Aims and Scope

The Journal of Trauma and Injury (J Trauma Inj, JTI) is an official publication of the Korean Society of Traumatology and an international, peer-reviewed open access journal.

This journal aims to contribute to saving lives of patients who underwent traumatic events through active communication and exchange of study information on trauma and provision of education and training on trauma. Thus, the journal publishes original basic and clinical research on trauma-associated medical fields, such as surgeries (which include general surgery, chest surgery, orthopedic surgery, neurosurgery, plastic surgery, and head and neck surgery), gynecology and ophthalmology, emergency medicine, anesthesiaology, neuro-psychiatrics, rehabilitation medicine, and radiology (which include interventional radiology). Due to the special circumstances Korea is under with North Korea, JTI also publishes basic and clinical research on battlefield trauma unique in Korea and has established ties with the Armed Forces Medical Command and Armed Forces Capital Hospital. Furthermore, this journal includes all items closely associated with medicine, disaster and department of emergency, emergency medical technicians and nurses, social infrastructures and systems, and government policies and supports.

JTI was launched in June 1988 with publications in the Korean and English languages and was eventually converted to an English-only journal. The journal publishes original articles, case reports/case series, review articles, editorials, correspondence, and articles commissioned by the Editorial Board, related to basic or clinical research on trauma.

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Publisher
The Korean Society of Traumatology

Editor-in-Chief
Gil Jae Lee, MD, Gachon University, Incheon, Korea

Editorial Office
The Korean Society of Traumatology
2619 TwinCity-namseon, 366 Hangang-daero, Yongsan-gu, Seoul 04323, Korea
Tel: +82-10-4391-0788 E-mail: office@jtraumainj.org

Printing Office
M2PI
8th FL, DreamTower, 66 Seongsu-daero, Seongdong-gu, Seoul 04784, Korea
Tel: +82-2-6966-4930 Fax: +82-2-6966-4945 E-mail: support@m2-pi.com

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I enjoy action movies like the James Bond (007) series because many famous landmarks are filmed in them. The title of the 14th film in the 007 series was *A View to a Kill* (1985, starring Roger Moore). While watching this movie, I enjoyed the depiction of several places in France, especially the Château de Chantilly. This castle has a very beautiful garden and the Musée Condé.

Among the many collections of the museum, a drawing in a book intrigued me. A naked man is holding his neck with both hands. He seems to be suffering from asphyxia. A naked woman with an apple in her right hand is looking at him. Between the man and woman, a snake is slithering up a tree. The name of the book is *Abstract of the Bible, Revelation* (Chantilly, Condé Museum, 0028, printed in 1378) (Fig. 1).

This drawing was made very early, in 1378, well before the publication of Milton's *Paradise Lost* in 1667, which reads:

Of man's first disobedience, and the fruit  
Of that forbidden tree, whose mortal taste  
Brought death into the world, and all our woe,  
With loss of Eden, till one greater man  
Restore us, and regain the blissful seat, Sing Heav'nly Muse . . .

Among the many paintings of Adam and Eve, this one is unique because it expresses the suffering face of Adam as he experiences asphyxia caused by eating an apple. This leads to an intriguing question: why do people believe that the fruit was an apple and use the term “Adam’s apple” for the thyroid cartilage? In Genesis 3:5, Vulgate, Satan says, “You will be like God, knowing good and evil (Eritis sicut Deus, scientes bonum et malum).” The Latin word “malum” has several meanings: evil, disaster, and apple. It seems that in this context, “malum” was understood as an apple.

As trauma surgeons, we frequently encounter patients who suffer from airway obstructions, like Adam in the above-described picture, especially in cases of facial injuries. Airway obstruction due to a foreign body often can be easily treated; if the foreign body is removed, the patency of the airway can be restored. Airway obstruction caused by trauma, however, may lead to hypoxic brain damage. In acute upper airway obstruction, an evaluation should be conducted im-
mediately. The necessary airway equipment should be made available at the time of evaluation.

In trauma patients, since the tongue has fallen backwards towards the posterior pharynx and blocks the airway, we can lift the tongue and clear the airway by hyperextending the head and pulling up the chin. Additionally, gentle pressure behind the jaw lifts the mandible and maintains airway patency. If this maneuver cannot restore the airway, tracheostomy should be performed following the relevant guidelines, especially in children [1].

In trauma patients, airway management is challenging beyond the placement of an endotracheal tube, and the outcomes depend upon the provider’s ability to anticipate difficulty [2]. Among the types of facial trauma, panfacial fractures are caused by high-energy trauma and potentially result in upper airway obstruction, which needs a rapid diagnosis to save the patient’s life [3].

With appropriate training, percutaneous cricothyrotomy can be easily performed as part of prehospital care [4]. Recently, four cases of prehospital surgical airway cannulation on the battlefield demonstrated three successful uses of prehospital cricothyrotomy kits [5].

As known, in cricothyrotomy, a limited skin incision is made to the cricothyroid membrane between the thyroid and cricoid cartilages; in the midline just beneath the Adam’s apple. Thus, Adam—the founding father of humanity, as portrayed in the Bible—gave us a landmark to maintain the airway!

NOTES

Ethical statement
Not applicable.

Conflicts of interest
The author has no conflicts of interest to declare.

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REFERENCES

Characteristics of injuries associated with electric personal mobility devices: a nationwide cross-sectional study in South Korea

Maro Kim, MD, Dongbum Suh, MS, Jin Hee Lee, PhD, Hyuksool Kwon, MS, Yujin Choi, MS, Joo Jeong, MD, Sola Kim, PhD, Soyun Hwang, MS, Joong Wan Park, MS, You Hwan Jo, PhD

1Department of Emergency Medicine, Seoul National University Bundang Hospital, Seongnam, Korea
2Department of Emergency Medicine, Ajou University Hospital, Suwon, Korea
3Department of Emergency Medicine, Hallym University Dongtan Sacred Heart Hospital, Hwaseong, Korea
4Department of Emergency Medicine, Seoul National University Hospital, Seoul, Korea
5Department of Emergency Medicine, Seoul National University College of Medicine, Seoul, Korea

Purpose: The increasing use of electric personal mobility devices (ePMDs) has been accompanied by an increasing incidence of associated accidents. This study aimed to investigate the characteristics of ePMD-related injuries and their associated factors.

Methods: This cross-sectional study was conducted using data from the Emergency Department-based Injury In-depth Surveillance database from 2014 to 2018. All patients who were injured while operating an ePMD were eligible. The primary outcome was the rate of severe injury, defined as an excess mortality ratio-adjusted Injury Severity Score of ≥25. We calculated the adjusted odds ratios (AORs) of outcomes associated with ePMD-related injuries.

Results: Of 1,391,980 injured patients, 684 (0.05%) were eligible for inclusion in this study. Their median age was 28 years old, and most injuries were sustained by men (68.0%). The rate of ePMD-related injuries increased from 3.1 injuries per 100,000 population in 2014 to 100.3 per 100,000 population in 2018. A majority of the injuries occurred on the street (32.7%). The most commonly injured area was the head and face (49.6%), and the most common diagnosis was superficial injuries or contusions (32.9%). Being aged 55 years or older (AOR, 3.88; 95% confidence interval, 1.33–11.36) and operating an ePMD while intoxicated (AOR, 2.78; 95% confidence interval, 1.52–5.08) were associated with severe injuries.

Conclusions: The number of emergency room visits due to ePMD-related injuries is increasing. Old age and drunk driving are both associated with serious injuries. Active traffic enforcement and safety regulations regarding ePMDs should be implemented to prevent severe injuries caused by ePMD-related accidents.

Keywords: Injury Severity Score; Accidents; Traumatic brain injuries; Epidemiology; Wounds and injuries

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INTRODUCTION

Electric personal mobility devices (ePMDs) are electrically powered wheeled devices that provide personal transport. These devices provide simple, fast, and convenient transportation and are attracting considerable interest as a novel tool for short-haul transport and leisure activities [1].

The demand for ePMDs has increased rapidly in South Korea in recent years, and their increasing use has been accompanied by an increasing incidence of ePMD-related injuries [2-6]. However, the epidemiologic characteristics of ePMD-related injuries have only been studied in a few countries. In one study from Singapore, ePMD-related injuries were generally found not to be severe and were primarily external wounds and upper and lower limb injuries [7]. In a Swedish study, most of the reported ePMD-related injuries resulted from the driver hitting the ground due to device turnover [8]. Few studies on ePMD-related injuries have been conducted in South Korea, however.

Under South Korea’s Road Traffic Act, ePMDs are classified as “motorized bicycles”, and their operation is prohibited outside of roadways [9]. Furthermore, a driver’s license and helmet are required for their use. However, many ePMD owners operate them outside of roadways to avoid collisions with motor vehicles and rarely wear helmets during use [10,11]. These behaviors can lead to severe injuries. This study aimed to examine the characteristics of ePMD-related injuries and identify risk factors associated with severe ePMD-related injuries in South Korea.

METHODS

The present study protocol was reviewed and approved by the Institutional Review Board of the Seoul National University Bundang Hospital (No. X-1903-528-902).

Study design

This cross-sectional study was performed using data from the Emergency Department-based Injury In-depth Surveillance (EDIIS) database sponsored by the Korea Disease Control and Prevention Agency (KDCA). The EDIIS is a prospective nationwide injury database that stores data on patients with injuries who present to the emergency rooms (ERs) of specific representative medical institutions in Korea.

Data source

In total, 17 (in 2014), 20 (in 2015), and 23 (from 2016 to 2018) tertiary academic hospitals shared data on patients with injuries who presented to ERs using the EDIIS database. The EDIIS database includes demographic, injury prevention-related, and epidemiologic information as well as pre-hospital procedures, initial clinical findings from the ER visit, diagnoses (coded using the International Classification of Diseases, 10th Revision [ICD-10]), treatments, dispositions, and patient outcomes after admission. Individual incidents were described in written Korean. Primary information was obtained by physicians from each medical institution during clinical practice and by trained coordinators from the EDIIS project assigned to each hospital. The coordinators collected the data from a standardized registry. The data from each ER were registered on a web-based database hosted by the KDCA, and a quality improvement program was conducted regularly [12].

Selection of participants

Among all injuries reported in the EDIIS database between January 2014 and December 2018, only patients who were injured while operating an ePMD were included in this study. To identify ePMD-related injuries, we searched the database with ePMD-related keywords, including “electric scooter”, “e-scooter”, “electric kickboard”, “e-kickboard”, “hoverboard(s)”, “electric unicycle”, “e-unicycle”, “Segway”, “Lime scooter”, and “Ninebot”, and two researchers reviewed the incident descriptions. After reviewing each entry, data were excluded if 1) the injury was caused by an ePMD used as an aid for a disabled person, such as an electric wheelchair or mobility scooter, or 2) the accident was not related to the operation of the ePMD.

Variables and measurements

This study collected information for each injury on age, sex, injury date, device type, injury mechanism, injury location, the rider’s state of intoxication, helmet use, diagnosis (ICD-10 code), and disposition. Age was classified as 0 to 14, 15 to 24, 25 to 34, 35 to 44, 45 to 54, and 55 years or older, based on previous studies [13]. An “e-scooter” was defined as a device powered by an electric motor with wheels and handlebars that is designed to be stood upon by the operator. An “electric unicycle” and “hoverboard” were defined as narrow, horizontal boards with one or two wheels, respectively, that move when the rider leans forward. Mechanisms of injury were categorized as falloff, collision with a motor vehicle, collision with a human, collision with another ePMD, or other. Possible injury locations were indoors, public property (a car-free public facility), street (a thoroughfare for cars), sidewalk (a foot traffic-only pathway), bike-way (a bicycle-only pathway), driveway/ parking lot, and alley (a road
without sidewalks). Anatomical injury sites were categorized as head and face, neck, torso (including the thorax, abdomen, back, pelvis, and genitals), and upper and lower extremities (including the shoulders, upper arms, elbows, forearms, wrists, hips, thighs, knees, lower legs, ankles, and feet) according to the ICD-10 codes for the injury mortality diagnosis matrix by the Centers for Disease Control and Prevention of the United States [14].

To assess injury severity, the excess mortality ratio-adjusted Injury Severity Score (EMR-ISS) was calculated using ICD-10 codes. The EMR-ISS classifications used in this study were mild (scores 1–8), moderate (scores 9–24), severe (scores 25–74), or critical (scores ≥ 75 or death), as in a previous study [15].

Study outcomes
The primary outcome of the study was the incidence of severe injury. The secondary outcome was the incidence of acute traumatic brain injury, defined by ICD-10 codes of S02.0xx, S02.1, S06.2, and S06.3x [16]. The tertiary outcome was the rate of intensive care unit (ICU) admission.

Statistical analysis
All statistical analyses were performed using STATA version 14.2 (StataCorp LP, College Station, TX, USA). Continuous variables were presented as medians with interquartile ranges (IQR), and categorical variables were presented as frequencies with percentages. To identify statistically significant differences between the outcome groups, we used the Wilcoxon rank-sum test for continuous variables and the chi-square test or Fisher exact test for categorical variables. Odds ratios (ORs) with 95% confidence intervals (CI) were calculated using multivariate logistic regression analysis to evaluate the factors associated with the outcomes. The level of statistical significance was defined as a P-value of ≤ 0.05.

RESULTS
Incidence and characteristics of ePMD-related injuries
Of the 1,391,980 patients injured between 2014 and 2018, 1,472 patients (0.11%) had records that included ePMD-related keywords in their descriptions. After excluding ineligible cases, 684 cases (0.05%) were ultimately used in the final analysis. Among them, 505 cases (73.8%) were related to e-scooters and 179 cases (26.2%) were related to electric hoverboards (Fig. 1).

Fig. 2 shows the trends in ePMD-related injuries among the study population. The rate of ePMD-related injuries due to e-scooters or hoverboards increased from 3.1 ePMD-related ER visits per 100,000 population in 2014 to 100.3 per 100,000 population in 2018.

Table 1 shows demographic characteristics and clinical features according to ePMD type. The median age was 28 years old (IQR, 19–38 years old) and a higher proportion of men (68.0%) sustained injuries related to ePMDs. Patients who were injured while operating electric hoverboards tended to be younger than those who were injured while operating e-scooters. The distribution of the time of injury was different between the two groups. The rate of helmet use was low in both groups, at 3.4% for the e-scooter group and 2.2% for the hoverboard group (P = 0.210), and operation while intoxicated was more common in the e-scooter group than in the hoverboard group. Fall-off injuries were the most common injury mechanism, at 69.9% in the e-scooter group and 83.8% in the hoverboard group; however, collisions with vehicles or stationary objects were more fre-
Table 1. Demographic findings and clinical outcomes of the study population by ePMD type

