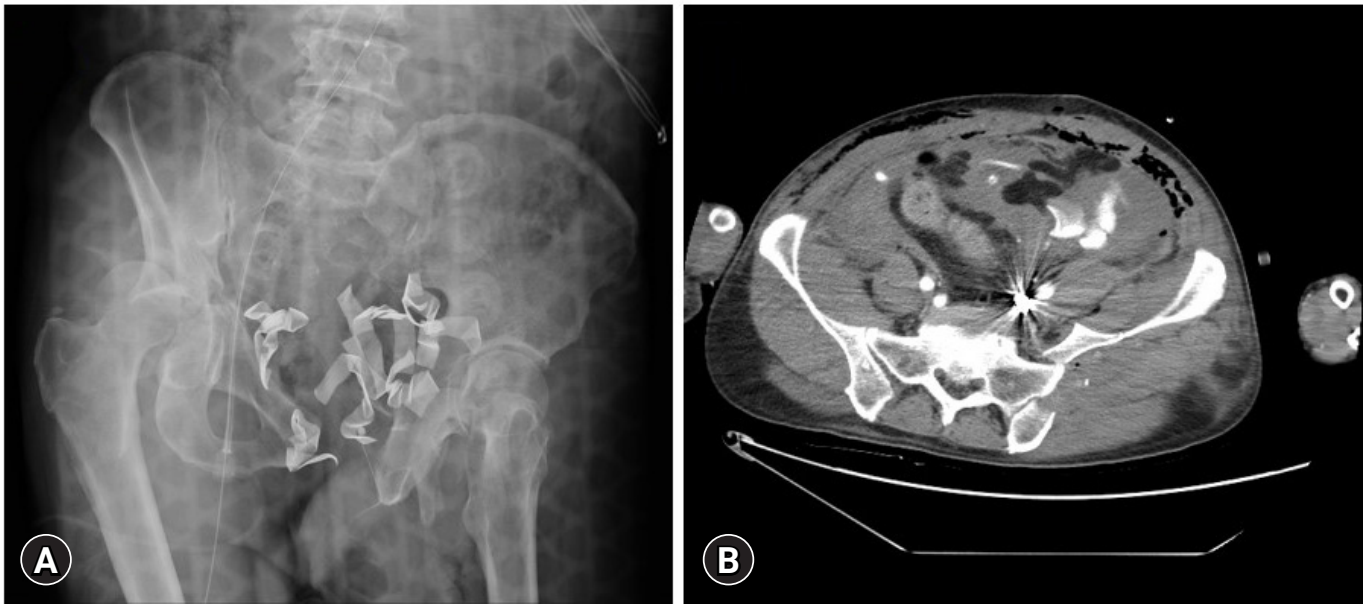

Fig. 1. Radiologic findings. (A) Initial radiographic finding at the trauma bay. (B) Results of the computed tomography scan performed 1 day after admission. Intraabdominal extravasation was observed.