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total (n=684)</th>
<th>E-scooter (n=505)</th>
<th>Hoverboard/e-unicycle (n=179)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
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<tr>
<td>0–14</td>
<td>133 (19.4)</td>
<td>73 (14.5)</td>
<td>60 (33.5)</td>
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<tr>
<td>15–24</td>
<td>164 (24.0)</td>
<td>135 (26.7)</td>
<td>29 (16.2)</td>
<td></td>
</tr>
<tr>
<td>25–34</td>
<td>157 (23.0)</td>
<td>125 (24.8)</td>
<td>32 (17.9)</td>
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</tr>
<tr>
<td>35–44</td>
<td>151 (22.1)</td>
<td>115 (22.8)</td>
<td>36 (20.1)</td>
<td></td>
</tr>
<tr>
<td>45–54</td>
<td>57 (8.3)</td>
<td>44 (8.7)</td>
<td>13 (7.3)</td>
<td></td>
</tr>
<tr>
<td>≥55</td>
<td>22 (3.2)</td>
<td>13 (2.8)</td>
<td>9 (5.0)</td>
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<tr>
<td>Median (interquartile range)</td>
<td>-</td>
<td>29 (21–38)</td>
<td>26 (12–39)</td>
<td>0.026</td>
</tr>
<tr>
<td>Male sex</td>
<td>465 (68.0)</td>
<td>350 (69.3)</td>
<td>115 (64.2)</td>
<td>0.210</td>
</tr>
<tr>
<td>Year of injury</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2014</td>
<td>8 (1.2)</td>
<td>8 (1.6)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>37 (5.4)</td>
<td>21 (4.2)</td>
<td>16 (8.9)</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>111 (16.2)</td>
<td>54 (10.7)</td>
<td>57 (31.8)</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>243 (35.5)</td>
<td>175 (34.7)</td>
<td>68 (38.0)</td>
<td></td>
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<tr>
<td>2018</td>
<td>285 (41.6)</td>
<td>247 (48.9)</td>
<td>38 (21.2)</td>
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<tr>
<td>Day of injury (weekend)</td>
<td>298 (43.6)</td>
<td>216 (42.8)</td>
<td>82 (45.8)</td>
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</tr>
<tr>
<td>Time of injury</td>
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<td></td>
<td>0.012</td>
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<tr>
<td>0–6 AM</td>
<td>180 (26.3)</td>
<td>147 (29.1)</td>
<td>33 (18.4)</td>
<td></td>
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<tr>
<td>6–12 AM</td>
<td>35 (5.1)</td>
<td>29 (5.7)</td>
<td>6 (3.4)</td>
<td></td>
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<tr>
<td>12–6 PM</td>
<td>204 (29.8)</td>
<td>146 (28.9)</td>
<td>58 (32.4)</td>
<td></td>
</tr>
<tr>
<td>6–12 PM</td>
<td>265 (38.7)</td>
<td>183 (36.2)</td>
<td>82 (45.8)</td>
<td></td>
</tr>
<tr>
<td>Helmet use</td>
<td>21 (3.1)</td>
<td>17 (3.4)</td>
<td>4 (2.2)</td>
<td>0.210</td>
</tr>
<tr>
<td>Drunk driving (alcohol)</td>
<td>70 (10.2)</td>
<td>64 (12.7)</td>
<td>6 (3.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>EMS use</td>
<td>267 (39.0)</td>
<td>226 (44.8)</td>
<td>41 (22.9)</td>
<td>&lt;0.001</td>
</tr>
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<td>Mechanism of injury</td>
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<td>0.002</td>
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<td>Fall-off</td>
<td>503 (73.5)</td>
<td>353 (69.9)</td>
<td>150 (83.8)</td>
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<tr>
<td>Collision with motor vehicles</td>
<td>76 (11.1)</td>
<td>68 (13.5)</td>
<td>8 (4.5)</td>
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</tr>
<tr>
<td>Collision with stationary objects</td>
<td>52 (7.6)</td>
<td>45 (8.9)</td>
<td>7 (3.9)</td>
<td></td>
</tr>
<tr>
<td>Collision with humans</td>
<td>25 (3.7)</td>
<td>20 (4.0)</td>
<td>5 (2.8)</td>
<td></td>
</tr>
<tr>
<td>Collision with another ePMD</td>
<td>13 (1.9)</td>
<td>10 (2.0)</td>
<td>3 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>15 (2.2)</td>
<td>9 (1.8)</td>
<td>6 (3.4)</td>
<td></td>
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<tr>
<td>Location of injury</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
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<td>Indoor</td>
<td>41 (6.0)</td>
<td>21 (4.2)</td>
<td>20 (11.2)</td>
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<td>Public property</td>
<td>109 (15.9)</td>
<td>65 (12.9)</td>
<td>44 (24.6)</td>
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<tr>
<td>Street</td>
<td>224 (32.7)</td>
<td>180 (35.6)</td>
<td>44 (24.6)</td>
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<tr>
<td>Sidewalk</td>
<td>137 (20.0)</td>
<td>109 (21.6)</td>
<td>28 (15.6)</td>
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<tr>
<td>Bike-way</td>
<td>29 (4.2)</td>
<td>22 (4.4)</td>
<td>7 (3.9)</td>
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<tr>
<td>Driveway/parking</td>
<td>8 (1.2)</td>
<td>6 (1.2)</td>
<td>2 (1.1)</td>
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<td>136 (19.9)</td>
<td>102 (20.2)</td>
<td>34 (19.0)</td>
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<td>Injury severity, EMR-ISS</td>
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<td>Mild</td>
<td>233 (34.1)</td>
<td>150 (29.7)</td>
<td>83 (46.4)</td>
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<tr>
<td>Moderate</td>
<td>363 (53.1)</td>
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<td></td>
</tr>
<tr>
<td>Severe</td>
<td>82 (12.0)</td>
<td>74 (14.7)</td>
<td>8 (4.5)</td>
<td></td>
</tr>
<tr>
<td>Critical</td>
<td>6 (0.9)</td>
<td>5 (1.0)</td>
<td>1 (0.6)</td>
<td></td>
</tr>
</tbody>
</table>
quent in the e-scooter group than in the hoverboard group. A higher proportion of injuries in the e-scooter group had EMR-ISS classifications of moderate or severe, and the e-scooter group also had a higher ICU admission rate than the hoverboard group. One death was recorded in the e-scooter group.

Table 2 shows the clinical results and demographic findings by age group. Injuries related to e-scooters were more common than injuries related to hoverboards across all age groups. The rate of emergency medical service utilization was highest among those aged >55 years old. Those aged 0 to 14 years old experienced the most injuries on public property, while the majority of injuries occurred on the street or sidewalk for the other age groups.

Main outcomes
The results of the multivariate logistic regression models are shown in Table 3. The occurrence of severe injury, traumatic brain injury, and ICU admission was higher among those aged 55 and older. There were no cases of traumatic brain injury or ICU admission when the rider wore a helmet. The likelihood of a severe injury (i.e., with an EMR-ISS of ≥ 25) was higher for men and for patients who had consumed alcohol before riding (adjusted OR [AOR], 2.11; 95% CI, 1.14–3.90 for men and AOR, 2.78; 95% CI, 1.52–5.08 for those with alcohol consumption). Moreover, patients who sustained injuries on roads or streets (AOR, 2.68; 95% CI, 1.11–6.45) were more likely to be admitted to the ICU than patients injured elsewhere.

DISCUSSION
Thus far in South Korea, only one study on ePMD-related injuries has been conducted, and it only examined injuries at one center. The present study analyzed multicenter data collected from evenly distributed, representative medical institutions in South Korea to examine the demographics of patients injured by ePMDs [17].

As ePMD use has grown in popularity worldwide, the burden of ePMD-related injuries has similarly increased. In Singapore, the incidence of ePMD-related injuries increased by 68% over 3 years [7]. Similarly, we found that the rate of ePMD-related injuries in South Korea also increased rapidly, from 3.1 injuries per 100,000 population in 2014 to 100.3 injuries per 100,000 population in 2018. Despite this increase in ePMD-related injuries, there have been few changes in legislation and infrastructure in South Korea. The Korean Road Traffic Act has not yet been updated to distinguish this new means of personal transport from motorcycles, which has led to an increase in the number of citizens who defy traffic laws. This can lead to an increase in traffic

Table 1. Continued

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total (n=684)</th>
<th>E-scooter (n=505)</th>
<th>Hoverboard/e-unicycle (n=179)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation (yes)</td>
<td>60 (8.8)</td>
<td>47 (9.3)</td>
<td>13 (7.3)</td>
<td>0.41</td>
</tr>
<tr>
<td>Anatomical location of injury&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Head and face</td>
<td>332 (49.6)</td>
<td>271 (55.0)</td>
<td>61 (34.5)</td>
<td></td>
</tr>
<tr>
<td>Neck</td>
<td>11 (1.6)</td>
<td>7 (1.4)</td>
<td>4 (2.3)</td>
<td></td>
</tr>
<tr>
<td>Torso</td>
<td>30 (4.5)</td>
<td>22 (4.5)</td>
<td>8 (4.5)</td>
<td></td>
</tr>
<tr>
<td>Extremities</td>
<td>297 (44.3)</td>
<td>193 (39.1)</td>
<td>104 (58.8)</td>
<td></td>
</tr>
<tr>
<td>Diagnosis&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td>0.326</td>
</tr>
<tr>
<td>Fracture</td>
<td>264 (28.6)</td>
<td>200 (27.4)</td>
<td>64 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Dislocation</td>
<td>38 (4.1)</td>
<td>30 (4.1)</td>
<td>8 (4.2)</td>
<td></td>
</tr>
<tr>
<td>Internal organ injuries</td>
<td>80 (8.7)</td>
<td>61 (8.4)</td>
<td>19 (9.9)</td>
<td></td>
</tr>
<tr>
<td>Open wound</td>
<td>232 (25.2)</td>
<td>193 (26.4)</td>
<td>39 (20.3)</td>
<td></td>
</tr>
<tr>
<td>Superficial injury or contusion</td>
<td>303 (32.9)</td>
<td>242 (33.2)</td>
<td>61 (31.8)</td>
<td></td>
</tr>
<tr>
<td>Amputation, blood vessel injuries, or crushing</td>
<td>5 (0.5)</td>
<td>4 (0.6)</td>
<td>1 (0.5)</td>
<td></td>
</tr>
<tr>
<td>Disposition</td>
<td></td>
<td></td>
<td></td>
<td>0.075</td>
</tr>
<tr>
<td>Discharge</td>
<td>584 (85.4)</td>
<td>422 (83.6)</td>
<td>162 (90.5)</td>
<td></td>
</tr>
<tr>
<td>Transfer</td>
<td>15 (2.2)</td>
<td>12 (2.4)</td>
<td>3 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Admission</td>
<td>85 (12.4)</td>
<td>71 (14.1)</td>
<td>14 (7.8)</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as number (%).
EMS, emergency medical services; ePMD, electric personal mobility devices; EMR-ISS, excess mortality ratio-adjusted Injury Severity Score.
<sup>a</sup>In case of several parts of the injury, it was counted as duplicate.
### Table 2. Demographic findings and clinical outcomes of the study population by age group

<table>
<thead>
<tr>
<th>Variable</th>
<th>0–14 Years (n=133)</th>
<th>15–34 Years (n=321)</th>
<th>35–54 Years (n=208)</th>
<th>≥55 Years (n=22)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>9 (7–11)</td>
<td>22 (22–30)</td>
<td>42 (38–46)</td>
<td>61.5 (60–65)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male sex</td>
<td>82 (61.7)</td>
<td>211 (65.7)</td>
<td>157 (75.5)</td>
<td>15 (68.2)</td>
<td>0.036</td>
</tr>
<tr>
<td>Type of ePMD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-scooter</td>
<td>73 (54.9)</td>
<td>260 (81.0)</td>
<td>159 (76.4)</td>
<td>13 (59.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hoverboard/e-unicycle</td>
<td>60 (45.1)</td>
<td>61 (19.0)</td>
<td>49 (23.6)</td>
<td>9 (40.9)</td>
<td></td>
</tr>
<tr>
<td>Year of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.700</td>
</tr>
<tr>
<td>2014</td>
<td>1 (0.8)</td>
<td>3 (0.9)</td>
<td>4 (1.9)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>8 (6.0)</td>
<td>15 (4.7)</td>
<td>13 (6.2)</td>
<td>1 (4.5)</td>
<td></td>
</tr>
<tr>
<td>2016</td>
<td>28 (21.1)</td>
<td>45 (14.0)</td>
<td>32 (15.4)</td>
<td>6 (27.3)</td>
<td></td>
</tr>
<tr>
<td>2017</td>
<td>48 (36.1)</td>
<td>115 (35.8)</td>
<td>74 (35.6)</td>
<td>6 (27.3)</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td>48 (36.1)</td>
<td>143 (44.5)</td>
<td>83 (40.9)</td>
<td>9 (40.9)</td>
<td></td>
</tr>
<tr>
<td>Day of injury (weekend)</td>
<td>73 (54.9)</td>
<td>126 (39.3)</td>
<td>89 (42.8)</td>
<td>10 (45.5)</td>
<td>0.024</td>
</tr>
<tr>
<td>Time of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>0–6 AM</td>
<td>10 (7.5)</td>
<td>102 (31.8)</td>
<td>64 (30.8)</td>
<td>4 (18.2)</td>
<td></td>
</tr>
<tr>
<td>6–12 AM</td>
<td>2 (1.5)</td>
<td>16 (5.0)</td>
<td>15 (7.2)</td>
<td>2 (9.1)</td>
<td></td>
</tr>
<tr>
<td>12–6 PM</td>
<td>68 (51.1)</td>
<td>75 (23.4)</td>
<td>52 (25.0)</td>
<td>9 (40.9)</td>
<td></td>
</tr>
<tr>
<td>6–12 PM</td>
<td>53 (39.8)</td>
<td>128 (39.9)</td>
<td>77 (37.0)</td>
<td>7 (31.8)</td>
<td></td>
</tr>
<tr>
<td>Helmet use</td>
<td>7 (5.3)</td>
<td>7 (2.2)</td>
<td>7 (3.4)</td>
<td>0</td>
<td>0.290</td>
</tr>
<tr>
<td>Drunk driving (alcohol)</td>
<td>0</td>
<td>44 (13.7)</td>
<td>23 (11.1)</td>
<td>3 (13.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>EMS use</td>
<td>22 (16.5)</td>
<td>141 (43.9)</td>
<td>93 (44.7)</td>
<td>11 (50.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.002</td>
</tr>
<tr>
<td>Fall-off</td>
<td>107 (80.5)</td>
<td>221 (68.8)</td>
<td>160 (76.9)</td>
<td>15 (68.2)</td>
<td></td>
</tr>
<tr>
<td>Collision with vehicles</td>
<td>2 (1.5)</td>
<td>43 (13.4)</td>
<td>27 (13.0)</td>
<td>4 (18.2)</td>
<td></td>
</tr>
<tr>
<td>Collision with stationary object</td>
<td>8 (6.0)</td>
<td>34 (10.6)</td>
<td>8 (3.8)</td>
<td>2 (9.1)</td>
<td></td>
</tr>
<tr>
<td>Collision with humans</td>
<td>8 (6.0)</td>
<td>9 (2.8)</td>
<td>8 (3.8)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Collision with another ePMD</td>
<td>2 (1.5)</td>
<td>8 (2.5)</td>
<td>2 (1.0)</td>
<td>1 (4.5)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>6 (4.5)</td>
<td>6 (1.9)</td>
<td>3 (1.4)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Location of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Indoor</td>
<td>21 (4.5)</td>
<td>7 (2.4)</td>
<td>11 (5.9)</td>
<td>2 (9.1)</td>
<td></td>
</tr>
<tr>
<td>Public property</td>
<td>37 (31.2)</td>
<td>42 (13.0)</td>
<td>27 (8.8)</td>
<td>3 (13.6)</td>
<td></td>
</tr>
<tr>
<td>Street</td>
<td>21 (21.4)</td>
<td>123 (30.8)</td>
<td>75 (29.4)</td>
<td>5 (22.7)</td>
<td></td>
</tr>
<tr>
<td>Sidewalk</td>
<td>25 (17.0)</td>
<td>64 (20.2)</td>
<td>43 (20.6)</td>
<td>5 (22.7)</td>
<td></td>
</tr>
<tr>
<td>Bike-way</td>
<td>3 (0.9)</td>
<td>16 (5.9)</td>
<td>10 (2.9)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Driveway/parking</td>
<td>3 (0.9)</td>
<td>5 (1.2)</td>
<td>0 (5.9)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Alley</td>
<td>23 (24.1)</td>
<td>64 (20.6)</td>
<td>42 (26.5)</td>
<td>7 (31.8)</td>
<td></td>
</tr>
<tr>
<td>Injury severity, EMR-ISS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.036</td>
</tr>
<tr>
<td>Mild</td>
<td>55 (41.4)</td>
<td>106 (32.0)</td>
<td>66 (31.7)</td>
<td>6 (27.3)</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>72 (54.1)</td>
<td>171 (53.3)</td>
<td>110 (52.9)</td>
<td>10 (45.5)</td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>6 (4.5)</td>
<td>42 (13.1)</td>
<td>29 (13.9)</td>
<td>5 (22.7)</td>
<td></td>
</tr>
<tr>
<td>Critical</td>
<td>0</td>
<td>2 (0.6)</td>
<td>3 (1.4)</td>
<td>1 (4.5)</td>
<td></td>
</tr>
<tr>
<td>Operation (yes)</td>
<td>13 (9.8)</td>
<td>20 (6.2)</td>
<td>23 (11.1)</td>
<td>4 (18.2)</td>
<td>0.088</td>
</tr>
<tr>
<td>Disposition</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Discharge</td>
<td>122 (91.7)</td>
<td>282 (87.9)</td>
<td>165 (79.3)</td>
<td>15 (68.2)</td>
<td></td>
</tr>
<tr>
<td>Transfer</td>
<td>0</td>
<td>10 (3.1)</td>
<td>5 (2.4)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Admission</td>
<td>11 (8.3)</td>
<td>29 (9.0)</td>
<td>38 (18.3)</td>
<td>7 (31.8)</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as median (interquartile range) or number (%).
ePMD, electric personal mobility devices; EMS, emergency medical services; EMR-ISS, the excess mortality ratio-adjusted Injury Severity Score.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Severe injury severity (\text{EMR-ISS} \geq 25)</th>
<th>AOR</th>
<th>95% CI</th>
<th>ICU admission</th>
<th>AOR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>OR 0–14</td>
<td>0.30</td>
<td>0.12–0.72</td>
<td>0.53</td>
<td>0.21–1.36</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OR 15–34</td>
<td>1.34</td>
<td>0.70–1.87</td>
<td>1.17</td>
<td>0.70–1.98</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OR 35–54</td>
<td>2.36</td>
<td>0.88–4.36</td>
<td>2.11</td>
<td>1.14–3.90</td>
<td></td>
</tr>
<tr>
<td></td>
<td>OR ≥55</td>
<td>2.50</td>
<td>0.42–4.53</td>
<td>0.21</td>
<td>0.14–0.38</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adjusted for age, sex, type of ePMD, year of injury, time of injury, helmet use, drink-driving, mechanism of injury, and location of injury.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3. Logistic regression of risk factors for severe injury, traumatic brain injury, and ICU admission related to electric personal mobility devices.**

We classified the most popular types of ePMDs into e-scooters and hoverboards or e-unicycles. Injuries related to e-scooters were more common than injuries related to hoverboards or e-unicycles in 2017 and 2018. Furthermore, injuries related to e-scooters were more likely to involve motor vehicle collisions than injuries related to hoverboards or e-unicycles, and they were also more likely to be severe and lead to hospital admission.

Wearing a helmet is one of the most important safety precautions required by law when operating an ePMD. One of the most remarkable findings in this study was the low rate of helmet use across all age groups. In this study, there were no cases of traumatic brain injury or admission to the ICU when the patient had been wearing a helmet. Given this finding, it is essential for riders to wear a helmet when operating ePMDs.

Injuries under the influence of alcohol accounted for approximately 10% of all cases, and intoxication was significantly related to severe injury. At present, operating an ePMD while intoxicated is illegal, and greater measures must be taken to enforce this law. The incidence of ePMD-related injuries on roads and streets was associated with admission to the ICU. Currently, the law in Korea requires ePMDs to be operated only on roadways.

Considering that operation on sidewalks can also lead to accidents, particularly involving pedestrians, laws regarding the operation of ePMDs must be reevaluated for optimal safety. If necessary, new infrastructure for ePMDs should be considered in addition to roadways.

One limitation of this study is that the number of ePMD-related injuries was small (684 cases). However, as this study used data from representative regional medical institutions, most severe injuries that required specialized treatment were likely included in the EDIIS database. Therefore, we believe that the data are representative of the population of South Korea. Another limitation is that data related to fatalities may have been missing since, if the rider had already died, he or she would not have been transferred to one of the medical institutions from this study. Therefore, further studies on ePMD-related injuries based on pre-hospitalization data should be conducted to examine incidents in which riders are not hospitalized.

In conclusion, there has been a recent increase in ER visits in South Korea due to ePMD-related injuries. Wearing a helmet...
while operating an ePMD is essential, as doing so can reduce the risk of traumatic head injury and ICU treatment. Drunk driving increases the likelihood of serious injury, and active administrative enforcement targeting the illegal operation of ePMDs should be increased. Furthermore, regulations related to the operation of ePMDs should be updated to prevent serious injuries from ePMD-related accidents. The results of this study may help inform the development of policies to prevent ePMD-related injuries.

NOTES

Ethical statement
The present study protocol was reviewed and approved by the Institutional Review Board of the Seoul National University Bundang Hospital (No. X-1903-528-902). The requirement for written informed consent was waived by the Institutional Review Board.

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

Funding
None.

Author contributions
Conceptualization: MK, DS, JWP, YHK; Study design: MK, DS, JWP, YHK; Acquisition, analysis, or interpretation of data: MK, DS, JJ, SK; Statistical analysis: DS; Writing–original draft: MK, DS; Writing–review&editing: JHL, HK, YC, JWP, YHJ.

All authors read and approved the final copy of the manuscript.

REFERENCES


Evaluation of the accuracy of mobile cone-beam computed tomography after spinal instrumentation surgery

Ki Seong Eom, MD, PhD*, Eun Sung Park, MD†, Dae Won Kim, MD*, Jong Tae Park, MD†, Kwon-Ha Yoon, MD‡

1Department of Neurosurgery, Wonkwang University School of Medicine, Iksan, Korea
2Department of Radiology, Wonkwang University Hospital, Iksan, Korea

Purpose: Pedicle screw fixation provides 3-column stabilization, multidimensional control, and a higher rate of interbody fusion. Although computed tomography (CT) is recommended for the post-operative assessment of pedicle screw fixation, its use is limited due to the radiation exposure dose. The purpose of this preliminary retrospective study was to assess the clinical usefulness of low-dose mobile cone-beam CT (CBCT) for the postoperative evaluation of pedicle screw fixation.

Methods: The author retrospectively reviewed postoperative mobile CBCT images of 15 patients who underwent posterior pedicle screw fixation for spinal disease from November 2019 to April 2020. Pedicle screw placement was assessed for breaches of the bony structures. The breaches were graded based on the Heary classification.

Results: The patients included 11 men and four women, and their mean age was 66±12 years. Of the 122 pedicle screws, 34 (27.9%) were inserted in the thoracic segment (from T7 to T12), 82 (67.2%) in the lumbar segment (from L1 to L5), and six (4.9%) in the first sacral segment. Although there were metal-related artifacts, the image of the screw position (according to Heary classification) after surgery could be assessed using mobile CBCT at all levels (T7–S1).

Conclusions: Mobile CBCT was accurate in determining the location and integrity of the pedicle screw and identifying the surrounding bony structures. In the postoperative setting, mobile CBCT can be used as a primary modality for assessing the accuracy of pedicle screw fixation and detecting postoperative complications.

Keywords: Pedicle screws; Cone-beam computed tomography; Surgical instruments

INTRODUCTION

Pedicle screw fixation provides three-column stabilization, multidimensional control, and a greater rate of interbody fusion [1]. It is ideal for the screw to be fully contained within the pedicle without breaching it. Inaccurate pedicle screw fixation with a breach can lead to serious complications such as nervous or connective tissue injuries and spinal instability [2]. Although...
computed tomography (CT) is considered to be the most useful imaging modality for the postoperative assessment of pedicle screw fixation, its use is limited due to the radiation exposure dose. Although multi-detector CT (MDCT) is currently used in most hospitals, its use to evaluate surgical outcomes and prognoses during follow-up increases the radiation exposure dose received by patients in proportion to the number of tests. Cone-beam CT (CBCT), in contrast, has a significantly lower radiation exposure dose than medical MDCT because it can obtain a high-definition image with a single scan using a flat panel detector. The purpose of this preliminary retrospective study was to assess the clinical usefulness of postoperative evaluation of pedicle screw fixation using low-dose mobile CBCT.

METHODS

This study was approved by the Institutional Ethical Committee of the Wonkwang University Hospital and was conducted in compliance with the institution's requirements (No. 202002021).

The authors retrospectively reviewed the postoperative mobile CBCT images of 15 patients who underwent posterior pedicle screw fixation for spinal disease between November 2019 and April 2020. All operations were performed by one of two neurosurgeons. The inclusion criteria were patients with an adult spinal disorder over the age of 19 years, not falling under the category of vulnerable subjects, the willingness to participate in a clinical trial based on voluntary consent, and the ability to undergo CT. The exclusion criteria were unstable vital signs, pregnancy, having a spine containing a substance that could affect image acquisition, and having been judged as unsuitable for participation in clinical trials due to other reasons.

Mobile CBCT scanners and imaging interpretation

The use of two axis detectors with a larger area and a cone-shaped X-ray beam with a large aperture angle (widely divergent X-ray beam) is the specific feature of CBCT scanners. CBCT makes it possible to obtain a three-dimensional image with high spatial resolution in the course of a single rotation of the emitter and detector without moving the patient through the gantry. The radiation dose received in the course of CBCT is much lower than that received during MDCT [3,4]. CBCT has been widely used for the diagnosis of diseases and injuries of the maxillofacial, ear, nose, and throat regions for about 20 years. Due to its advantages, CBCT also holds considerable promise for examining orthopedic patients. In recent years, several manufacturing companies have developed specialized CBCT scanners for extremity imaging, which, among other advantages, allow carrying out studies under loading with patients in a vertical position [3,5]. Mobile CBCT scans were obtained using MX-CBT1240 (Phion 2.0; NanoFocusRay, Iksan, Korea) (Fig. 1). The components of the MX-CBT1240 system included a high-frequency generator, a rotating anode X-ray tube, and an amorphous silicon thin-film transistor flat panel detector. The system had the following specifications: scan time, 7–13 seconds; bore size, 650 mm; single scan, 360° rotation; field of view, transaxial 260 mm and length 165 mm; reconstruction time, <41 seconds; AC power, 200–230 V/13 A, 50/60 Hz; weight, 400 kg. The typical scanning parameters were 110 kV, 20 mA, one pitch, a slice thickness of 3 mm, and a rotation time of 20 milliseconds.

Surgical technique

The surgical procedures involved open standard posterior transpedicular screw fixation with the patient in the prone position. The surgeon checked the surgical level using the C-arm, and the pedicle screws were inserted based on the anatomic landmarks under the C-arm. After awakening the patient from anesthesia after surgery, it was confirmed that the patient's vital signs stabilized in the recovery room. The patient was moved to a mobile CT room located next to the recovery room and postoperative mobile CBCT was taken. Mobile CBCT was performed to assess the screw positions and surrounding bony structure after surgery.

Accuracy of pedicle screw insertion

The accuracy of pedicle screw placement was assessed based on the breach of bony structures. Breaches were graded according to the Heary classification (Table 1) [6]. The Heary classification

---

**Table 1:** Heary Classification of Pedicle Screw Insertion

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Perfectly inserted, no breach</td>
</tr>
<tr>
<td>1</td>
<td>Breach less than 1 cm</td>
</tr>
<tr>
<td>2</td>
<td>Breach 1–2 cm</td>
</tr>
<tr>
<td>3</td>
<td>Breach greater than 2 cm</td>
</tr>
</tbody>
</table>

---

Fig. 1. Mobile cone-beam computed tomography using MX-CBT1240 (Phion 2.0; NanoFocusRay, Iksan, Korea).
includes five grades: grade I refers to a screw completely contained within the pedicle; grade II refers to an in-out-in screw with a lateral breach, with a screw tip completely contained within the vertebral body; grade III refers to a pedicle screw with a tip that penetrates the anterior or lateral vertebral body; grade IV refers to medial and inferior pedicle breaches; and grade V refers to a screw that endangers neural or vascular structures and requires immediate repositioning. Three patients with grade III had no specific clinical symptoms and did not require additional treatment.

RESULTS

Demographic characteristics
A total of 15 patients who underwent posterior transpedicular screw fixation for spinal trauma or diseases were included in this preliminary study. The demographic characteristics of the patients are summarized in Table 2. The patients included 11 men (73.3%) and four women (26.7%), and their mean age was 66 ± 12 years (range, 41–74 years). Their mean weight and height were 71 ± 10 kg and 168 ± 15 cm, respectively. The diagnosis was trauma in ten patients (66.7%) and degenerative disease in five (33.3%). The mean surgical duration was 199 ± 72 minutes (range, 121–368 minutes). Of the 122 pedicle screws, 34 (27.9%) were inserted in the thoracic segment (from T7 to T12), 82 (67.2%) in the lumbar segment (from L1 to L5), and six (4.9%) in the first sacral segment.

Breaches according to the Heary classification
The number of pedicle screws at each vertebral level and the results of the screw placement assessment using postoperative mobile CBCT imaging are shown in Table 3. The grading of the screws based on the Heary classification was as follows: 106 of the screws (86.9%) were placed within the pedicle without any breach (grade I); 13 (10.7%) were in-out-in screws with a lateral breach, and the screw tip was inside the vertebral body (grade II); three (2.5%) had an anterior or lateral breach (grade III); none had a medial breach (grade IV); and none had a breach that required immediate revision (grade V).

Table 1. Heary classification for pedicle screw breaches on postoperative computed tomography imaging [6]

<table>
<thead>
<tr>
<th>Grade</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>No breach</td>
</tr>
<tr>
<td>II</td>
<td>Screw shaft violates the lateral pedicle, but the screw tip is entirely within the vertebral body</td>
</tr>
<tr>
<td>III</td>
<td>Screw tip penetrates the anterior or lateral vertebral body</td>
</tr>
<tr>
<td>IV</td>
<td>Screw shaft breaches the medial or inferior pedicle wall</td>
</tr>
<tr>
<td>V</td>
<td>Screw endangers the spinal cord, nerve root(s), or great vessels and requires immediate revision</td>
</tr>
</tbody>
</table>

Table 2. Demographic characteristics of patients

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age (yr)</td>
<td>66±12</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>11</td>
</tr>
<tr>
<td>Female</td>
<td>4</td>
</tr>
<tr>
<td>Mean weight (kg)</td>
<td>71±10</td>
</tr>
<tr>
<td>Mean height (cm)</td>
<td>168±15</td>
</tr>
<tr>
<td>Diagnosis</td>
<td></td>
</tr>
<tr>
<td>Trauma</td>
<td>10</td>
</tr>
<tr>
<td>Degenerative disease</td>
<td>5</td>
</tr>
<tr>
<td>Mean surgical duration (min)</td>
<td>199±72 (range, 121–368)</td>
</tr>
<tr>
<td>Instrumented level</td>
<td></td>
</tr>
<tr>
<td>Thoracic</td>
<td>34</td>
</tr>
<tr>
<td>Lumbar</td>
<td>82</td>
</tr>
<tr>
<td>Sacrum</td>
<td>6</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation or number.

Table 3. Number of pedicle screws at each vertebral level and the frequency of breaches on postoperative mobile cone-beam computed tomography images based on the Heary classification

<table>
<thead>
<tr>
<th>Segment</th>
<th>No. of screws</th>
<th>Heary classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>I</td>
</tr>
<tr>
<td>T7</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>T8</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>T9</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>T10</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>T11</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>T12</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>L1</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>L2</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>L3</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>L4</td>
<td>22</td>
<td>18</td>
</tr>
<tr>
<td>L5</td>
<td>20</td>
<td>16</td>
</tr>
<tr>
<td>S1</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>122</td>
<td>106</td>
</tr>
</tbody>
</table>

https://doi.org/10.20408/jti.2021.0010
Imagery interpretation using mobile CBCT
Although there were some metal-related artifacts, the images of the screw position (according to Heary classification) after surgery using mobile CBCT at all levels (T7–S1) were readable.

Illustrative case
A 46-year-old male patient reported to the hospital with low back pain after falling from a height of 5 m. He had undergone posterior lumbar interbody fusion (PLIF) with transpedicular screw fixation at L3–L4 for spinal stenosis at another hospital 5 years earlier. A physical examination revealed severe direct tenderness at the thoracolumbar junction. On neurological examination, he had numbness and paresthesia in both legs. Lumbar CT revealed an acute burst fracture of the L1 body with mild depression and previous PLIF at L3–L4 (Fig. 2A, B). Lumbar magnetic resonance imaging (MRI) revealed an acute burst fracture with a partial tear of the posterolateral ligament complex at L1 and an epidural hematoma extending from T11 to L2/3 (Fig. 2C, D). Preoperative evaluations, including electrocardiography, cardiac sonography, pulmonary function tests, and laboratory tests, revealed no abnormalities. He underwent posterior transpedicular screw fixation at T12, L1, and L2. Postoperative mobile CBCT revealed that the screw shaft violated the lateral pedicle, and the screw tip was entirely within the vertebral body of the right L1. However, the screw shaft and the tip of the left L1 were entirely within the pedicle and vertebral body without breach (Fig. 2E–G). The postoperative course was uneventful, and the patient was discharged without any neurological defects 14 days after surgery.

DISCUSSION
Pedicle screw fixation, which was first described by Boucher in the 1950s and further investigated by Roy-Camille later in the 1960s and 1970s, is extensively used for spinal fixation and stabilization in several spinal diseases, including spinal fracture,
deformities, spondylitis, and degenerative diseases [2,7,8]. The screw should be inserted within the central part of the pedicle, and it should enter the vertebral body parallel to the endplate without breaching the cortex, although sacral screws can penetrate the anterior cortex for short distances [9]. Misplacement of the pedicle screw can lead to nerve root injury, pedicle fracture, dural tear injury with cerebrospinal fluid leakage, vascular injury, visceral injury from screw overpenetration, and facet joint violation [1,2]. All of these complications lead to spinal pain or disability in patients and increase the need for reoperation and related healthcare costs [2]. The rate of screw malpositioning in this study was 13.1%; although the reported rate of screw malpositioning varies considerably in the literature, it may be as high as 40% [10]. This variation may be associated with several factors, such as the surgeon’s experience, techniques, and differences in imaging devices. Several intraoperative techniques have been developed in recent years to improve the accuracy and safety of pedicle screw placement. However, the versatility of the shape and dimensions of the spine makes it difficult to place the pedicle screws accurately in some cases [11].

Most spine surgeons may still use the so-called conventional freehand technique, which tends to be based on the use of image intensifiers in at least one plane [11]. The conventional insertion of the pedicle screw is performed by identifying the entry point and directly palpating the pedicle wall using a probe [2]. Radiological imaging equipment can be used to increase the accuracy of pedicle screw placement. Among the various types of intraoperative imaging equipment, the C-arm is most commonly used because it is easy to use, familiar, and relatively inexpensive. Because the C-arm is used for two-dimensional fluoroscopy and it has a low resolution, the accuracy of screw insertion may be poor in complex anatomical areas. Although the fluoroscopic C-arm may be acceptable for pedicle screw fixation, more advanced equipment such as CT is recommended for higher accuracy [11,12]. However, CT-guided pedicle screw insertions for spinal disease have several disadvantages, including the radiation exposure of patients, surgeons, and operating room staff, which is significantly higher than that of intraoperative C-arm fluoroscopy. The surgery duration and the risk of infection can also increase. A follow-up CT examination to evaluate the position of the pedicle screw after surgery can also increase patients’ radiation exposure. CT is therefore considered more useful for postoperative evaluation of the insertion of the screw and follow-up observations after surgery rather than for use during surgery.