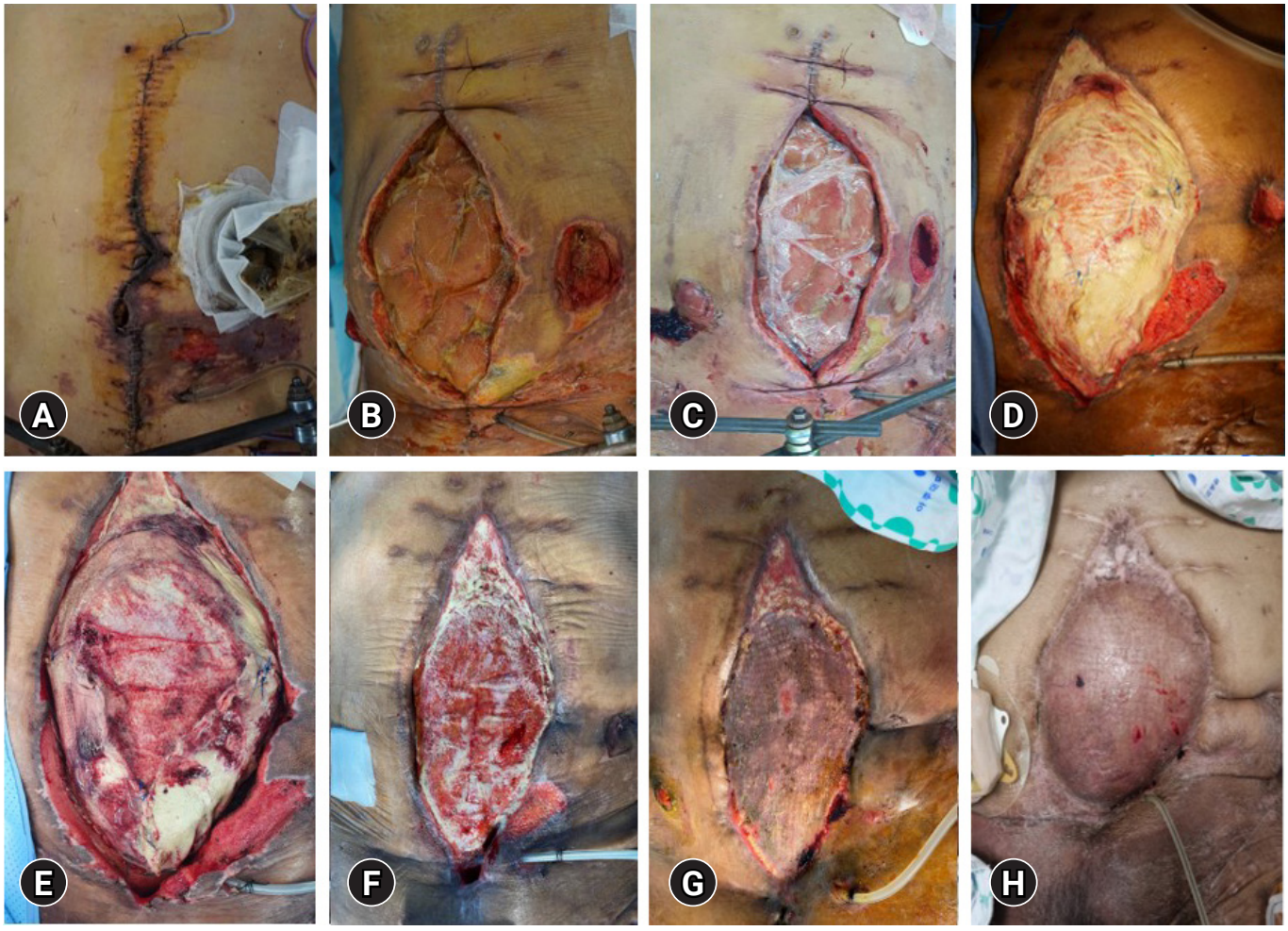

Fig. 2. Abdominal wound findings. (A) Colostomy was performed at the third-look operation. (B) End ileostomy with an open abdomen was performed. (C) Intraabdominal inflammation and intestinal swelling improved. (D) Open abdomen was covered by an acellular dermal matrix (ADM) graft. (E) Partial loss of the ADM graft. (F) Granulation tissue formed at the surface of the ADM graft. (G) Wound healed after the placement of a split-thickness skin graft. (H) Wound at the last follow-up (13 months after the injury).

The OA was managed through continuous negative pressure wound therapy (NPWT). To avoid direct pressure on the intestine, we used a sterile bag as the first layer of dressing directly in contact with the intestine and a soft silicon dressing (Mepitel, Mölnycke Health Care) as the second layer of dressing (Fig. 2C). The pressure of the dressing was usually maintained at 120 mmHg (Fig. 3). Wound debridement and irrigation were repeated every 2 to 3 days in the operating room. Coagulation and abdominal inflammation considerably improved; however, primary fascia closure was not feasible due to massive and destructive tissue loss.

After consulting with a plastic surgeon, we applied an ADM graft and planned a skin graft. As an intermediate step, wound covering with an ADM graft was attempted on the 48th day of hospitalization (Fig. 2D). Afterward, the ADM graft was partially lost; however, granulation tissue formation resulted in a membrane covering most of the surgical area (Fig. 2E, F). A split-thickness skin graft was used by the plastic surgery team 100 days after the second OA was created. The skin graft was well stabilized; it healed without an EAF or ulcer (Fig. 2G). Abdominal wall defects were not observed until the last follow-up (Fig. 2H) and patients were transferred to local hospital.

Ethics statements

Informed consent was obtained from the patient.

DISCUSSION

In this case, we demonstrated that a chronically inflamed OA could be repaired through constant wound management. The

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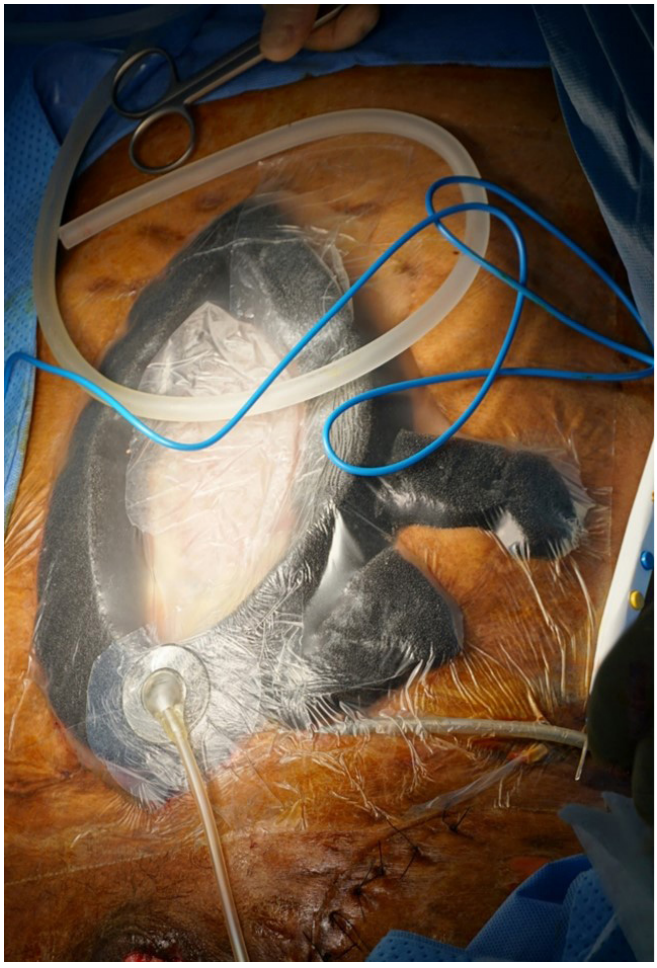

Fig. 3. Negative pressure wound therapy.

management of patients with OA requires three fundamental steps: (1) hemodynamic resuscitation, (2) source control of abdominal infection, and (3) delayed abdominal closure [3]. Thus, a severe abdominal infection may extend the period of the second step, resulting in delayed abdominal closure. In this case, abdominal contamination had seriously progressed due to multiple necrosis of the small and large intestines and the occurrence of an EAF following rectal and colon damage.

An OA can be definitively closed in various ways. According to a recent guideline, these are principally divided into nonmesh-mediated and mesh-mediated techniques. Nonmesh-mediated techniques include primary fascia closure, component separation method, and planned ventral hernia. Primary fascia closure is an ideal solution to restore abdominal closure; however, it is difficult to perform in an OA with fascial retraction [5]. The component separation method may be useful in managing an abdominal wound with fascial retraction; however, it should only be considered as a definitive closure technique; it destabilizes the outer layer of the abdominal wall, allowing the skin to shift in relation to the underlying myoaponeurotic tissue, making its application difficult in patients with enterostomies [6]. A planned ventral hernia is another treatment option to cover the abdominal viscera. It can be considered in cases of persistent contamination, several comorbidities, or severely ill patients [1]. Various skin coverage techniques that involve using skin grafts, or vascularized, pedicled, or free flaps, can be performed by comprehensively considering the condition of the wound, donor site, and patient [7]. In mesh-mediated techniques, a nonabsorbable synthetic mesh (i.e., polypropylene mesh) or biological prostheses can be used as wound closing materials. Synthetic meshes in contaminated fields are not recommended by the guidelines for emergency abdominal wall reconstruction [1,8].