The frequency of spinal surgery has steadily increased over the past decades due to innovations in surgical techniques and devices. X-rays are a primary imaging modality used for postoperative evaluation and regular long-term follow-up after spinal pedicle screw fixation. Although X-ray examinations for spine surgery have some limitations, they can often be used to check the location of instruments and the degree of bone fusion and diagnose certain complications such as fractures and deformities [13]. Comparing the subsequent X-ray findings with the immediate postoperative radiographic findings is important for detecting changes in the inserted spine instruments and adjacent bony structures. Although X-ray examinations and CT are commonly used to evaluate pedicle screw placement postoperatively, their accuracy has been debated. Farber et al. [14] used postoperative radiographs and CT to evaluate the placement of 74 pedicle screws in 16 consecutive patients undergoing lumbar pedicle screw fixation. In their series, fewer screws were clearly within the pedicle on CT than on radiograph, and CT showed 10 times as many screws violating the medial cortex as did radiographs. They showed that conventional radiographs alone may not accurately reveal pedicle screw placement. Laine et al. [15] performed a prospective study of the accuracy of pedicle screw placement in 30 low back operations. The total number of screws was 152. CT imaging diagnosed a total of 32 misplaced pedicle screws (21%), whereas conventional radiographs diagnosed only four of these misplaced placements (3%). They concluded that conventional radiographs give a false impression of accuracy and safety in pedicular screw placement. Learch et al. [16] reported that 63% of screw placements were correctly identified as in or out of the pedicle using conventional radiographs, whereas CT improved the accuracy to 87%. Although ultrasonography can be used to detect superficial fluid collection, hematoma, and abscess, it has several limitations for assessing the surgical results of pedicle screw fixation [9]. MRI also has limitations in evaluating the postoperative state of pedicle screw fixation due to artifacts from metallic implants. CT is appropriate for postoperatively assessing pedicle screw fixation and detecting postoperative complications. CT also provides a very detailed description of the bone structure and uses a multi-plane reconstruction function that improves the location and alignment of implants and facilitates the evaluation of bone fusion through a high spatial resolution isotropic dataset [9]. When X-ray beams pass through a metallic screw, photon starvation, beam hardening, and beam scattering occur, and distinct dark and bright bands may appear as artifacts in a CT image. These artifacts limit the visibility of the screws and surrounding bones [17]. To reduce the metal ar-
tifarts and improve image quality, an optimized CT protocol and advanced artifact reduction technology are required. For CT to be a more useful device for postoperative evaluation of spine patients, the amount of irradiation should be small, the image should be acquired quickly, and the movement of the equipment should be convenient. The radiation exposure dose of mobile CBCT used in this study was a mean volume computed tomography dose index (CTDIvol) of 2.9 mGy. The radiation exposure dose of MDCT used in spine imaging is a CTDIvol of about 10 mGy. Although this difference in the diagnostic radiation dose does not directly affect the human body, the accumulation of radiation doses from repeated exposure can cause serious health problems, including cancer [18]. Brenner and Hall [18] reported direct evidence from epidemiological studies that the organ doses corresponding to common CT studies (two or three scans) resulted in an increased risk of cancer, which was reasonably convincing for adults and very convincing for children. Economic considerations should also be kept in mind. In Korea, medical insurance currently covers mobile CBCT for limb joints, but not for spinal images. In addition, using mobile CBCT in a recovery room with radiation shielding facilities would have the advantage of enabling rapid identification and treatment of screw malposition. We believe that these studies will provide a basis for discussing insurance coverage of mobile CBCT spinal imaging after sufficient verification of its clinical usefulness and safety. The most important prerequisite for CT to be a more useful device for postoperative spinal evaluation is to obtain a high-quality image that can accurately confirm the screw position in the spine through low-dose CT.

Study limitations
There are several limitations of this study. First, the number of cases is small for judging the accuracy of pedicle screw placement. Additional research is required to compare and evaluate a larger number of pedicle screws. Second, as a postoperative assessment of pedicle screw fixation, the accuracy of mobile CBCT was not compared with that of other imaging devices such as conventional radiographs, MDCT, and MRI. Third, there are several limitations in evaluating the usefulness of CBCT because there no comparison was made between MDCT and mobile CBCT in terms of the time required for the CT scan, radiation exposure, and convenience.

In conclusions, mobile CBCT was accurate for determining the location and integrity of the pedicle screw and identifying the surrounding bony structures. The authors could obtain high-quality images within a short scan duration with a low dose using mobile CBCT. In the postoperative setting, mobile CBCT can be used as a primary modality for assessing the accuracy of pedicle screw fixation and detecting postoperative complications. Further research is warranted to evaluate the usefulness of mobile CBCT compared to MDCT.

NOTES

Ethical statements
The study was approved by the Institutional Ethical Committee of the Wonkwang University Hospital and was conducted in compliance with the institution’s requirements (No. 2020002021). Informed consent was obtained from all individual participants included in this study.

Conflicts of interest
Kwon-Ha Yoon is the CEO of NanoFocusRay, Iksan, Korea. The authors have no other conflicts of interest to declare.

Funding
None.

Author contributions
Conceptualization: KSE, KHY; Data curation: ESP, JTP; Formal analysis: KSE, ESP; Funding acquisition: JTP, KHY; Investigation: KSE, DWK; Methodology: KSE, DWK; Project administration: JTP, KHY.

All authors read and approved the final copy of the manuscript.

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Perioperative complications of the modified Stoppa approach for the treatment of pelvic bone fractures: a single-institution review of 48 cases

Hyeonjoon Lee, MD ©, Suenghwan Jo, MD, PhD ©, Gwangchul Lee, MD, PhD ©, Yongjin Cho, MD, PhD ©

Department of Orthopedic Surgery, Chosun University Hospital, Chosun University College of Medicine, Gwangju, Korea

Purpose: The current study aimed to report the perioperative complications of the modified Stoppa approach for the treatment of pelvic bone fractures.

Methods: We analyzed 48 consecutive operations in 45 patients who were treated with internal fixation using the modified Stoppa approach between March 2016 and July 2018. This included three revision operations. The mean age of the patients was 54.5 years, and the patients included 35 male patients and 10 female patients. All fractures occurred as a consequence of high-energy trauma and 70.3% had associated injuries at the time of the fracture. The mean Injury Severity Score was 9.03±5.60. The perioperative complications found during and immediately after surgery were recorded and were classified into three categories: vascular injuries, nerve injuries, and other complications.

Results: Overall, 14 perioperative complications (29.2%) in 14 cases were identified. The most common complications were nerve injuries, which occurred in seven cases, all involving the obturator nerve. Uncontrollable vascular injuries occurred in six cases, which required additional incisions and support of vascular surgeons or postoperative interventions. Additionally, one case of peritoneal tearing occurred, which required help from an abdominal surgeon.

Conclusions: While the modified Stoppa approach seems to be a viable method to treat pelvic fractures, significant perioperative complications may occur, suggesting that surgeons should pay careful attention to minimize the damage to other structures and that appropriate support from other surgical departments is paramount.

Keywords: Pelvis; Acetabulum; Fracture; Modified Stoppa approach; Perioperative complication

INTRODUCTION

Pelvic fractures with acetabular involvement occur at the weight-bearing joints and are best treated through open reduction and internal fixation. Anatomic reduction with stable column fixation is required to provide optimal outcomes [1]. However, a surgical approach to the fractured pelvis is difficult because of its sophisticated anatomical structure and its...
A currently used approach for the treatment of acetabular fractures is the modified Stoppa approach, which was described by Hirvensalo et al. [3] in 1993 and Cole and Bölhofer [4] in 1994. Compared to the present ilioinguinal approach, the modified Stoppa approach can be done with a smaller incision and with minimal dissection of the pelvic structures. Operations using the modified Stoppa approach are mostly successful. However, the potential complications during the operation, such as vascular and nerve injuries, may be a significant concern, especially for novice surgeons. Nonetheless, there are limited reports on the perioperative complications associated with the modified Stoppa approach. Herein, we report our experiences of perioperative complications using the modified Stoppa approach.

**METHODS**

This study was approved by the Institutional Review Board of the Chosun University Hospital (No. 2021-06-033). A retrospective study of 48 operations in 45 patients using the modified Stoppa approach between March 2016 and July 2018 was conducted. Using hospital records and radiographic examinations, the following data were collected: demographics, Injury Severity Score, the mechanism of injury, the presence of associated injuries, and perioperative complications. The demographic data of these patients are listed in Table 1. Operations were performed by a single surgeon specializing in hip and pelvis fractures. The quality of the reduction was not evaluated in this study because the correlations with clinical outcomes have already been well-described and the aim of the present study was to identify the perioperative complications [5].

### Surgical methods

All operations were performed using the method described previously. The first case was operated using a Deaver retractor, while the other 47 cases were operated with a carbon precurved retractor designed for the modified Stoppa approach. Eleven cases used a conventional reconstruction plate, while 37 cases used a precontoured anatomical plate designed specifically for medial buttress fixation (Stryker, Kalamazoo, MI, USA). During surgery, the obturator nerve and vessels were identified using the vessel loops to protect them from further damage. If we encountered vascular anastomoses between the external iliac vessels and obturator vessels (i.e., corona mortis), they were dissected and ligated using vascular clips. According to the fracture patterns, the Kocher-Langenbeck approach was also performed posteriorly in seven patients. One of those seven patients had a pelvic fracture without an acetabular-involved fracture pattern, and six of the seven patients had pelvic fractures showing acetabular involvement. Reconstruction plates (Synthes, Solothurn, Switzerland) contoured to patients’ specific pelvic bony structures were used.

### Records of complications

All complications were recorded by the surgeon immediately after surgery. The complications were categorized as vascular injuries, nerve-related injuries, and other complications. Vascular injuries were defined as uncontrolled bleeding that required additional incision, postoperative embolization, or assistance from a vascular surgeon.

A nerve-related injury was defined as any alteration or deficiency of motor or sensory function that was not observed prior to surgery. Symptoms of numbness, adductor muscle weakness or neuropathy, and any condition diagnosed with an electrodiagnostic test were included. The occurrence of neurological symptoms was evaluated during outpatient postoperative follow-up after surgery considering the possibility that the surgeons might not have been aware of neurological complications during surgery. Postoperative complications such as post-traumatic osteoarthritis and infection were not evaluated in this study.

### RESULTS

Overall, there were 14 perioperative complications: seven cases
of nerve injuries, six cases of vascular injuries, and one case of peritoneal injury (Table 2).

All seven cases of nerve-related injuries involved the obturator nerve (Fig. 1). The patients with nerve-related symptoms complained of numbness and some degree of tingling. As there were no cases of iatrogenic nerve disruption during surgery, it was assumed that the nerve-related symptoms may have occurred due to traction of the nerve during plate insertion or direct compression by the medial buttress plate. Of the six cases of vascular injuries, two were external iliac vein injuries that occurred during revision surgery. The external iliac vein was repaired with the help of vascular surgeons. One case involved rupture of a branch of the internal iliac artery. In that case, an additional incision was made for exploration and ligation was performed by a vascular surgeon. Another two cases involved abrupt bleeding deep in the sciatic notch. The bleeding was controlled by gauze packing followed by clipping of the vessels. While the exact location of the bleeding was unidentified, it was assumed to occur in vascular branches of the superior gluteal artery. One other case was related to the epigastric artery and occurred during Hemovac insertion (Fig. 2). This injury was controlled with a radiologic intervention. It should be noted that four of the six cases of vascular injuries occurred in patients who had previous abdominal surgery, such as a cesarean section or peritonitis surgery.

In addition to the nerve- and vascular-related complications, one case of peritoneal tearing occurred (Fig. 3). The patient had a history of abdominal surgery because of previous trauma. Due to severe adhesions during the approach, the anatomical structure of the abdominal wall was not easily distinguished. The peritoneal tear occurred during the dissection, and an area of the small intestine was observed in the operative field. A general surgeon investigated the possibility of internal organ damage and confirmed that no additional damage was present; subsequently, peritoneal repair was performed.

In the 48 operations, there were three revision operations. Two cases were performed because of unsatisfactory reductions and one case was performed because of nonunion. In all three cases, we tried to achieve anatomical reduction and perform refixation using a plate without additional procedures.

**DISCUSSION**

Treatment of pelvic ring injuries and acetabular fractures is very challenging for trauma surgeons, and especially orthopedic surgeons. Since these fractures are caused by high-energy

<table>
<thead>
<tr>
<th>Table 2. Perioperative complications (n=48)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtype</td>
</tr>
<tr>
<td>Vascular injury</td>
</tr>
<tr>
<td>Nerve injury</td>
</tr>
<tr>
<td>Other complications</td>
</tr>
</tbody>
</table>

Fig. 1. (A) Obturator nerve lies cross the iliopectineal line (arrow). (B) The obturator nerve can be injured during initial injury or reduction of the fracture site, so attention must be needed. The patient provided written informed consent for publication of the research details and clinical images.
trauma, which is accompanied by damage to internal organs and blood vessels, collaboration with several departments may be needed to treat these patients.

The modified Stoppa approach is very useful for the treatment of acetabular fractures and pelvic ring injuries. It can help to access and visualize the displaced quadrilateral surface, directly reduce the medially displaced quadrilateral surface, and easily insert a buttress plate into the inferior pelvic brim through only a single incision. It also enables direct reduction of the impacted acetabular dome. However, it has some disadvantages. For instance, the obturator nerve can be injured during exposure of the quadrilateral surface. In cases of posterior column fractures, the screw insertion angle is limited. A hernia may occur postoperatively. The complications of the modified Stoppa approach are known to include external iliac vein injuries, obturator nerve injuries, sciatic nerve palsy, wound infection, and fixation failure. Other complications have also been reported, such as inguinal hernia, violation of the peritoneal cavity, cystotomy, lateral femoral cutaneous nerve palsy, superior gluteal artery, atrophy of the rectus abdominis muscle, and deep vein thrombosis [4,6,7].

In this study, we experienced a total of 14 perioperative complications. Obturato nerve injuries were the most common, in seven cases (50.0%), followed by vascular injuries in six cases (42.9%), and peritoneal tearing in one case (7.1%).

Vascular injuries are among the most fatal complications that can occur during the modified Stoppa approach. The authors experienced six vascular injuries. In four out of the six cases, the patients had a history of previous abdominal surgery (e.g., cesarean section and peritonitis surgery). The damaged vessels were the external iliac vein in two cases (33.3%), a branch of the internal iliac artery in one case (16.7%), and bleeding from deep in the sciatic notch in two cases (branches of the inferior gluteal artery or inferior epigastric artery) (33.3%). According to Archdeacon et al. [7], the most common complications related
to vessels associated with the modified Stoppa approach are external iliac vein injury, while another complication of note is superior gluteal artery injury. Soni et al. [8] described injuries of the corona mortis, obturator artery, external vein, and superior gluteal artery. In our experience, the corona mortis was found in 27 cases (57.4%). In several cases, the corona mortis was injured in the initial trauma.

If surgeons use the modified Stoppa approach, they must pay attention to ways of reducing the complications related to vascular injuries. First, retraction of the anterior abdominal wall elements causes tension on the femoral vessels. The femoral vessels and nerve can be damaged by direct or traction injuries during retraction of the anterior abdominal elements. In elderly patients, the femoral vessels are particularly friable and susceptible to retraction [9]. Second, the obturator vessels or nerve can be damaged during exposure of the quadrilateral plate or by incorrect application of a medial plate in the quadrilateral plate. In the first third of dissection of the pelvic brim, the anastomotic branches between the internal and external iliac systems are described as the corona mortis. Although it was reported in 49.3% of cases, the corona mortis varies in terms of its size and surgical significance [10]. In all cases, the anastomotic vessels need to be dissected and ligated. Third, injuries to the superior gluteal vessels, for which bleeding control is difficult, can take place during careless retraction or reduction. Fourth, another obstacle is posed by the nutrient vessel branches from the iliopectineal artery. Before elevation of the posterior iliacus, it can be clipped at the internal iliac artery to prevent excessive bleeding. We recommend the following to surgeons unfamiliar with the modified Stoppa approach as ways to reduce these vascular complications and respond appropriately: (1) preparing sufficient blood, (2) starting with compression, (3) using a vascular clip that is kept handy, and (4) performing the operation during regular hours.

The obturator nerve is one of the most important structures that should be considered during intrapelvic approaches. The prevalence of the accessory obturator nerve is reported to be between 0% and 29%, and obturator nerve injuries occurred in 14.6% of cases in our study. Other studies have reported that the incidence of obturator nerve injuries associated with the modified Stoppa approach ranged from 0% to 26% [4,11–13]. However, those studies did not distinguish between traumatic and iatrogenic injuries. In contrast, Isaacson et al. [14] and Kim et al. [15] reported no complications of obturator nerve injury using the modified Stoppa approach. The course of the obturator nerve originates from the obturator canal and lies across the iliopectineal line. The course of this nerve makes it vulnerable to injury. There are two main mechanisms by which the obturator nerve can be damaged. First, it can be injured in initial trauma, which is particularly related to the extent of displacement of the quadrilateral plate. Kim et al. [15] reported that the prevalence of obturator nerve injuries from the initial trauma was 9% in their series of cases using the modified Stoppa approach, and these injuries were related to the extent of displacement of the quadrilateral plate (>24 mm). Second, it can be injured intraoperatively. The obturator nerve passes through the obturator canal as it crosses the iliopectineal line, and the risk of injury increases during plate application or when using various instruments for reduction (e.g., a collinear clamp) [16]. The nerve was distracted only by 13.1 mm from the iliopectineal line via retraction [17]. To reduce the risk of obturator nerve injury, surgeons should recognize the possibility of obturator nerve injury in the initial trauma and explore and release the obturator nerve using the modified Stoppa approach. When reducing the quadrilateral lateral plate, if using reduction tools (e.g., a collinear clamp) it is necessary to check the entrapment of the obturator nerve at the fracture site, and care must be taken not to damage the nerve when fixing the plate and holding the retractors.