Despite several treatment strategies for OA treatment, using a synthetic mesh was contraindicated in our patient due to prolonged intraabdominal infection. Likewise, the component separation method could not be performed because the abdominal soft tissues, including the skin, subcutaneous fat, and fascia, became fibrotic tissue.

Since its introduction in the mid-1990s, NPWT has continuously developed and become a popular treatment modality for managing acute and chronic wounds [2,9]. As a treatment modality, it provides the following clinical benefits: control of drainage of fluids, reduction of local edema, reduction of bacterial load, and early development of granulation tissue by angiogenic stimulation [10]. Therefore, we used NPWT as a wound management method for the reduction of tissue edema and stimulation of granulation tissue development.

NPWT is an effective technique to reconstruct the abdominal wall; however, it poses a risk of developing complications, such as a fistula. In a systematic review, Boele et al. [11] reported primary fascia closure rates ranging from 35% to 92% and fistula rates ranging from 0% to 15%]. To avoid this complication, we used a sterile bowel bag as an impermeable barrier to protect and avoid direct pressure on the intestine; the sponge was in contact with the wound margin. Fascia retraction and intraabdominal adhesions may occur in a prolonged OA. If the fascia cannot be closed primarily, the defect may bridge with the ADM. At this time, NPWT can be instituted to help reduce edema, control wound exudates, and maintain the abdominal domain while encouraging abdominal fascial closure. It can be used in combination with a biological mesh to facilitate granulation and skin closure [12,13]. The skin graft can be used after the granulation tissue has grown on the ADM.

There were three reasons for selecting ADM grafts. First, we

intended to prevent the loss of additional nutrients and moisture by using it as a temporary coverage. ADM acts like a barrier because it has a dermis structure like that of human skin. Also, ADM with skin graft is expected to be better for hernia prevention than skin graft alone. Second, ADM promotes the wound healing process. Third, ADM could prevent adhesion by direct contact with internal organs, thereby lowering the chance of intestinal obstruction. However, ADM is quite expensive because it is not covered by the National Medical Insurance of Korea (it costs approximately 20,000 KRW/cm^2).

In conclusion, definitive abdominal closure can be performed through stepwise management. The combination of ADM and skin graft may be considered a reasonable treatment option, especially in patients with a prolonged OA.

NOTES

Conflicts of interest
The authors have no conflicts of interest to declare.

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Case Report

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Endovascular treatment of traumatic iliac venous injury combined with phlegmasia cerulea dolens in Korea: a case report

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Traumatic iliac venous injury is rare but can be fatal. Although surgical management is considered a primary treatment method, urgent treatment is required when deep venous thrombosis and subsequent phlegmasia cerulea dolens is combined. It is difficult to treat by surgical management, and pharmaceutic thrombolysis cannot be applied due to the trauma history. Here, we describe a case of unilateral traumatic iliac venous injury and subsequent diffuse venous thrombosis in the affected iliofemoral and infrapopliteal veins, combined with phlegmasia cerulea dolens, treated with endovascular management, including bare metal stent insertion and aspiration thrombectomy.

Keywords: Wounds and injuries; Venous thrombosis; Iliac vein; Endovascular procedures; Case reports

INTRODUCTION

Traumatic iliac venous injury (TIVI) is rare and often underestimated but can be fatal [1]. TIVI without pelvic bone fracture is reported to be even more rare [2,3]. Surgical repair or ligation is considered a first-line treatment modality [4]; however, it has not yet been established and remains controversial. In particular, urgent treatment is required when deep venous thrombosis (DVT) and subsequent phlegmasia cerulea dolens (PCD) are complicated by TIVI. It is difficult to treat those patients with surgery alone, and pharmaceutic thrombolysis cannot be applied due to trauma history. There is no consensus on a treatment strategy for TIVI combined with DVT and PCD.

We describe a case with unilateral TIVI and subsequent diffuse DVT in the affected lower limb, combined with PCD, treated by endovascular management.

CASE REPORT

A 46-year-old male patient who had a pedestrian traffic accident was admitted to a regional trauma center. The patient was in a semicomatose state with unstable initial vital signs (blood pressure, 63/32 mmHg; heart rate, 110 beats/min). Complete blood count (serum hemoglobin, 13.5 g/dL; hematocrit, 39.6%) and coagulation profile (platelet count, $276 \times 10^3/mm^3$; international normalized ratio, 1.1) was normal. Contrast-enhanced abdominopelvic computed tomography (CT) showed a retroperitoneal hematoma, without evidence of pelvic bone fracture, and DVT in

the adjacent right common and external iliac veins. Iliac venous rupture and subsequent adjacent hematoma formation were suspected, but it was thought that active venous bleeding had stopped due to the formation of venous thrombus; therefore, conservative treatment with blood transfusion (4 units of packed red blood cells and 4 units of fresh frozen plasma) was initiated for the lesion. The patient's vital signs were stabilized. However, PCD developed in the right lower extremity 1 day later. Follow-up lower extremity CT venography showed not only an increased volume of pelvic hematoma and diffuse DVT involving the right iliofemoral and right infrapopliteal veins (Fig. 1A) but also decreased enhancement of the muscles of the right deep thigh and calf (Fig. 1B, C).