Regarding other complications, we experienced one case of peritoneal tearing. The patient had a history of previous abdominal surgery, and the peritoneal tear is thought to have occurred in this patient due to adhesions in the peritoneum resulting from previous surgery. Another study mentioned the possibility of damage to the peritoneal cavity as a disadvantage of the modified Stoppa approach [18]. In order to reduce these unexpected injuries, in the preoperative planning stage, if the patient has a history of gynecological or urological surgery, it should be recognized that there is a risk of perforation of bladder and infection after surgery. In particular, in patients with a history of previous prostatectomy or radiotherapy, the risk of bleeding during the approach is high, so the surgeon should consider other surgical approaches as a way to reduce complications that may occur during surgery [7]. Other contraindications include abdominal distension and ileus [4].

Limitations of this study include the small number of study subjects and the inability to analyze the factors for the occurrence of various complications due to the limited applicability of statistical methods. However, this was the first report describing perioperative complications that occurred during the modified Stoppa approach performed by a single surgeon at a single institution, and it is expected that these findings will be
helpful for surgeons performing the modified Stoppa approach for the first time.

In conclusions, injury to the obturator nerve was the most common nerve-related injury, and care should be taken when inserting the retractor and performing plate fixation. Vascular injuries and unexpected injuries can be fatal to the patient. Therefore, the authors recommend that the surgeons should pay careful attention when operating on patients at high risk of complications (e.g., with previous abdominal procedures, old age, and other risk factors) using the modified Stoppa approach.

NOTES

Ethical statement
This study was approved by the Institutional Review Board of the Chosun University Hospital (No. 2021-06-033). Due to the retrospective nature of this study, the Institutional Review Board waived consent.

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

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None.

Author contributions
Conceptualization: CYJ, JSH; Data curation: LHJ, JSH; Investigation: LHJ; Supervision: CYJ; Writing–original draft: LHJ, JSH; Writing–review&editing: LGC.

All authors read and approved the final copy of the manuscript.

REFERENCES

Validity of the scoring system for traumatic liver injury: a generalized estimating equation analysis

Kangho Lee, MD1,2, Dongyeon Ryu, MD1,2, Hohyun Kim, MD1,2,3, Chang Ho Jeon, MD4, Jae Hun Kim, MD1,2, Chan Yong Park, MD5, Seok Ran Yeom, MD2,3,6

1Department of Trauma and Surgical Critical Care, Pusan National University Hospital, Busan, Korea
2Biomedical Research Institute, Pusan National University Hospital, Busan, Korea
3Department of Emergency Medicine, Pusan National University School of Medicine, Yangsan, Korea
4Department of Diagnostic Radiology, The Catholic University of Korea Eunpyeong St. Mary’s Hospital, Seoul, Korea
5Department of Trauma Surgery, Seoul National University Hospital, Seoul, Korea
6Department of Emergency Medicine, Pusan National University Hospital, Busan, Korea

Purpose: The scoring system for traumatic liver injury (SSTLI) was developed in 2015 to predict mortality in patients with polytraumatic liver injury. This study aimed to validate the SSTLI as a prognostic factor in patients with polytrauma and liver injury through a generalized estimating equation analysis.

Methods: The medical records of 521 patients with traumatic liver injury from January 2015 to December 2019 were reviewed. The primary outcome variable was in-hospital mortality. All the risk factors were analyzed using multivariate logistic regression analysis. The SSTLI has five clinical measures (age, Injury Severity Score, serum total bilirubin level, prothrombin time, and creatinine level) chosen based on their predictive power. Each measure is scored as 0–1 (age and Injury Severity Score) or 0–3 (serum total bilirubin level, prothrombin time, and creatinine level). The SSTLI score corresponds to the total points for each item (0–11 points).

Results: The areas under the curve of the SSTLI to predict mortality on post-traumatic days 0, 1, 3, and 5 were 0.736, 0.783, 0.830, and 0.824, respectively. A very good to excellent positive correlation was observed between the probability of mortality and the SSTLI score ($\gamma=0.997$, $P<0.001$). A value of 5 points was used as the threshold to distinguish low-risk (<5) from high-risk ($\geq$5) patients. Multivariate analysis using the generalized estimating equation in the logistic regression model indicated that the SSTLI score was an independent predictor of mortality (odds ratio, 1.027; 95% confidence interval, 1.018–1.036; $P<0.001$).

Conclusions: The SSTLI was verified to predict mortality in patients with polytrauma and liver injury. A score of $\geq$5 on the SSTLI indicated a high-risk of post-traumatic mortality.

Keywords: Wounds and injuries; Liver; Trauma severity indices; Prognosis
INTRODUCTION

The abdominal cavity is the third most common site affected by trauma [1]. The liver is the most frequently injured organ in abdominal trauma despite being relatively shielded by the ribs [2–5], and liver trauma is the leading cause of death in major abdominal trauma [6,7]. Therefore, one of the most important roles of trauma centers is the successful treatment of liver injuries. Previously, patients with liver trauma underwent surgical treatment with techniques including packing, hepatorrhaphy, vessel ligation, and hepatic resection [8]. Emergent operative management (OM) for liver injuries in hemodynamically unstable patients is essential [7,9]. However, nonoperative management (NOM), including watchful waiting and/or arterial embolization, is the preferred treatment modality in hemodynamically stable patients [7,10].

There are various scoring systems to establish the physiological severity of injuries and the prognoses of patients who have sustained trauma. The Acute Physiology and Chronic Health Evaluation Score [11], Injury Severity Score (ISS) [12], Revised Trauma Score [13], and Trauma and Injury Severity Score [14] are used to determine the severity and prognosis of injuries. However, these scoring systems are not specific to liver trauma; they are specific to various other types of injuries [15].

Given the lack of a liver-specific scoring system despite the importance of liver trauma treatment, we published a study that examined prognostic factors in patients with polytrauma and liver injury and developed a scoring system for traumatic liver injury (SSTLI) to predict mortality in 2015 [15]. This study aimed to validate the SSTLI as a prognostic factor in patients with polytrauma and liver injury.

METHODS

This study was approved by the Institutional Review Board of the Pusan National University Hospital, Busan (No. H-2012-022-098).

Components of the SSTLI

We published a study on the SSTLI in 2015 using patients’ laboratory values and initial history data [15]. As shown in Table 1, the SSTLI uses five clinical measures (age, ISS, serum total bilirubin level, prothrombin time, and creatinine level), and each measure was scored from 0 to 1 (age and ISS) or from 0 to 3 (serum total bilirubin level, prothrombin time, and creatinine level). The SSTLI score corresponds to the sum of points for each item (0–11 points).

<table>
<thead>
<tr>
<th>Measure</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>&lt;60</td>
<td>≥60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>&lt;25</td>
<td>≥25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serum total bilirubin (mg/dL)</td>
<td>&lt;1</td>
<td>1–2</td>
<td>2–3</td>
<td>&gt;3</td>
</tr>
<tr>
<td>Prothrombin time (INR)</td>
<td>&lt;1</td>
<td>1–1.7</td>
<td>1.7–2.3</td>
<td>&gt;2.3</td>
</tr>
<tr>
<td>Serum creatinine (mg/dL)</td>
<td>&lt;1</td>
<td>1–2</td>
<td>2–3</td>
<td>&gt;3</td>
</tr>
</tbody>
</table>

INR, international normalized ratio.

Study population

Patients with polytrauma and liver injury were included in this study because liver trauma is almost always accompanied by other organ injuries. In total, 564 patients with polytrauma and liver injury admitted to the emergency room at Pusan National University Hospital, Busan between January 2015 and December 2019 were considered for this study. Patients who died within 24 hours or who were discharged or transferred within 7 days were excluded because they were judged to be unsuitable for determining patients’ prognosis after successful resuscitation. With the additional exclusion of those with inadequate medical records, 43 patients were excluded. Therefore, 521 patients were enrolled in this study. If a patient was hemodynamically stable after initial resuscitation, had a normal mental status, and had no signs of peritoneal irritation upon arrival at the emergency room, the patient underwent NOM. According to this protocol, 446 patients underwent NOM and 75 patients underwent OM.

We performed a retrospective chart review of 521 patients with polytrauma and liver injury. We collected data on age, sex, and laboratory values (levels of total bilirubin, prothrombin time, and creatinine) from electronic medical records.

Outcome measures

The primary outcome variable was in-hospital mortality. Clinical variables were analyzed to identify factors predicting mortality after hospital management.

Statistical analysis

The Mann-Whitney U-test and the Wilcoxon rank-sum test were used to compare the mean values of the continuous variables and ordinal data, respectively. The chi-square test and Fisher exact test were used to compare the frequencies of categorical variables between groups. We modelled repeated measurements of all variables related to the SSTLI over time using a generalized estimating equation (GEE) extension of a logistic regression model [16]. We used the receiver operating characteris-
tic curve and area under the curve (AUC) to evaluate prognostic factors predicting death. All risk factors were analyzed using multivariate logistic regression analysis. The SSTLI was created based on the predictive power of each factor. A P-value of ≤ 0.05 was considered to indicate statistical significance. All statistical analyses were performed using IBM SPSS ver. 20.0 (IBM Corp., Armonk, NY, USA) and Stata ver. 14.2 (Stata Corp., College Station, TX, USA).

RESULTS

Clinical characteristics of patients with traumatic liver injury
The clinical characteristics of patients (382 male patients [73.3%] and 139 female patients [26.7%]; median age, 50 years; interquartile range [IQR], 33–61 years) are shown in Table 2. The average ISS was 22 (IQR, 4–50). In total, 446 patients (85.6%) underwent NOM, 75 patients (14.4%) underwent OM, and 165 patients (31.7%) underwent angiography (Fig. 1).

Of the 521 patients, 30 patients (5.8%) died in the hospital. There was no significant difference between survivors and nonsurvivors with regard to sex. The median age, median ISS, and percentage of OM were higher in nonsurvivors than in survivors (P = 0.037, P< 0.001, and P = 0.002, respectively). The serum total bilirubin level (after post-traumatic day [PTD] 3), prothrombin time, and creatinine level were higher in nonsurvivors than in survivors. The AUC values for age and ISS showed a significant increase relative to the null curve (AUC = 0.613, P = 0.037 and AUC = 0.740, P< 0.001, respectively) (Fig. S1).

Table 2. Clinical characteristics of patients with traumatic liver injury

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Survivor group (n=491)</th>
<th>Nonsurvivor group (n=30)</th>
<th>Total (n=521)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>49 (33–60)</td>
<td>56 (47–67)</td>
<td>50 (33–61)</td>
<td>0.037</td>
</tr>
<tr>
<td>Age group (yr)</td>
<td></td>
<td></td>
<td></td>
<td>0.048</td>
</tr>
<tr>
<td>&lt;60</td>
<td>360 (73.3)</td>
<td>17 (56.7)</td>
<td>277 (72.4)</td>
<td></td>
</tr>
<tr>
<td>≥60</td>
<td>131 (26.7)</td>
<td>13 (43.3)</td>
<td>144 (27.6)</td>
<td></td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>360:131</td>
<td>22:8</td>
<td>277:139</td>
<td>0.999</td>
</tr>
<tr>
<td>ISS</td>
<td>22 (17–29)</td>
<td>29 (25–41)</td>
<td>22 (4–50)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ISS group</td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&lt;25</td>
<td>284 (57.8)</td>
<td>7 (23.3)</td>
<td>281 (55.9)</td>
<td></td>
</tr>
<tr>
<td>≥25</td>
<td>207 (42.2)</td>
<td>23 (76.7)</td>
<td>230 (44.1)</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td></td>
<td></td>
<td></td>
<td>0.002</td>
</tr>
<tr>
<td>NOM</td>
<td>426 (86.8)</td>
<td>20 (66.7)</td>
<td>446 (85.6)</td>
<td></td>
</tr>
<tr>
<td>OM</td>
<td>65 (13.2)</td>
<td>10 (33.3)</td>
<td>75 (14.4)</td>
<td></td>
</tr>
<tr>
<td>Angiography</td>
<td>153 (31.2)</td>
<td>12 (40.0)</td>
<td>165 (31.7)</td>
<td>0.312</td>
</tr>
<tr>
<td>Total bilirubin (mg/dL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTD 0</td>
<td>0.6 (0.4–0.9)</td>
<td>0.6 (0.4–0.9)</td>
<td>0.6 (0.4–0.9)</td>
<td>0.972</td>
</tr>
<tr>
<td>PTD 1</td>
<td>0.9 (0.6–1.2)</td>
<td>0.9 (0.6–1.5)</td>
<td>0.9 (0.5–1.2)</td>
<td>0.482</td>
</tr>
<tr>
<td>PTD 3</td>
<td>0.9 (0.6–1.4)</td>
<td>1.7 (0.9–3.5)</td>
<td>1.0 (0.7–1.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 5</td>
<td>1.3 (0.8–2.1)</td>
<td>3.1 (1.5–7.2)</td>
<td>1.3 (0.8–2.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prothrombin time (INR)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTD 0</td>
<td>1.1 (1.0–1.2)</td>
<td>1.2 (1.2–1.4)</td>
<td>1.1 (1.0–1.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 1</td>
<td>1.2 (1.1–1.3)</td>
<td>1.3 (1.3–1.5)</td>
<td>1.2 (1.1–1.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 3</td>
<td>1.2 (1.1–1.3)</td>
<td>1.4 (1.2–1.7)</td>
<td>1.2 (1.1–1.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 5</td>
<td>1.2 (1.1–1.3)</td>
<td>1.3 (1.2–1.5)</td>
<td>1.2 (1.1–1.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Creatinine (mg/dL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTD 0</td>
<td>0.9 (0.7–1.1)</td>
<td>1.1 (0.9–1.3)</td>
<td>0.9 (0.7–1.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 1</td>
<td>0.8 (0.6–0.9)</td>
<td>1.3 (0.9–1.7)</td>
<td>0.8 (0.6–1.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 3</td>
<td>0.6 (0.5–0.8)</td>
<td>1.3 (0.9–1.8)</td>
<td>0.7 (0.5–0.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 5</td>
<td>0.6 (0.5–0.8)</td>
<td>1.3 (0.7–1.5)</td>
<td>0.6 (0.5–0.8)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are presented as median (interquartile range) or number (%).

ISS, Injury Severity Score; NOM, nonoperative management; OM, operative management; INR, international normalized ratio; PTD, post-traumatic day.
Clinical characteristics of patients according to the treatment method (NOM vs. OM)
The clinical characteristics of patients according to the treatment method (NOM vs. OM) are summarized in Table S1. Median age, sex, and ISS did not significantly differ between the OM and NOM groups.

Validation of the SSTLI and the cutoff point to distinguish between low-risk and high-risk patients
The application and effectiveness of the SSTLI in predicting mortality are summarized in Table 3. The mean and standard error plots of the SSTLI are shown in Fig. 2. The effectiveness of the SSTLI for predicting mortality was significant for PTDs 0, 1, 2, 3, and 5 (P < 0.001, P < 0.001, P < 0.001, P < 0.001, and P < 0.001, respectively).

The AUCs of the SSTLI to predict mortality on PTDs 0, 1, 3, and 5 were 0.736 (P < 0.001), 0.783 (P < 0.001), 0.830 (P < 0.001), and 0.824 (P < 0.001), respectively (Fig. 3). When the ability of the SSTLI to predict death was compared with that of age and ISS, the AUC of the SSTLI on PTD 0 was not statistically significantly different from that of age and ISS (P = 0.081) (Fig. 4A). However, the AUC of the SSTLI was higher than that of age and ISS on PTDs 1, 3, and 5 (P = 0.032, P < 0.001, and P < 0.001, respectively) (Fig. 4B–D). Table 4 shows the probability of mortality in our population according to the SSTLI. A very good to excellent positive correlation was observed between the probability of mortality and the SSTLI score (γ = 0.997, P < 0.001) (Fig. 5). Based on this result, we used a value of 5 points as the threshold to distinguish between low-risk (< 5) and high-risk (≥ 5) patients. The sensitivity, specificity, positive predictive value, negative predictive value, and the correctly classified rate of the SSTLI with a cutoff of 5 points are shown in Table 5.

Multivariate analysis using a GEE
Multivariate analysis using a GEE in a logistic regression model indicated that the SSTLI score was an independent predictor of mortality (odds ratio, 1.027; 95% confidence interval, 1.018–1.036; P < 0.001) (Table 6).

DISCUSSION
This study demonstrated the efficiency and performance of the SSTLI in predicting mortality in patients with polytraumatic liver injury. Although several scoring systems to predict the prognosis after trauma have been developed, they are not specific to traumatic liver injury. In the case of patients with trauma and chronic liver disease, chronic liver disease scoring systems such as the Child-Turcotte-Pugh system or the model for end-
Stage liver disease can be useful predictors of hepatic complications and the overall prognosis [17,18]. Hence, we developed the SSTLI in 2015 for traumatic liver injury based on the Child-Pugh scoring system (Table 1) [15,19].

The SSTLI employs five clinical measures (serum total bilirubin, prothrombin time, serum creatinine, age, and the ISS) [15]. Each risk factor is assigned a point value. The discriminatory value of the SSTLI was high. In addition, the SSTLI was found to be more predictive of mortality than age or ISS alone. In this study, multivariate analysis using the GEE with a logistic regression model indicated that the SSTLI was an independent predictor of mortality. A cutoff of 5 points in the SSTLI was used to distinguish patients at a high-risk of mortality. With its high specificity and negative predictive value, this scoring system demonstrated the potential to rule out mortality risk. Multivariate analysis using the GEE with the logistic regression model indicated that the SSTLI was an independent predictor of mortality. These data resemble the findings of a previous study [15], and the SSTLI also predicted mortality in patients with traumatic liver injury in this study.

The SSTLI has several advantages. First, it is easy to calculate and intuitive because it involves only addition using the SSTLI table. The mortality of patients with polytrauma and liver injury can be predicted immediately. Second, the SSTLI can be calculated daily using the daily laboratory data of serum bilirubin level, prothrombin time, and creatinine level, and changes in the SSTLI can be used to predict the prognosis of patients with polytrauma and liver injury. If the SSTLI score decreases after PTD 0, the patient’s prognosis may be better. Alternatively, if the SSTLI score consistently increases or remains >5 points, the patient’s prognosis may be worse. Third, the selected variables are indicators of poor outcomes of any injury. Therefore, we think that this model can be extended to encompass other injury types as well as liver injury.

This study was a result of follow-up with a larger group of patients over a longer period than in our previous study [15]. This study suggests that the SSTLI is useful, as it was verified to be a prognostic factor in patients with polytrauma with liver injury.

Table 3. Effectiveness of the SSTLI for predicting mortality

<table>
<thead>
<tr>
<th>SSTLI</th>
<th>Survivor group</th>
<th>Nonsurvivor group</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall (n=521)</td>
<td>491</td>
<td>30</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 0</td>
<td>2 (1–3)</td>
<td>3 (2–4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 1</td>
<td>3 (2–3)</td>
<td>4 (3–4.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 3</td>
<td>3 (2–4)</td>
<td>5 (4–6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PTD 5</td>
<td>2 (3.5–5)</td>
<td>6 (5–6)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

| NOM group (n=446) | 426 | 20 | <0.001 |
| PTD 0 | 2 (1–3) | 3 (2–4) | <0.001 |
| PTD 1 | 2 (2–3) | 4 (3–5) | <0.001 |
| PTD 3 | 3 (2–3) | 4 (4–5) | <0.001 |
| PTD 5 | 3 (3–5) | 5 (5–6) | <0.001 |

| OM group (n=75) | 65 | 10 | <0.001 |
| PTD 0 | 2 (2–3) | 3.5 (3–4) | 0.010 |
| PTD 1 | 3 (2–4) | 4 (4–4) | 0.028 |
| PTD 3 | 3 (2–4) | 6 (4–7) | 0.011 |
| PTD 5 | 4 (2–5) | 6 (6–7) | 0.006 |

Values are presented as number or median (interquartile range).

SSTLI, scoring system for traumatic liver injury; PTD, post-traumatic day; NOM, nonoperative management; OM, operative management.

Fig. 2. Mean and standard error plots of the scoring system for traumatic liver injury (SSTLI); shaded areas represent ±2 standard errors. CI, confidence interval.
Fig. 3. Receiver operating characteristic (ROC) curves for the scoring system for traumatic liver injury; all areas under the ROC curves were significantly greater than that of the null area. (A) PTD 0, (B) PTD 1, (C) PTD 3, and (D) PTD 5; P<0.001. PTD, post-traumatic day; AUC, area under the curve.

Fig. 4. Receiver operating characteristic (ROC) curves for age, Injury Severity Score (ISS), and the scoring system for traumatic liver injury (SSTLI); the area under the curve of the SSTLI on (A) post-traumatic day (PTD) 0 was not statistically significantly different from that of age and ISS. However, the area under the curve of the SSTLI was greater than that of age and ISS on (B) PTD 1, (C) PTD 3, and (D) PTD 5.
Table 4. Risk of mortality in patients with polytrauma and liver injury according to the SSTLI

<table>
<thead>
<tr>
<th>Score</th>
<th>Probability of mortality (%)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PTD 0</td>
<td>PTD 1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1.7</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4.1</td>
<td>2.4</td>
</tr>
<tr>
<td>3</td>
<td>7.8</td>
<td>7.1</td>
</tr>
<tr>
<td>4</td>
<td>17.0</td>
<td>18.5</td>
</tr>
<tr>
<td>5</td>
<td>15.4</td>
<td>14.8</td>
</tr>
<tr>
<td>6</td>
<td>20.0</td>
<td>40.0</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>50.0</td>
</tr>
<tr>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

SSTLI, scoring system for traumatic liver injury; PTD, post-traumatic day.

Table 5. Sensitivity, specificity, positive predictive value, and negative predictive value of the SSTLI with a cutoff of 5 points

<table>
<thead>
<tr>
<th>PTD</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV (%)</th>
<th>NPV (%)</th>
<th>Correctly classified (%)</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10.0</td>
<td>96.9</td>
<td>16.7</td>
<td>94.6</td>
<td>91.9</td>
<td>5.8</td>
</tr>
<tr>
<td>1</td>
<td>25.0</td>
<td>92.8</td>
<td>23.1</td>
<td>93.5</td>
<td>87.4</td>
<td>7.9</td>
</tr>
<tr>
<td>3</td>
<td>52.2</td>
<td>90.8</td>
<td>50.0</td>
<td>91.5</td>
<td>85.0</td>
<td>15.0</td>
</tr>
<tr>
<td>5</td>
<td>83.3</td>
<td>68.4</td>
<td>38.5</td>
<td>94.5</td>
<td>71.3</td>
<td>19.1</td>
</tr>
</tbody>
</table>

SSTLI, scoring system for traumatic liver injury; PTD, post-traumatic day; PPV, positive predictive value; NPV, negative predictive value.

Table 6. Multivariate analysis using a generalized estimating equation extension of the logistic regression model for patients with traumatic liver injury

<table>
<thead>
<tr>
<th>Variable</th>
<th>Z-score</th>
<th>Estimate (SE)</th>
<th>OR (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSTLI</td>
<td>5.84</td>
<td>0.027 (0.005)</td>
<td>1.027 (1.018–1.036)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

SE, standard error; OR, odds ratio; CI, confidence interval; SSTLI, scoring system for traumatic liver injury.

This study has several limitations. First, there are many other variables that could have been considered, but were not included in our model (e.g., serum levels of base deficit and lactic acid increase in the case of sepsis, multiple organ dysfunction, and shock) [20–24]. Second, age and ISS, which are the major factors we used in the scoring system, are themselves major factors already used to predict the prognosis of trauma patients. In addition, the question remains of whether serum total bilirubin, prothrombin time, and creatinine are specific factors related to liver injury in trauma patients. In the future, a comparative study between patients without liver damage and those with liver injury using this scoring system would be helpful. Finally, this study included patients from a single center and also was a nonrandomized, retrospective analysis. Our study population might be specific to a region, which might limit the generalizability of our findings. External validation would be required to confirm the generalizability of the SSTLI. Additional prospective, randomized, controlled trials with larger sample sizes are necessary to confirm the validity of the SSTLI.

In conclusions, we investigated prognostic factors in patients with traumatic liver injury and reaffirmed the validity of the SSTLI to predict mortality. An SSTLI score of 5 or higher indicated a high-risk of post-traumatic mortality. Our study suggests that the SSTLI could be used to predict mortality in patients with traumatic liver injury. Patients who score 5 or higher on the SSTLI should be monitored particularly carefully.

SUPPLEMENTARY MATERIALS

Fig. S1. Receiver operating characteristic (ROC) curves for (A) age and (B) Injury Severity Score (ISS); the area under the curve (AUC) for age and ISS were significantly greater than the null area (P<0.01).

Table S1. Clinical characteristics of patients with traumatic liver injury according to the treatment method

Supplementary materials are available from: https://doi.org/10.20408/jti.2021.0009.
Ethical statement
This study was approved by the Institutional Review Board of the Pusan National University Hospital, Busan (No. H-2012-022-098).

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

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Author contributions
Conceptualization: RDY, KHH; Data curation: RDY; Formal analysis: KHH, JCH, KHH; Project administration: RDY, KHH; Resources: LGH, KHH; Supervision: KJH, YSR; Validation: KHH, KJH; Visualization: JCH; Writing–original draft: LGH; Writing–review & editing: KHH, PCY, YSR.

All authors read and approved the final copy of the manuscript.

REFERENCES


Percutaneous two unilateral iliosacral S1 screw fixation for pelvic ring injuries: a retrospective review of 38 patients

Whee Sung Son, MD¹, Jae-Woo Cho, MD, PhD¹, Nam-Ryeol Kim, MD², Jun-Min Cho, MD², Nak-Jun Choi, MD², Jong-Keon Oh, MD, PhD¹, HanJu Kim, MD¹

¹Department of Orthopedic Surgery, Korea University Guro Hospital, Seoul, Korea
²Department of General Surgery, Korea University Guro Hospital, Seoul, Korea

Purpose: Percutaneous iliosacral (IS) screw fixation for pelvic ring injuries is a minimally invasive technique that reduces the amount of blood loss and shortens the procedure time. Moreover, two unilateral IS S1 screws exhibit superior stability to a single IS screw and are also safer for neurological injuries than an S2 screw. Therefore, this study aimed to evaluate fixation using percutaneous two unilateral IS S1 screws for pelvic ring injuries and its subsequent clinical outcomes.

Methods: We retrospectively reviewed 38 patients who underwent percutaneous two unilateral IS S1 screw fixation for pelvic ring injuries. The procedure time, blood loss, achievement of bone union, radiological outcomes (Matta and Tornetta grade), and postoperative complications were evaluated.

Results: The mean procedure time, hemoglobin loss, bone union rate, and time to union were 40.1 minutes (range, 18–102 minutes), 0.6 g/dL (range, 0.3–1.0 g/dL), 100%, and 153.2 days (range, 61–327 days), respectively. The Matta and Tornetta grades were excellent, good, and fair in 24 (63.1%), 11 (28.9%), and three patients (7.9%), respectively, and the postoperative complications were S1 screw loosening, widening of the symphysis pubis (2.3 and 2.5 mm), lumbosacral plexopathy, and S1 radiculopathy in one (2.6%), two (5.3%), one (2.6%), and one patient (2.6%), respectively. However, all neurological complications recovered spontaneously.

Conclusions: Percutaneous two unilateral IS S1 screw fixation was useful for treating pelvic ring injuries. In particular, it involved a short procedure time with little blood loss and also led to 100% bone union and good radiological outcomes.

Keywords: Pelvic bones; Fracture fixation; Minimally invasive surgical procedures; Bone screws

INTRODUCTION

Percutaneous iliosacral (IS) screw fixation for pelvic ring injuries is a minimally invasive technique that more effectively reduces blood loss and operative time than the open reduction technique [1–3]. Thus, it has several advantages, particularly in patients...
with unstable hemodynamic conditions. However, the use of one IS screw is inferior with respect to rotational stability and load cycles [4,5]. Therefore, the fixation of two unilateral IS S1 screws or the addition of an IS S2 screw is recommended in completely unstable pelvic ring injuries [4]. Among these two procedures, the fixation of two unilateral IS S1 screws can be a reasonable option for unstable pelvic ring injuries, considering that IS screw positioning in S1 is safer in iatrogenic neurological injuries than IS screw positioning in S2 [6].

However, limited data have been reported on the clinical outcomes of two unilateral IS S1 screw fixation. Only one study has evaluated the functional and radiological outcomes of two unilateral IS S1 screw fixation and compared them with the outcomes of single IS S1 screw fixation [7]. Moreover, no other studies have evaluated the clinical outcomes of two unilateral IS S1 screw fixation. Therefore, this study aimed to retrospectively review patients who underwent percutaneous two unilateral IS S1 screw fixation and evaluate their clinical outcomes.

**METHODS**

This study was a retrospective review of a prospectively collected cohort at a level 1 trauma center, Korea University Guro Hospital and approved by the Institutional Review Board of the Korea University Guro Hospital (No. 2021GR0439).

**Patients**

In total, 221 patients who underwent surgery for unstable pelvic ring injuries from May 2012 to May 2021 were reviewed. The inclusion criteria for these patients were as follows: (1) fixation of two ipsilateral IS S1 screws (7.3 or 7.0 mm); (2) fixation procedure performed percutaneously under two-dimensional fluoroscopic guidance; (3) at least a 1-year postoperative follow-up; and (4) available medical charts and radiographs to review exact data. Of the 221 patients, 38 patients were included in the analysis. Table 1 shows the included patients’ demographic data, and Table 2 shows the fixation constructs of the included patients.

**Surgical technique**

Before surgery, we measured the inlet angle, which is tangent to the anterior cortex of S1, and the outlet angle, which is perpendicular to the midline of the trapezoidal S1 body, using a midline sagittal computed tomography (CT) image (Fig. 1A). Based on the measured angles and fluoroscopic findings, we accurately determined the angle of the inlet and outlet views. The inlet view visualized the anterior cortex of the S1 body and spinal canal, whereas the outlet view visualized the sacral foramen (Fig. 2A). Lines perpendicular to the determined inlet and outlet angles were drawn on the patient along with the line of iliac cortical density (ICD), which could be confirmed in the true lateral view (Fig. 1B). Surgery was then performed on a radiolucent operating table, and the patient was prepared in the supine position. The entry of the first guide pin was made anterior in S1 and inferior to ICD. The height of the entry and coronal direction of the guide pin were determined via the outlet view, and the anteri-

**Table 1.** Demographic characteristics of the included patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value (n=38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>51 (14–78)</td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>19 (50):19 (50)</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
</tr>
<tr>
<td>Fall down</td>
<td>12 (31.6)</td>
</tr>
<tr>
<td>Crushing injury</td>
<td>5 (13.2)</td>
</tr>
<tr>
<td>Pedestrian injury</td>
<td>13 (34.2)</td>
</tr>
<tr>
<td>Motor vehicle injury</td>
<td>5 (13.2)</td>
</tr>
<tr>
<td>Bicycle injury</td>
<td>1 (2.6)</td>
</tr>
<tr>
<td>Slip down</td>
<td>2 (5.3)</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>19.57 (4–50)</td>
</tr>
<tr>
<td>Young-Burgess classification</td>
<td></td>
</tr>
<tr>
<td>LC type I</td>
<td>6 (15.8)</td>
</tr>
<tr>
<td>LC type II</td>
<td>19 (50.0)</td>
</tr>
<tr>
<td>LC type III</td>
<td>4 (10.5)</td>
</tr>
<tr>
<td>APC type II</td>
<td>3 (7.9)</td>
</tr>
<tr>
<td>APC type III</td>
<td>4 (10.5)</td>
</tr>
<tr>
<td>VS type</td>
<td>1 (2.6)</td>
</tr>
<tr>
<td>Tile classification</td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>2 (5.3)</td>
</tr>
<tr>
<td>B2</td>
<td>13 (34.2)</td>
</tr>
<tr>
<td>B3</td>
<td>1 (2.6)</td>
</tr>
<tr>
<td>C1</td>
<td>8 (21.1)</td>
</tr>
<tr>
<td>C2</td>
<td>13 (34.2)</td>
</tr>
<tr>
<td>C3</td>
<td>1 (2.6)</td>
</tr>
<tr>
<td>Location of posterior pelvic injury</td>
<td></td>
</tr>
<tr>
<td>Sacroiliac joint (involving crescent fracture)</td>
<td>18 (47.3)</td>
</tr>
<tr>
<td>Sacral zone I</td>
<td>6 (15.8)</td>
</tr>
<tr>
<td>Sacral zone II</td>
<td>13 (34.2)</td>
</tr>
<tr>
<td>Sacral zone III</td>
<td>1 (2.6)</td>
</tr>
<tr>
<td>Type of anterior pelvic ring injury</td>
<td></td>
</tr>
<tr>
<td>Unilateral rami fracture</td>
<td>16 (42.1)</td>
</tr>
<tr>
<td>Bilateral rami fracture</td>
<td>14 (36.8)</td>
</tr>
<tr>
<td>Pubic symphysis diastasis</td>
<td>7 (18.4)</td>
</tr>
<tr>
<td>Vertical displacement of the pubic symphysis</td>
<td>1 (2.6)</td>
</tr>
</tbody>
</table>

Values are presented as mean (range) or number (%). LC, lateral compression; APC, anterior-posterior compression; VS, vertical shear.

https://doi.org/10.20408/jt1.2021.0075
or-posterior position and direction were determined through the inlet view (Fig. 2B). The drawn perpendicular line of the determined inlet and outlet angles helped modify the position of the guide pin entry and direction of the guide pin. For example, if the guide pin position or direction needed modification in the outlet view, moving the pin along the line drawn perpendicular to the outlet angle could modify the position or direction of the pin effectively in the outlet view. After making the accurate position of entry and direction, we advanced the guide pin. The guide pin was advanced cranial to the S1 foramen in the outlet view and near the anterior cortex, but within it, in the inlet view (Fig. 2D). After passing the S1 foramen, the true lateral view was used to confirm that the ICD had not been penetrated, and the guide pin was then advanced to the S1 body (Fig. 2F). Finally, reaming was performed, and a cannulated screw with a washer was inserted via the guide pin. When tightening the screws, the obturator inlet view was used to confirm the narrowing of the sacroiliac joint gap, thereby confirming the precise state of the screw head and washer to prevent excessive intrusion (Fig. 2G–I). The second unilateral IS screw was fixed whenever possible; however, if the safe corridor was not sufficiently wide and pelvic dysmorphism was observed, the second screw was not used. The guide pin of the second screw was inserted; the guide pin of the first screw was not removed because it helped to guide the direction of the second guide pin (Fig. 3A). The second guide pin was positioned cranial to the first screw in the outlet view and positioned in a manner that did not penetrate the anterior cortex or the spinal canal in the inlet view and ICD in the lateral view (Fig. 3A–C). As a result, the second guide pin usually overlapped with or was slightly posterior to the first screw. The interval between the first screw and the second guide pin was at least half of the screw diameter to prevent collision between the screws. After confirming the adequate position of the second guide pin, the second screw was inserted (Fig. 3D–F). The type of screws was selected based on the need for compression. If compression was not required or overcompression needed to be avoided, a fully threaded screw was fixed. If compression was required, a partially threaded screw was fixed. Moreover, if additional compression was required after the first partially threaded screw fixation, the second screw was also selected for the partially threaded screw. A washer was routinely applied.