Urgent fasciotomy was performed at the bedside, and subsequent endovascular treatment for DVT and TIVI was requested. A retrievable filter (Denali, Bard Peripheral Vascular Inc) was inserted into the infrarenal inferior vena cava via the right internal jugular vein to prevent pulmonary artery embolism that might occur during the procedure. The patient was placed in a prone position, and the right popliteal vein was punctured under ultrasonographic guidance. An 8F sheath (Glidesheath, Terumo Interventional Systems) was inserted. Venography showed diffuse DVT involving the right iliofemoral vein and extravasation of contrast media from the right external iliac vein (Fig. 2A). One 14×100-mm self-expandable bare metal stent (E-luminexx, Bard Peripheral Vascular Inc) was inserted across the rupture site, and poststent balloon dilation was performed inside the stent using a 12×100-mm balloon catheter (Mustang, Boston Scientific Corp). Aspiration thrombectomy was performed in the right iliofemoral vein using an 8F guiding catheter (Mach 1, Boston Scientific Corp). A large amount of the red thrombus was aspirated, but small DVT was still remaining in the external iliac vein and venous flow was not improved. Additional stent insertion was performed using a stent of the same size overlapping the existing stent, and additional poststent balloon dilation was performed using the same balloon catheter. Completion venography showed improved venous drainage and the absence of contrast media extravasation (Fig. 2B). The access sheath was removed, and access site hemostasis was achieved by manual compression. A 6-week fol-

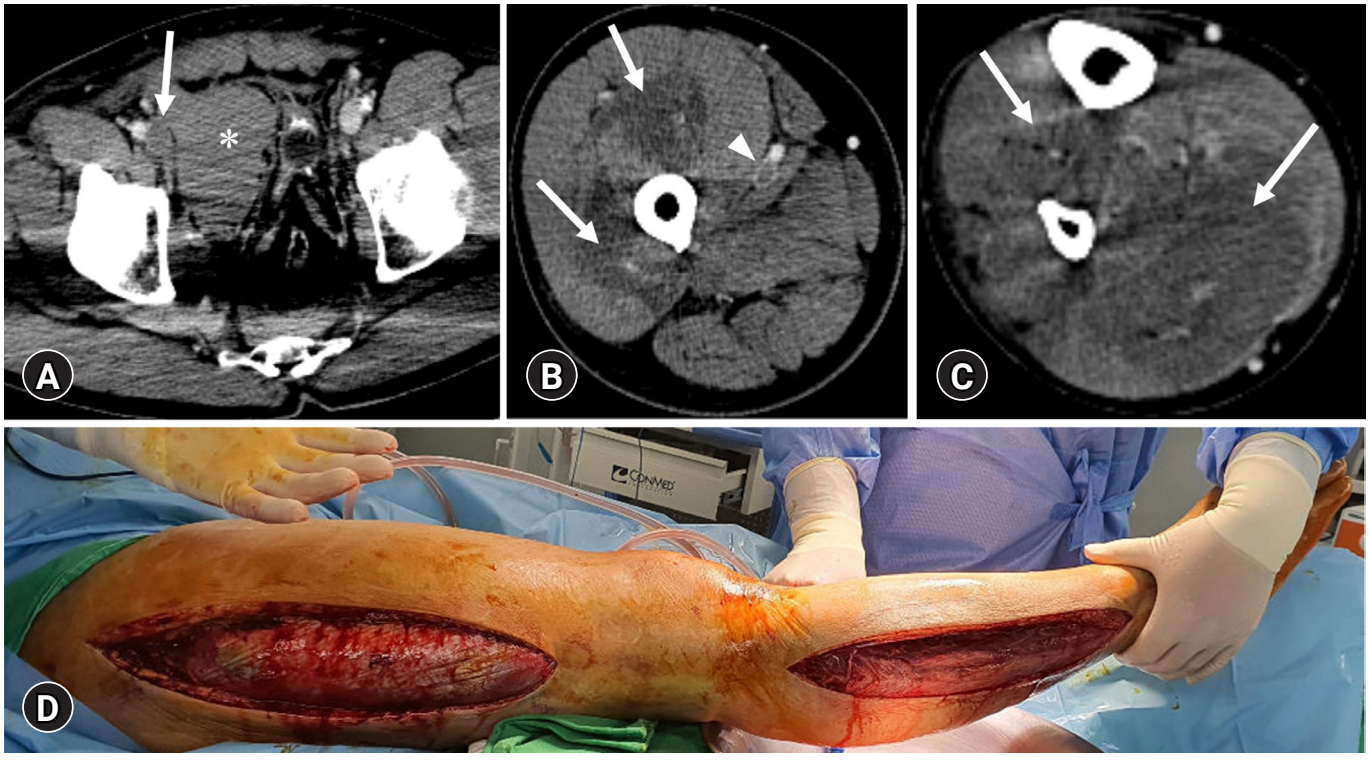

Fig. 1. Computed tomography before the surgical and interventional procedures and a photo taken during fasciotomy. (A-C) Contrast-enhanced computed tomography taken 1 day after the onset of trauma. (A) Hyperdense fluid collection in the pelvic cavity (asterisk), suggestive of hematoma, contrast filling defect in a right iliac vein (arrow), and (B, C) right femoral vein (arrowhead), suggestive of thrombosis, and decreased enhancement of right deep thigh and calf muscles (arrows), suspicious of ischemic changes. (D) The photo of right lower extremity taken during fasciotomy before the endovascular procedure shows the color change with edematous muscles.

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low-up CT venography showed a patent stent, a significantly decreased volume of the right pelvic hematoma without evidence of hemorrhage (Fig. 3A), and improved perfusion of the thigh muscles (Fig. 3B), although that of calf muscles were not (Fig. 3C).

Ethics statements

Informed consent for publication of the research details and clinical images was obtained from the patient.

DISCUSSION

TIVI may be fatal, with a mortality of 50% to 70%, if left untreated [1,5]. Surgical treatments, including packing, surgical repair, or ligation, are considered the treatment of choice if conservative treatment fails [4,6]; however, surgery is challenging because the overlying hematoma interferes with the surgical field and the tamponade effect decreases during surgery [7]. Therefore, endovascular management has been reported as an alternative treatment modality, most of which involves covered stent insertion [6,8–10], and there are a few case reports of bare metal stent insertion [1,5,7].

Massive exposure to thrombogenic agents in the bloodstream due to traumatic vascular shearing injury can cause thrombosis [11]. In particular, massive amounts of iliofemoral and infrapopliteal DVT can occur in a short period of time due to acute blockage of the draining iliac vein, which can lead to complications such as PCD and phlegmasia alba dolens. Surgical or interventional procedures in most of the previously reported TIVI cases have been performed to treat hemorrhage due to iliac venous rupture rather than DVT and subsequent PCD. Hu et al. [12] reported a case in which PCD, which occurred after surgical ligation was performed for TIVI, was treated with surgical venous reconstruction.

In contrast, in our case, diffuse iliofemoral and infrapopliteal DVT and subsequent PCD were present and urgent intervention was requested. It is noteworthy that the contrast media leakage disappeared even though bare metal, not covered, stents were inserted. Stent placement likely pushed the remaining thrombus towards the injured venous wall, and hemostasis was achieved by covering the ruptured site.

Compared to covered stents, bare metal stents are suitable for emergency use because they usually have higher availability in hospitals and have lower migration risk, even with stents with relatively smaller diameters [5]. And it is also a method worth considering because venous pressure is much lower than arterial

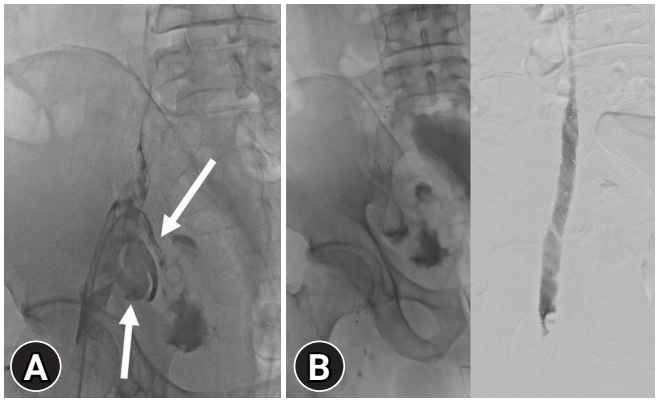

Fig. 2. Images taken during the interventional procedure. (A) Venography during procedure shows contrast media extravasation from the right external iliac vein (arrows). Bare metal stent insertion, balloon tamponade, and aspiration thrombectomy were performed. (B) Completion of venography shows improvement of venous drainage and absence of contrast media leakage. The native image is marked on the left to determine the location.

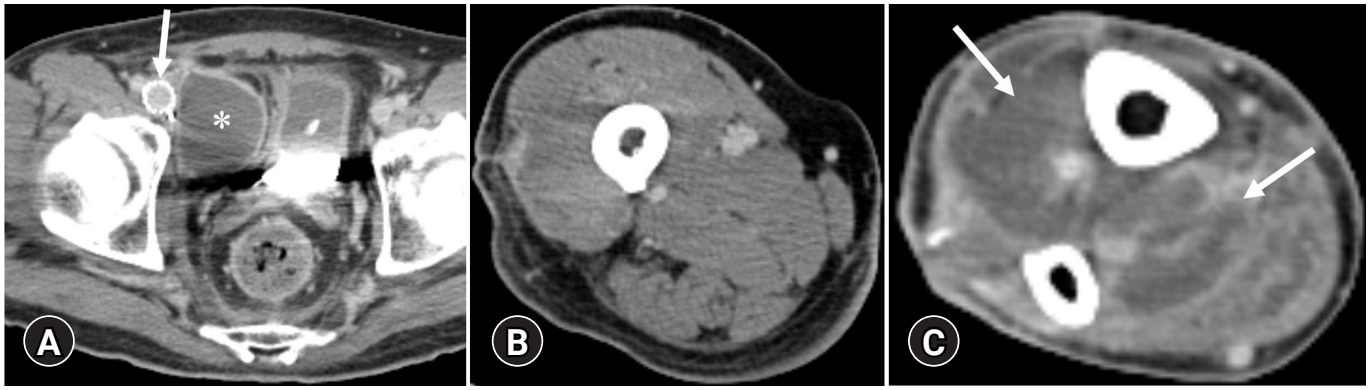

Fig. 3. Follow-up contrast-enhanced computed tomography. (A) Patent stent (arrow) is shown with decreased volume of right pelvic hematoma with chronic changes (asterisk). (B) Perfusion of the thigh muscles are improved, (C) but that of calf muscles are not (arrows).

pressure. For this reason, the use of bare metal stents as treatment for venous injury is increasing [13]. Although not indicated in our case, prolonged balloon tamponade or additional coil embolization might be considered if bleeding is not resolved with bare metal stent insertion [14,15].

In conclusion, we successfully treated a patient with PCD complicated by TIVI-related DVT using aspiration thrombectomy, bare metal stent insertion and subsequent balloon tamponade.

NOTES

Conflicts of interest

Jayun Cho serves on the Editorial Board of *Journal of Trauma and Injury*, but was not involved in the peer reviewer selection, evaluation, or decision process of this article. The authors have no other conflicts of interest to declare.

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Case Report

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Spontaneous recanalization of complete urethral injury treated by suprapubic cystostomy alone after severe pelvic bone fracture in a young male patient in Korea: a case report

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Injury to the genitourinary tract is rare, with an incidence of less than 1%. Younger men (mean age, approximately 30 years) are predominantly affected. We introduce an unusual case of a 25-year-old male patient with complete urethral injury combined with a severe open pelvic bone fracture. During the emergency surgery, the primary realignment of the posterior urethra could not be performed due to a large defect. With suprapubic cystostomy alone, follow-up voiding cystourethrography showed spontaneous recanalization of the transected urethra after four months. Suprapubic cystostomy is an efficient treatment option when primary realignment is not possible.

Keywords: Urethra; Pelvic bones; Wounds and injuries; Cystostomy; Case reports

INTRODUCTION

Urethral injury is a consequence of major blunt trauma to the pelvis, with a reported incidence ranging from 1.6% to 25.0% [1,2]. Men are predominantly affected by injury due to a long urethra and attachment to the pubis. These injuries can be catastrophic and incapacitating, causing urethral strictures, erectile dysfunction, and urinary incontinence.