Postoperative management
All patients were instructed to perform a hip joint range of motion exercise and quadriceps strengthening exercises immediately after surgery. Furthermore, “toe-touch” weight-bearing to partial weight-bearing immediately after surgery was initially advised to patients with vertically stable injuries. However, patients with vertically unstable injuries started partial weight-bearing 4 to 6 weeks postoperatively. Thereafter, we progressively increased the amount of weight-bearing according to patients’ tolerance. The patients were followed up at 2 weeks, 6 weeks, 3 months, 6 months, and 1 year postoperatively.

Outcome measurements
The procedure time was evaluated using fluoroscopic data. Because all procedures were performed under fluoroscopic guidance, we could determine the exact start and end times of the

Table 2. Fixation constructs of the included patients

<table>
<thead>
<tr>
<th>Fixation construct</th>
<th>Value (n=38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of two S1 screws</td>
<td></td>
</tr>
<tr>
<td>Two partially threaded screws</td>
<td>4 (10.5)</td>
</tr>
<tr>
<td>One partially threaded screw and one fully threaded screw</td>
<td>18 (47.4)</td>
</tr>
<tr>
<td>Two fully threaded screws</td>
<td>16 (42.1)</td>
</tr>
<tr>
<td>Combined posterior fixation</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>20 (52.6)</td>
</tr>
<tr>
<td>Iliosacral S2 screw</td>
<td>10 (26.3)</td>
</tr>
<tr>
<td>Transiliac-transsacral S2 screw</td>
<td>6 (15.8)</td>
</tr>
<tr>
<td>Contralateral iliosacral S1 screw</td>
<td>2 (5.3)</td>
</tr>
<tr>
<td>Combined anterior fixation</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>12 (31.6)</td>
</tr>
<tr>
<td>Retrograde pubic ramus screw</td>
<td>8 (21.0)</td>
</tr>
<tr>
<td>Plate</td>
<td>18 (47.4)</td>
</tr>
</tbody>
</table>

Values are presented as number (%).
Fig. 2. Fluoroscopic images of the first iliosacral screw procedure. (A) Image of the outlet view visualizing the S1 foramen and determining the height of entry and coronal direction of the guide pin. The dotted line indicates the right S1 foramen. (B) Inlet view visualizing the anterior cortex of the S1 body and spinal canal and determining the anterior-posterior position and direction of the guide pin. The dotted lines indicate the anterior cortex of the S1 body, and the lines indicate the spinal canal. (C) Lateral view showing the iliac cortical density (ICD) line. The dotted lines indicate the ICD. (D) Outlet view showing that the guide wire should be cranial to the S1 foramen. (E) Inlet view showing that the guide wire should not penetrate the anterior cortex or the spinal canal. (F) Lateral view demonstrating that the guide wire is not penetrating the ICD after passing the S1 foramen. (G, H) Outlet and oblique inlet views show the sacroiliac joint gap and precise state of the screw and washer before tightening of the screw. (I) Oblique inlet view demonstrates both a compressed sacroiliac joint and an unintruded screw head and washer into the ilium. The patient provided written informed consent for publication of the research details and clinical images.
procedure using fluoroscopic data. If surgery involved only percutaneous two ipsilateral S1 screw fixation with intraoperative transfusion, blood loss was evaluated using hemoglobin (Hb) loss between the preoperative and postoperative periods. Intraoperative complications (e.g., guide wire breakage) were also evaluated. Bone union was defined as the absence of a fracture line. In addition, the time to union was evaluated. Moreover, we measured radiological outcomes using the method of Matta and Tornetta [8]; reductions were graded as excellent (< 4 mm), good (5–10 mm), fair (11–20 mm), and poor (> 20 mm) using maximal displacement measured on the three standard radiographic views of the pelvis. The bone union and radiographic outcomes were determined by a consensus of two orthopedic trauma fellowship-trained independent observers who were blinded to clinical information. Finally, several postoperative complications, including reduction loss, implant loosening or failure, neurological complication, and infection, were evaluated.

RESULTS

The mean procedure time was 40.1 minutes (range, 18–102 minutes). Blood loss was evaluated in five patients, and the mean Hb loss was 0.6 g/dL (range, 0.3–1.0 g/dL). There were no intraoperative complications. Bone union was achieved in all 38 patients; hence, the bone union rate was 100%. The mean time to union was 153.2 days (range, 61–327 days). The Matta and Tornetta grades were as follows: excellent in 24 (63.2%), good in 11 (28.9%), fair in three (7.9%), and poor in zero patients. S1 screw loosening was observed in one patient, combined S2 screw loosening in two patients, widening of the symphysis pubis (2.3 and 2.5 mm) in two patients, and infection of the anterior pelvic implant in one patient. Moreover, lumbosacral plexopathy was ob-

Fig. 3. Fluoroscopic images of the second iliosacral screw procedure. (A) Outlet view showing that both the first and second screws are cranial to the S1 foramen and that the first guide pin was not removed to help guide the first guide pin. (B) Inlet view showing that the second guide pin is not penetrating the anterior cortex or the spinal canal. (D) Lateral view showing that the second guide pin is not penetrating the iliac cortical density line. (E, F) Final position of the second iliosacral screw. The patient provided written informed consent for publication of the research details and clinical images.
Table 3. Outcomes of ipsilateral two S1 iliosacral screws

<table>
<thead>
<tr>
<th>Outcome measurement</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure time (min)</td>
<td>40.1 (18–102)</td>
</tr>
<tr>
<td>Hemoglobin loss (g/dL) (n=5)</td>
<td>0.6 (0.3–1.0)</td>
</tr>
<tr>
<td>Bone union rate</td>
<td>38/38 (100.0)</td>
</tr>
<tr>
<td>Time to bone union (day)</td>
<td>153.2 (61–327)</td>
</tr>
<tr>
<td>Matta and Tornetta’s grade</td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>24 (63.2)</td>
</tr>
<tr>
<td>Good</td>
<td>11 (28.9)</td>
</tr>
<tr>
<td>Fair</td>
<td>3 (7.9)</td>
</tr>
<tr>
<td>Poor</td>
<td>0</td>
</tr>
<tr>
<td>Intraoperative complication</td>
<td></td>
</tr>
<tr>
<td>S1 screw loosening</td>
<td>1 (2.6)</td>
</tr>
<tr>
<td>Combined S2 screw loosening</td>
<td>2 (5.3)</td>
</tr>
<tr>
<td>Widened symphysis pubis(^a)</td>
<td>2 (5.3)</td>
</tr>
<tr>
<td>Infection of the anterior pelvic implant</td>
<td>1 (2.6)</td>
</tr>
<tr>
<td>Lumbosacral plexopathy(^b)</td>
<td>1 (2.6)</td>
</tr>
<tr>
<td>S1 radiculopathy(^b)</td>
<td>1 (2.6)</td>
</tr>
</tbody>
</table>

Values are presented as mean (range) or number (%).
\(^a\)The widened distances of the symphysis pubis were 2.3 mm and 2.5 mm.
\(^b\)All patients spontaneously recovered.

In the present study, the mean procedure time of percutaneous two unilateral IS S1 screws fixation for pelvic ring injuries required a mean procedure time of 40.1 minutes and led to a mean Hb loss of 0.6 mg/dL during the procedure, a union rate of 100%, and an excellent to good radiological grade of 92.1%.

The biomechanical analysis of IS screws has been performed in several studies. Yinger et al. [9] compared nine different posterior pelvic ring fixation methods on hard plastic pelvic models, and the results revealed that two unilateral IS S1 screws were significantly stiffer in horizontal plane gapping and coronal plane rotation than single IS S1 screws, two anterior sacroiliac plates, one posterior pelvic tension band plate, one posterior pelvic tension band plate combined with one IS S1 screw, two transiliac bars, two transiliac bars combined with an IS screw, and one transiliac bar with one IS S1 screw. van Zwienen et al. [4] compared two unilateral IS S1 screws and a single IS S1 screw in a type C pelvic ring injury cadaveric model. The results showed that the two unilateral IS S1 screws were significantly stiffer in terms of rotation and load to failure than a single IS S1 screw. Moreover, Salari et al. [10] compared two unilateral IS S1 screws and one IS S1 screw with a transsacral S1 screw in a type C pelvic ring injury cadaveric model. They concluded that although a transsacral screw may appear to be more stable, the use of two long unilateral IS S1 screws yielded adequate stability in a single-limb stance-testing model compared with transsacral S1 screws. These studies demonstrated the usefulness of two unilateral IS S1 screws with respect to mechanical stability.

Only one study, however, has evaluated the clinical outcomes of two unilateral IS S1 screws to date. The authors compared radiological outcomes via the Matta and Tornetta grade and functional outcomes using the Majeed scoring system. Although the outcomes of both groups were comparable to those of other studies with respect to pelvic ring injuries, the outcomes showed no statistically significant differences between the two groups [7]. However, they did not report patient-related variables (e.g., age, fracture type, or combined injury) of each group and their differences. Therefore, selection bias could not be excluded with regard to the results of the previous study [7]. Suda et al. [5] recently evaluated the safety of two unilateral IS S1 screws in a three-dimensional dataset of 1,000 hemi-pelvises of 500 patients with trauma. They concluded that 99% of male and 96% of female hemi-pelvises had adequate room to place two 7.3-mm screws at a 5-mm distance into the S1 vertebra. In addition, they stated that two unilateral IS S1 screws increased the mechanical stability and posed a lower risk for neurological injuries than the positioning of additional S2 screws.

In the present study, the mean procedure time of percutaneous two unilateral IS S1 screws fixation was 40.1 minutes, which is comparable to the procedure time in previous studies that used a single IS screw. Routt et al. [11] reported that one percutaneous IS screw required a mean procedure time of 26 minutes, implying that 2-screw fixation would require a mean time of 52 minutes. Gras et al. [12] reported a mean time of 62 minutes for one percutaneous screw fixation for pelvic ring injury. Although positioning the second IS S1 screw to avoid the first IS S1 screw can be intuitively difficult and may need a longer time, it did not require more time in the present study. Thus, two unilateral IS S1 screws still have the advantage of a short procedure time for performing the percutaneous IS screw technique. We evaluated blood loss by measuring the decrease in Hb levels between the preoperative and postoperative periods, although most other studies utilized intraoperative blood loss volume. Because intraoperative blood loss volume cannot be evaluated objectively and is often estimated, we used Hb loss instead. The mean Hb loss of 0.6 g/dL was small, which is beneficial for hemodynamically unstable patients. Moreover, all patients showed bone union, and bone union required a mean duration of 153.2 days. These re-

DISCUSSION

The present study demonstrated that percutaneous two unilateral IS S1 screw fixation for pelvic ring injuries required a mean procedure time of 40.1 minutes and led to a mean Hb loss of 0.6 mg/dL during the procedure, a union rate of 100%, and an excellent to good radiological grade of 92.1%.

The biomechanical analysis of IS screws has been performed in several studies. Yinger et al. [9] compared nine different posterior pelvic ring fixation methods on hard plastic pelvic models, and the results revealed that two unilateral IS S1 screws were significantly stiffer in horizontal plane gapping and coronal plane rotation than single IS S1 screws, two anterior sacroiliac plates, one posterior pelvic tension band plate, one posterior pelvic tension band plate combined with one IS S1 screw, two transiliac bars, two transiliac bars combined with an IS screw, and one transiliac bar with one IS S1 screw. van Zwienen et al. [4] compared two unilateral IS S1 screws and a single IS S1 screw in a type C pelvic ring injury cadaveric model. The results showed that the two unilateral IS S1 screws were significantly stiffer in terms of rotation and load to failure than a single IS S1 screw. Moreover, Salari et al. [10] compared two unilateral IS S1 screws and one IS S1 screw with a transsacral S1 screw in a type C pelvic ring injury cadaveric model. They concluded that although a transsacral screw may appear to be more stable, the use of two long unilateral IS S1 screws yielded adequate stability in a single-limb stance-testing model compared with transsacral S1 screws. These studies demonstrated the usefulness of two unilateral IS S1 screws with respect to mechanical stability.

Only one study, however, has evaluated the clinical outcomes of two unilateral IS S1 screws to date. The authors compared radiological outcomes via the Matta and Tornetta grade and functional outcomes using the Majeed scoring system. Although the outcomes of both groups were comparable to those of other studies with respect to pelvic ring injuries, the outcomes showed no statistically significant differences between the two groups [7]. However, they did not report patient-related variables (e.g., age, fracture type, or combined injury) of each group and their differences. Therefore, selection bias could not be excluded with regard to the results of the previous study [7]. Suda et al. [5] recently evaluated the safety of two unilateral IS S1 screws in a three-dimensional dataset of 1,000 hemi-pelvises of 500 patients with trauma. They concluded that 99% of male and 96% of female hemi-pelvises had adequate room to place two 7.3-mm screws at a 5-mm distance into the S1 vertebra. In addition, they stated that two unilateral IS S1 screws increased the mechanical stability and posed a lower risk for neurological injuries than the positioning of additional S2 screws.

In the present study, the mean procedure time of percutaneous two unilateral IS S1 screws fixation was 40.1 minutes, which is comparable to the procedure time in previous studies that used a single IS screw. Routt et al. [11] reported that one percutaneous IS screw required a mean procedure time of 26 minutes, implying that 2-screw fixation would require a mean time of 52 minutes. Gras et al. [12] reported a mean time of 62 minutes for one percutaneous screw fixation for pelvic ring injury. Although positioning the second IS S1 screw to avoid the first IS S1 screw can be intuitively difficult and may need a longer time, it did not require more time in the present study. Thus, two unilateral IS S1 screws still have the advantage of a short procedure time for performing the percutaneous IS screw technique. We evaluated blood loss by measuring the decrease in Hb levels between the preoperative and postoperative periods, although most other studies utilized intraoperative blood loss volume. Because intraoperative blood loss volume cannot be evaluated objectively and is often estimated, we used Hb loss instead. The mean Hb loss of 0.6 g/dL was small, which is beneficial for hemodynamically unstable patients. Moreover, all patients showed bone union, and bone union required a mean duration of 153.2 days. These re-

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The results are comparable to those of other studies that used percutaneous IS screws or open reduction and plate fixation [12–14]. The results of the Matta and Tornetta grades were also comparable to or better than those of other studies. Matta and Tornetta et al. [8] reported an excellent grade in 67% of patients, good in 28%, fair in 4%, and poor in 1%. In addition, Suzuki et al. [15] reported an excellent grade in 51% of patients, good in 23%, fair in 16%, and poor in 10%. Furthermore, Khaled et al. [7] reported an excellent grade in 71.4% of patients, good in 20.8%, fair in 7.8%, and poor in none. There were no intraoperative complications; however, eight patients developed postoperative complications. In particular, S1 screw loosening (2.6%), widening of the symphysis pubis (5.3%), lumbosacral plexopathy (2.6%), and S1 radiculopathy (2.6%) were directly related to two unilateral IS S1 screws. Moreover, all neurological deficits recovered spontaneously; the 2.3- and 2.5-mm widenings of the symphysis pubis after surgery were relatively smaller than the mean values in previous studies [16–19]. The results for complications are also comparable to the findings of a study on a single IS screw; Osterhoff et al. [1] performed percutaneous single IS screw fixation on the S1 or S2 vertebrae in 38 patients and reported persistent hypoaesthesia in L5/S1 dermatomes in two patients (5.3%); screw malpositioning or loosening, which needed secondary surgery, in four (10.5%); pulmonary embolism in one (2.6%); and nonunion in

![Fig. 4](https://doi.org/10.20408/jti.2021.0075)
one (2.6%). Zwingmann et al. [20] evaluated the intraoperative and postoperative complications of the CT guidance and conventional technique groups for percutaneous IS screws in 784 patients and reported intraoperative and postoperative complications in 8.8% and 26.3% of patients in the CT guidance group and 5.9% and 29.3% of patients in the conventional technique group, respectively. Therefore, in this study, percutaneous two unilateral IS S1 screw fixation required a short procedure time and showed a small amount of blood loss, 100% bone union rate, comparatively good radiological outcomes, and few complications.

The limitations of this study are the retrospective study design and small number of cases, particularly for the outcome of Hb loss. In addition, this study was a case series and did not include a control group. Moreover, the outcomes of this study included many variables that were not controlled, including the initial fracture type or the fixation construct of the anterior pelvic ring. Thus, an additional study with a large number of cases and high power is needed.

In conclusions, percutaneous two unilateral IS S1 screw fixation is a useful option for pelvic ring injuries. In particular, the procedure requires less time and causes little blood loss, as well as leading to a 100% bone union rate and good radiological outcomes.