The male urethra can be classified into anterior (bulbous and pendulous) and posterior (prostatic and membranous) parts. Posterior urethral disruption injuries can occur due to severe pelvic blunt injuries, especially avulsion of the puboprostatic ligament and lengthening of the membranous urethra. The treatment of posterior urethral injury involves primary realignment (PR) with a urethral catheter or suprapubic cystostomy (SPC) with delayed repair [3]. A recent systematic review reported that PR appears superior in terms of stricture formation, but there is still debate regarding the proper management of posterior urethral disruption.

In this case report, we review an unusual experience of spontaneous recanalization of complete posterior urethral disruption combined with an open pelvic bone fracture in a young male patient who underwent SPC alone.

CASE REPORT

A 26-year-old male patient was a pedestrian struck by a forklift caught between a car and a wall. The patient was initially transported to a local emergency department, where he was diagnosed with an open pelvic bone fracture and a right distal femur fracture (Fig. 1). Active contrast leakage was not shown on abdomen and pelvis computed tomography scan. A Foley catheter was inserted constrainedly, and 50 mL of fresh blood was drained. Owing to a lack of capacity and unstable systolic blood pressure (< 60 mmHg), we decided to transfer the patient to the Armed Forces Trauma Center (Seongnam, Korea). Vital signs on arrival were stable (blood pressure, 123/77 mmHg; pulse rate, 109 beats/min; respiratory rate, 16 breaths/min) and extended focused assessment with sonography for trauma (eFAST) was negative. Therefore, we decided to perform emergency surgery for pelvic exploration and external fixation.

The trauma surgery team surveyed the pelvic cavity during the initial emergency surgery, but no active venous or arterial bleeding was observed. Orthopedic surgeons performed external pelvic fixation and decided not to mount anterior plating on the symphysis pubis due to contaminated wounds and urologic interventions. Urologists had previously explored the bladder and urethra. The bladder was perforated, and the posterior urethra was completely disrupted. In addition, the initial Foley catheter was exposed outside the bladder. PR of the urethra was initially attempted using interlocking urethroplasty; however, this failed because the resected part of the urethra was too extended, and the view was not clear (Fig. 2). Therefore, emergency surgery was completed with external pelvic fixation, internal fixation of the right femur, bladder repair, and SPC. The urologists planned a delayed repair of the urethral injury for 12 weeks later.

On the 8th day of hospitalization, orthopedic surgeons added an anterior plate to the symphysis pubis. After 3 months, voiding cystourethrography, which was planned pre-urethroplasty, showed spontaneous recanalization of the ruptured posterior urethra (Fig. 3) with no intervention except for SPC. Uroflowmetry showed that Qmax was 18 mL/sec and voided volume was 298 mL. Hence, we changed the plan for urethroplasty to observation. The SPC catheter was removed, and the patient did not com-

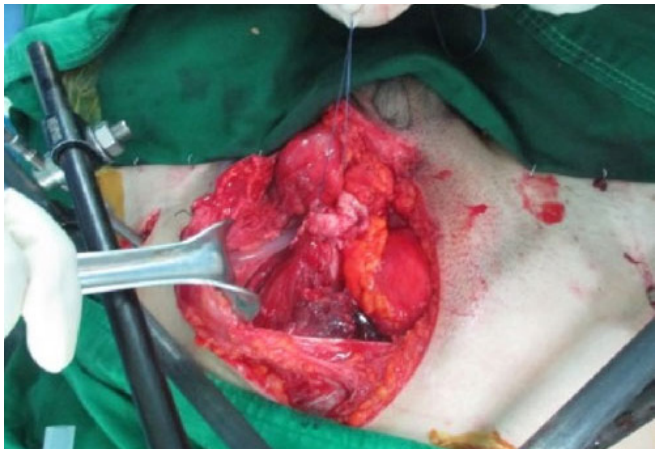

Fig. 2. Intraoperative finding showed that ruptured urethra could not be realigned via retrograde and antegrade Foley catheter insertion.

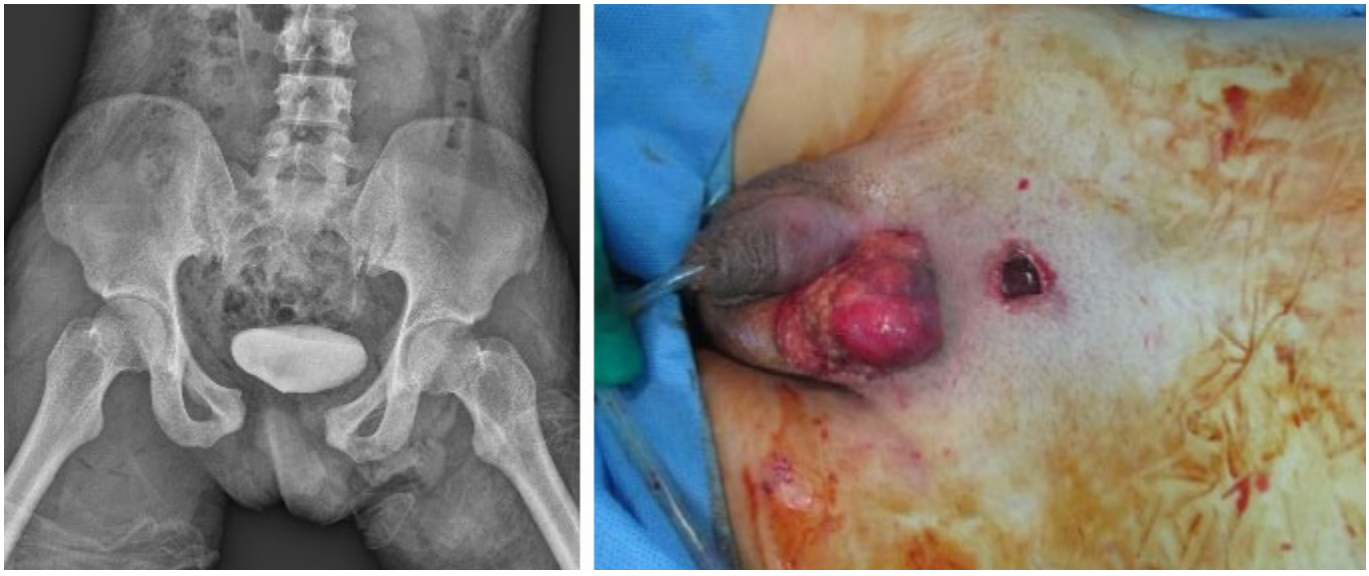

Fig. 1. Pictures of initial portable X-ray and wound showed the anterior posterior compression type III open pelvic bone fracture.

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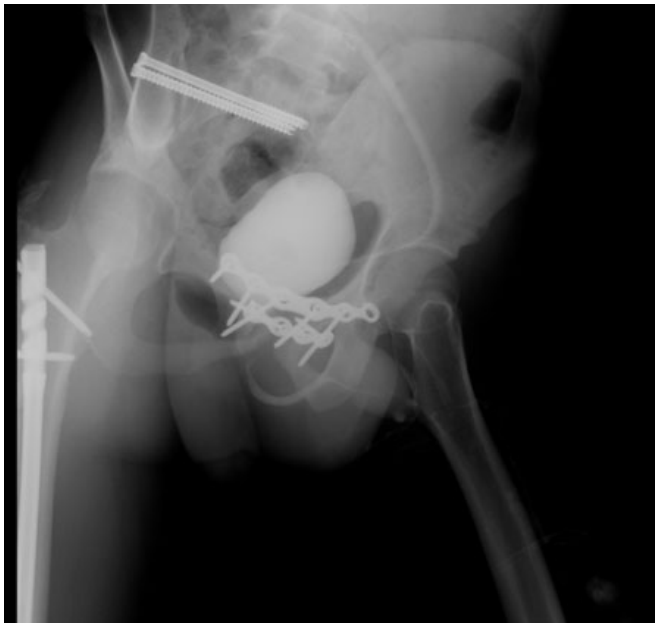

Fig. 3. After 3 months of suprapubic cystostomy alone, the patient showed complete healing of posterior urethral disruption. There was no evidence of urinary leakage or urethral stricture.

plain of any signs of urinary leakage or urethral stricture. In addition, he reported no erectile dysfunction or urinary incontinence.

Ten months after the initial injury, the patient reported mild residual urination. Follow-up uroflowmetry and residual urine test revealed no specific findings (Qmax, 19.9 mL/sec; voided volume, 473 mL; resiual urine, 7 mL). Any medications which might improve urinary symptoms was not administered to the patient during the whole treatment period.

Ethics statements

The case report was approved by the Institutional Review Board of the Armed Forces Capital Hospital (No. AFCH 2022-09-002-001). Data were collected and analyzed in an ethical manner while protecting the patient's right to privacy. The requirement for informed consent was waived because this was a retrospective study conducted using medical records.

DISCUSSION

Both anterior and posterior urethral injuries are commonly caused by blunt trauma to the pelvis. However, the posterior urethra is more easily affected by serious pelvic bone fractures, given its deeper location. The key vector for posterior urethral disruption is the upward displacement of the bladder and prostate. An estimated 10% of pelvic fractures are combined with posterior urethral injuries [4].

The risk of urethral injury is likely correlated with the type of pelvic fracture. Isolated acetabulum, ilium, and sacrum fractures are unlikely to damage the urethra (close to zero) [4]. However, diastasis of the symphysis pubis or inferomedial pubic bone fracture displacement was associated with an approximately 10% increased risk of urethral injury in one study [2]. Other high-risk pelvic bone fracture types involve all four rami of the pubis or both ipsilateral rami combined with high-grade disruption through the sacrum, sacroiliac joint, or ilium.

The standard diagnostic tool for urethral injury is retrograde urethrography. Computed tomography cannot efficiently survey the urethra, especially without delayed-phase scans, which are not routinely performed in trauma settings. Careful insertion of a Foley catheter in a patient with a pelvic bone fracture is a widely known common practice; however, in this case, incorrect, forced placement of the Foley catheter demonstrated the lack of a trauma program in the local emergency department.

The preferred repair for posterior urethral injuries has changed since the 1950s. One of the earliest procedures, described by Badenoch [5], was a "pull-through" operation, a retrograde catheterization through the defect to the bladder, which let the injury heal by scarring. Emerging procedures using the abdominal approach have become mainstream treatments involving delayed repair techniques [6,7]. In 1985, Webster described a complete perineal and stepwise approach to urethral repair. This procedure provides a meaningful success rate of 97% in adults [8]. However, the 2016 male urethral stricture guideline from the American Urological Association (AUA) insisted that definitive urethral reconstruction for pelvic fracture urethral injury should be planned only after major injuries stabilize and patients can be safely positioned for urethroplasty [9]. Thus, there is a need to perform immediate "bridging" treatment.

Despite advances in urethroplasty, the best immediate management for posterior urethral injury in pelvic fractures remains unclear. Currently, two interventions are commonly accepted: PR and SPC. Realignment of the injured urethra using a Foley catheter, open cystostomy, and interlocking sounds have supplanted primary suturing, but this has been associated with an increasing rate of erectile dysfunction and incontinence. Suprapubic cystostomy followed by delayed urethroplasty has become the preferred first-step treatment. The development of flexible urethroscopy has recently attracted renewed interest as an immediate option for early PR [2,4,10–13]. Two recent systematic reviews addressing the priority between PR and SPC have revealed incompatible results. Barrett et al. [10] demonstrated a significantly

lower rate of stricture in PR versus SPC and no differences for other complications (erectile dysfunction and incontinence). Light et al. [14] compared PR versus SPC and early endoscopic realignment versus SPC; they showed no significant differences in stricture, erectile dysfunction, or incontinence across the groups. No randomized controlled trials directly compared the PR group with SPC, and both reviews had limitations in the evidence. Nevertheless, the 2020 Urotrauma Guideline published by the AUA [15] added a new recommendation that clinicians should perform percutaneous or open suprapubic tube placement as the preferred initial management for most pelvic fracture urethral injury cases.

In this case report, we describe a young male patient with complete posterior urethral disruption combined with severe pelvic bone fracture and treated with SPC alone. In the emergency setting, PR could not be performed due to the large defect and damage to the structure of the urethra. Therefore, a delayed urethroplasty was not performed. This is a rare case in which SPC alone was definitive management for a complete posterior urethral injury pelvic bone fracture.

NOTES

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The authors have no conflicts of interest to declare.

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Author contributions
Conceptualization: all authors; Data curation: all authors; Formal analysis: all authors; Methodology: all authors; Resources: all authors; Supervision: all authors; Validation: all authors; Visualization: all authors; Writing–original draft: HKS; Writing–review & editing: HJL. All authors read and approved the final manuscript.

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Instructions for Authors

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MANUSCRIPT PREPARATION

Manuscripts should be written in English. Medical terminology should conform to the most recent edition of Dorland's Illustrated Medical Dictionary.

General Principles

- Format of manuscript: Manuscripts should be submitted in the file format of Microsoft Word 2010 or higher. Manuscripts should be typed on an A4-sized document, be double-spaced, and use a font size of 10–12 point with margins of 2 cm on each side and 3 cm for the upper and lower ends. We recommend the use of the template provided at https://www.jtraumainj.org/authors/authors.php/ when formatting the manuscript.
- Abbreviation of terminology: Abbreviations should be avoided as much as possible. One word should not be ex-

pressed through an abbreviation, although two or more words may be expressed through an abbreviation. The full term for which the abbreviation stands should be used at its first occurrence in the text. Abbreviations should not be present in the title. Common abbreviations, such as DNA or COVID-19, however, may be used.

- Units: The use of International Standardized (SI) units (https://www.nist.gov/pml/owm/metric-si/si-units/) is encouraged.
- Machines and equipment: When the use of reagents or devices is reported in the text, the name of the manufacturer, city, state, and country should be indicated.
- Statistics: Statistical methods must be described and the program used for analysis and its source should be stated.
- Reporting guidelines for specific study designs: Research reports frequently omit important information. As such, reporting guidelines have been developed for a number of study designs that some journals may ask authors to follow. Authors are encouraged to also consult the reporting guidelines relevant to their specific research design. A good source for reporting guidelines is the EQUATOR Network (https://www.equator-network.org/) and the US National Institutes of Health/National Library of Medicine (http://www.nlm.nih.gov/services/research_report_guide.html).
- Cover letter: The cover letter should inform the Editor that neither the submitted material nor portions thereof have been published previously or are under consideration for publication elsewhere. It should state any potential conflict of interest that could influence the authors' interpretation of the data, such as financial support from or connections to pharmaceutical companies, political pressure from interest groups, or academically related issues.

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1. Arrangement of the manuscript: Original articles should be organized in the order of Title page, Abstract & Keywords, Main text (Introduction, Methods, Results, Discussion), References, Tables, Figures, and Figure Legends. The title of each new section should begin on a new page. Number pages consecutively, beginning with the abstract page. Page numbers should be placed at the middle of the bottom of each page.

2. Title page

- The title page must include the article title, the authors' names (including ORCID), affiliations, corresponding authors' names and contact information, running title, and declarations.
- Title: The title should be concise and precise. The title should be written in sentence case, meaning the first letter of the first word and any proper nouns are capitalized, as in a typical sentence. Generic drug names should be used in the title, not brand names. The title should also indicate the study design. If the study involved human participants, the country where the study was conducted should be included.
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3. Abstract & Keywords

- All manuscripts should contain a structured abstract. Abstracts should be no more than 300 words in length and must have the following headings: Purpose, Methods, Results, and Conclusions. The quotation of references must not be included in the abstract.
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- References should be obviously related to the document. In the text, references should be cited with Arabic numerals in brackets, numbered in the order cited. In the references section, the references should be numbered and listed in order of appearance in the text.
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- The description of the References section is provided below. The References follow the NLM Style Guide for Authors, Editors, and Publishers (https://www.ncbi.nlm.nih.gov/books/NBK7256/) if not specified below.

• Sample

1. Yeo KH, Park CY, Kim HH. Abdomino-perineal organ injuries caused by cultivators. J Trauma Inj 2015;28:60–6.
2. Mattox KL, Moore EE, Feliciano DV. Trauma. 7th ed. McGraw Hill; 2013.
3. Burlew CC, Moore EE. Emergency department thoracotomy. In: Mattox KL, Moore EE, Feliciano DV, editors. Trauma. 7th ed. McGraw Hill; 2013. p. 236–50.
4. World Health Organization (WHO). World health statistics 2021: a visual summary [Internet]. WHO; 2021 [cited 2021 Feb 1]. Available from: https://www.who.int/data/stories/world-health-statistics-2021-a-visual-summary
5. Sharma N, Sharma P, Basu S, et al. The seroprevalence and trends of SARS-CoV-2 in Delhi, India: a repeated population-based seroepidemiological study [Preprint]. Posted 2020 Dec 14. medRxiv 2020.12.13.20248123. https://doi.org/10.1101/2020.12.13.20248123

6. Tables

Tables must be numbered in the order in which they are cited in the text. Each table must be simple and typed on a separate page. Supply a brief title at the top of the table. The titles of tables start with "Table 1." Footnotes should be provided consecutively in order of the information, statistics, and abbreviations. Footnoted information should be referenced using superscript lowercase letters (e.g., a, b) in alphabetical order.

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Authors must submit figures and illustrations as electronic files. Images must be provided as TIFF files. JPEG is also acceptable when it is the original format. Each figure must be of good quality, higher than 300 dpi resolution with good contrast and sharpness. Figures must be sized to 4 inches. If possible, submit the original file without any modifications.

Submit files of figures and photographs separately from the text of the paper. Number figures as "Figure Arabic numeral" (e.g., Fig. 1) in the order of their citation. If a figure is divided into more than two images, mark each figure with Arabic numerals and a capital letter (e.g., Fig. 1A, B). Authors should submit line drawings in black and white. Figures should be explained briefly in the titles. An individual should not be recognizable in photographs or X-ray films provided at the time of submission. Radiographic prints must have arrows for clarity if applicable. Pathological samples should be pictured with a measuring stick.

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