NOTES

Ethical statement
This study was a retrospective review of a prospectively collected cohort at a level 1 trauma center, Korea University Guro Hospital and approved by the Institutional Review Board of the Korea University Guro Hospital (No. 2021GR0439). Written informed consent was waived due to the retrospective nature of this study.

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

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Author contributions
Conceptualization: WSS, JWC, JKO; Data curation: HJK, NYK; Formal Analysis: NJC; Investigation: JMC; Methodology: JMC, NJC; Project administration: JKO, NYK; Resources: JKO; Software: WSS; Supervision: CWC, HJK; Validation: HJK; Visualization: WSS; Writing–original draft: WSS; Writing–review&editing: WSS, HJK, JWC, JKO.

All authors read and approved the final copy of the manuscript.

REFERENCES


INTRODUCTION

Epidural hematoma (EDH) in its acute form was first described by Jacobson in 1886 [1]. EDH can be a life-threatening condition; therefore, treatment has focused on its acute form. However, many cases of EDH improve spontaneously, and surgical treatment is only required for a relatively small proportion of acute cases.

Unlike subdural hematoma (SDH), there is no agreed-upon definition of chronic EDH or an established interval between the trauma and the diagnosis. This may result from the rarity of the condition, which is why most clinicians underestimate the clinical importance of chronic EDH. Herein, we introduce our experience with a successful operation for chronic EDH.

CASE REPORT

A 41-year-old male patient presented to Konyang University Hospital due to a fall from height. His consciousness was slightly drowsy and right-side motor power was reduced to grade III. The initial brain computed tomography (CT) scan showed left paravertebral EDH associated with a linear skull fracture along the sagittal suture line (Fig. 1A). Therefore, we planned an emergent operation. Although a very small portion of the hematoma extended to the right paravertex, we only evacuated the left-side hematoma because his left-side motor function was intact. The bleeding focus was a partial rupture of the superior sagittal sinus due to a skull fracture.

After surgery, brain CT showed evacuation of the EDH at the left paravertex, but an increased amount of EDH on the contra-
lateral side (Fig. 1B). The patient’s Glasgow Coma Scale improved to 14 from 10, and right hemiparesis also improved. Therefore, we planned conservative treatment for the remnant EDH in the right paravertical area. We expected spontaneous resorption of the hematoma, as commonly occurs with nonsurgical intracranial hematoma.

One month after the operation, the patient’s right hemiparesis had improved fully, but he reported left-side discomfort and paresthesia. We performed another brain CT scan, which showed a hypodense lesion on the right paravertical convexity with expansion of its volume in comparison to the previous CT scan (Fig. 2).

In light of the amount of time that had passed, we considered that this chronic EDH would not subside spontaneously, so we planned a second operation. The EDH, which consisted of a large amount of organized, solid clots and a small fluid component, was surgically evacuated via a large contralateral craniotomy (Fig. 3). The source of the hemorrhage was not identified during surgery. The patient was discharged 2 weeks after the second operation. No complications and neurological deficits were identified at 6 months after surgery.

**DISCUSSION**

EDH occurs as a complication in approximately 1.5% of treated head injuries, and chronic EDH accounts for less than 4% of these cases [2]. Chronic EDH is an unusual and distinctive entity that is not well established, unlike SDH. Some authors refer to chronic EDH as a hematoma observed from 48 hours to 13 days after the incident of trauma or surgery [2,3].

The pathophysiology of chronic EDH has not been well researched in comparison to chronic SDH. According to Punt [4] in 1978, the process of chronic EDH is similar to that of chronic SDH initiated by stripping of the dura due to trauma or surgery, leading to a small collection at the site that subsequently enlarges due to repeated hemorrhage. A dense fibrous capsule enclosing
the hematoma is known to be common [5,6], but did not occur in our case.

As observed in our case, during its transformation to the chronic form, the hematoma expands. Similar to chronic SDH, processes such as development of a membrane and liquefaction of the solid clot are also seen in chronic EDH [2,7]. The existence of a membrane is important. Neovascular proliferation in the membrane with increased permeability, as well as the hyperfibrinolytic activity of the hematoma, are considered important factors for hematoma development [8]. A dense fibrous capsule forms in response to the products of erythrocyte breakdown, but typical membrane formation as seen in chronic SDH is rare [4–6]. Some authors described this membrane on CT scans as a bright enhanced rim enveloping the hematoma [9]. Our case also showed an enhanced rim. Because the enhanced lesion may be confused with a brain abscess or tumor, it requires attention.

Chronic EDH is known to be more likely to arise from venous EDH, as in our case, than from a usual arterial EDH [10]. The reason for this is not clear, but we think that a venous EDH may spread out more slowly than an arterial EDH, facilitating the development of a chronic hematoma. It is also more common in younger age groups, as the dura is comparatively less adherent to the inner table of the skull [6].

Unlike chronic SDH, there is no established theory of the form of internal contents in chronic EDH. Some authors have found “liquefaction” in the cavity, needing only burr hole trephination [9,11]; others have found that the clots were almost always solid even after 1 month [12]. This issue has important implications for surgical treatment. Based on our case, we think that wide craniotomy is preferable to burr hole drainage considering this issue.

As we all know, the vast majority of EDH cases are self-limited. Therefore, many clinicians have focused on its treatment in the acute phase (e.g., surgical evacuation). However, as our case shows, EDH can transform into a chronic form and provoke a delayed neurologic deficit. Clinicians must keep this point in mind.

NOTES

Ethical statement
Informed consent was obtained from the patient.

Conflicts of interest
The author has no conflicts of interest to declare.

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REFERENCES

INTRODUCTION

Traumatic abdominal wall hernia (TAWH) is a relatively rare injury, accounting for only 1% of all blunt trauma admissions [1]. Traumatic flank hernia (TFH) is the most common type of these injuries [2], but trauma surgeons are not familiar with TFH, which frequently leads to misdiagnosis and delayed treatment [3]. Thus, the investigation of flank hernia with an abdominopelvic computed tomography scan is recommended when patients have high-energy blunt trauma to the torso, even in the absence of symptoms. TFH is best managed by a timely operative intervention in a patient with incarceration or strangulation [4,5]. However, the repair is complicated when the defect is large and involves all layers of the abdominal wall. Furthermore, to date, no well-defined guidelines exist on the optimal management strategy for these injuries. Herein, we describe the first successful treatment of TFH after blunt trauma using laparoscopic and open approaches with a dual tension-free repair method to maximize the strength of the herniorrhaphy.

CASE REPORT

A 46-year-old male patient whose right-sided torso had been sandwiched between industrial pressers presented to the emergency department of Dankook University Hospital. Upon admission, the patient's hemodynamics were stable. Upon physical ex-
amination, the peritoneal irritation sign with muscle guarding was positive. The patient had a minor laceration of the right chest wall and abdominal bulging with multiple abrasions in the left flank (Fig. 1). An abdominopelvic computed tomography scan showed multiple rib fractures, fractures of the transverse and spinous processes of multiple lumbar vertebrae, multiple ruptured discs in the lumbar spine, and complete abdominal wall disruption (65 × 83 mm) with herniation of the small bowel in the left flank (Fig. 2). No definite associated injuries of the intra-abdominal organs were found. The patient's Injury Severity Score was 17.

Even though there were no other life-threatening injuries, surgery could no longer be delayed as the peritoneal irritation sign increased over time. Herniorrhaphy was performed immediately on hospital day 3 with a laparoscopic specialist in attendance.

**Surgical technique**

A dual approach via both laparoscopic and open methods was planned. Under general anesthesia, the patient was placed in the right semi-lateral (45°) position. Laparoscopic surgery was conducted through the transabdominal approach. An 11-mm in-
fra-umbilical camera-port and three working ports (a 5-mm port in the upper midline, an 11-mm port in the lower midline, and a 5-mm port in the right lower abdomen) were placed. The TFH in the left flank was identified, which included the small bowel and the descending colon (Fig. 3A). After the exploration of the whole bowel, a superficial mesenteric laceration of the small bowel and hematoma of the transverse colon were also observed. First, the descending colon was mobilized by making an incision along the lateral peritoneal fold, exposing the bottom edge of the hernia sac. After incision of the peritoneum, total disruption of the abdominal wall, measuring about 7 × 10 cm, was revealed (Fig. 3B). A sublay mesh (Parietene Composite Mesh; Covidien, Minneapolis, MN, USA) was introduced into the abdomen. A synthetic film side was laid to face the peritoneum to prevent painful adhesion of the parietal peritoneum to the mesh. The mesh was implanted via titanium tacker and a 3-0 barbed string (V-Loc 90 Absorbable, Covidien) with a 2-cm overlap on the edge of the disrupted transversalis muscle (Fig. 3C). The posterior margin of the polypropylene mesh was fixed to the lateral border of the psoas muscle. The mesh was then buried by continuously re-suturing the peritoneum (Fig. 3D). Extracorporeal hernioplasty (i.e., the open approach) was initiated after the termination of pneumoperitoneum. Full-thickness disruption of the external and internal oblique muscles of 11 × 15 cm was observed. A muscle split dissection was performed until it faced the intracorporeally augmented mesh. The separated internal oblique muscles were approximated using a 2-0 barbed suture (2/0 Stratafix Symmetric PDS Plus; Ethicon, Raritan, NJ, USA), and an onlay mesh (Prolene Mesh, Ethicon) was anchored on the muscular layer via a 3-0 Prolene suture (Fig. 4). A Jackson-Pratt drain was placed on the mesh to prevent fluid collection. The Scarpà’s fascia was then brought and closed up to cover the mesh as the bounced-off external oblique muscles were unreachable. The total duration of the operation was 255 minutes (Video S1).

The immediate postoperative period was uneventful. The Jackson-Pratt drain was withdrawn on postoperative day 3 as the content was minimal. The patient was discharged on postoperative day 18 after placement of an abdominal binder and did not experience any hernia recurrence during a 6-month follow-up period (Figs. 5, 6).

**DISCUSSION**

A recent classification suggested by the largest single-institution series of TAWH categorizes it into three types: anterior abdominal, flank, and lumbar, which are affected by the rectus abdominis muscle, the oblique muscles, and the superior/inferior lumbar triangles, respectively [2]. TAWH does not always require operative repair, even though they are closely associated with other injuries. Several retrospective studies reported that delayed repair of TAWH was associated with fewer perioperative complications and lower recurrence [1]. The current consensus for patients with TAWH is conservative care unless the patient has hemodynamic instability or peritonitis [2]. In our case, the patient pre-

![Fig. 3. Intracorporeal approach for laparoscopic hernia repair. (A) Identification of traumatic flank hernia, (B) exposure of the muscle defect, (C) implantation of the synthetic mesh, and (D) closure of the peritoneum.](https://doi.org/10.20408/jti.2021.0008)

![Fig. 4. Extracorporeal approach for hernia repair after the identification of the total disruption of the external and internal oblique muscles. (A) Approximation of the internal oblique muscle, and (B) completion of additional mesh coverage.](https://doi.org/10.20408/jti.2021.0008)
sented with persistent abdominal tenderness. Thus, laparoscopy was attempted with the double purpose of seeking other intra-abdominal injuries and implanting a sublay mesh.

The open approach is traumatic and requires major dissection to expose the damaged planes and locate the defect, but it has the advantage of enabling complete parietal reconstruction. The laparoscopic approach has the advantages of being minimally invasive, producing less pain, resulting in a shorter length of hospital stay, and causing fewer wound complications. It also prevents major dissections, identifies the exact location of the lesion, and enables better visualization. However, the laparoscopic approach allows neither parietal reconstruction nor repair under controlled tension [4–6]. In our case, the sublay mesh implanted via laparoscopy alone was not enough to endure the large defect accompanying severe disruption of the external oblique muscle. Therefore, additional coverage of an onlay mesh was performed via the open approach.

A sandwich technique that utilizes both onlay and sublay meshes for hernioplasty has been reported for lumbar hernia repair in many studies [7,8]. Mesh fixation in TFH repair is highly limited because the shearing force of the injury usually disrupts the musculofascial attachments to adjacent structures based on our previous experience. This technique is particularly well-suited for repairing TFH as well as lumbar hernia, where ten-
sion-free mesh fixation is anticipated from a severe injury. However, only the open approach has been used to perform the sandwich technique utilizing subcutaneous and extraperitoneal spaces according to the previous literature [9]. This is the first report using the dual tension-free repair method, which is a hybrid method taking advantage of both laparoscopic and open approaches.

In conclusion, the dual tension-free repair method seems to be a feasible option for the treatment of large TFH, especially when concomitant intra-abdominal injuries are suspected. Although TFH is rare, the long-term success of this technique needs to be assessed to further prove its efficacy and safety. Trauma surgeons should reflect on the importance of making a correct preoperative assessment and an adequate choice of surgical techniques to offer the patients the best possible results.

SUPPLEMENTARY MATERIALS

Video S1. Dual repair of traumatic flank hernia using laparoscopic and open approaches
Supplementary material is available from: https://doi.org/10.20408/jti.2021.0008.

NOTES

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All authors read and approved the final copy of the manuscript.

REFERENCES

Concomitant bladder injuries have been reported to occur in 5% to 6% of pelvic ring injuries [1]; these two injuries usually occur simultaneously. However, relatively little research has investigated delayed genitourinary complications that occur late after surgery. A symphyseal plate is commonly used as a fixation method for anterior pelvic ring injuries. Because it is fixed across the joint, micro-movement occurs, and metal plate breakage or screw loosening is common. To the best of our knowledge, only three cases of delayed bladder perforation due to screw loosening after symphyseal plate fixation in anterior pelvic ring injury have been reported worldwide, and no such cases have yet been reported in Korea. Since the authors experienced this very rare complication after pelvic ring surgery, we report this case along with a literature review.

Keywords: Pelvic ring injury; Delayed bladder perforation; Screw loosening

Pelvic ring injuries have high mortality and morbidity rates, and they are difficult to treat because accompanying injuries to the pelvic organs, genitourinary organs, and neurovascular tissues are common. Genitourinary injuries are common comorbid injuries that have been reported to occur in 5% to 6% of all pelvic ring injuries. However, these injuries usually occur simultaneously with the pelvic ring injury, whereas relatively little research has dealt with genitourinary injuries that occur after treatment of a pelvic ring injury. To the best of our knowledge, only three cases of delayed bladder perforation due to screw loosening after symphyseal plate fixation in anterior pelvic ring injury have been reported worldwide, and no such cases have yet been reported in Korea. Since the authors experienced this very rare complication after pelvic ring surgery, we report this case along with a literature review.

Keywords: Pelvic ring injury; Delayed bladder perforation; Screw loosening

INTRODUCTION

Concomitant bladder injuries have been reported to occur in 5% to 6% of pelvic ring injuries [1]; these two injuries usually occur simultaneously. However, relatively little research has investigated delayed genitourinary complications that occur late after surgery. A symphyseal plate is commonly used as a fixation method for anterior pelvic ring injuries. Because it is fixed across the joint, micro-movement occurs, and metal plate breakage or screw loosening is common. To the best of our knowledge, only three cases of bladder perforation due to screw loosening have been reported worldwide [2–4]. Moreover, delayed bladder perforation due to screw loosening after fixation of the symphyseal plate has not been reported in Korea. In this study, we report a case of delayed bladder perforation due to screw loosening after anterior pelvic ring surgery using a symphyseal plate along with a literature review.

CASE REPORT

A 64-year-old male patient was presented to the emergency room after a motorcycle accident. Abdominal pelvic computed tomography showed symphysis pubis diastasis, right superior and inferior ramus fractures, and bilateral anterior and posterior sacroiliac joint injuries (Fig. 1), which corresponded to an anterior posterior compression type III pelvic ring injury. In addition, there was extravasation of the right internal iliac artery branch with hypotension; therefore, emergency angioem-
bolization was performed. Immediately after embolization, orthopedic damage control surgery (supracetabular external fixation) was performed. A Schanz screw was inserted into the supra-acetabular area. The right sacrum, which was more displaced than the left, was reduced using a Schanz screw as a joystick, and a sacroiliac screw was inserted. An external fixation device was then connected.

The patient was hemodynamically stabilized, and definitive orthopedic surgery was performed on the 8th day after the injury. Under general anesthesia, the patient was placed in a supine position on a radiolucent table. A sacroiliac screw (7.3 mm cannulated cancellous screw; DePuy Synthes, Raynham, MA, USA) was inserted into the left sacrum. The fracture site was exposed using a modified Stoppa approach. The pubic diastasis was reduced using a bone clamp, and the ramus fracture was naturally reduced due to ligamentotaxis. Fixation was then performed using a symphyseal plate (Matta pelvic plate; Stryker, San Jose, CA, USA). Although there is no significant difference between a conventional plate and a locking plate [5], a conventional plate was used because we assumed that plate breakage was more likely to occur with a locking plate due to the micro-motion of the symphysis pubis. As pubic symphysis diastasis accompanied the ramus fracture, it was fixed with a 14-hole symphyseal plate to obtain sufficient fixation force. The proximal screws were fixed to the ilium through the lateral window (Fig. 2). The external fixator was removed 6 weeks after surgery (Fig. 3) and partial weight-bearing using a walker was started. Loosening of the screw was observed 6 months after surgery, screw breakage and additional loosening were observed 8 months after surgery, and plate breakage was observed 1 year and 5 months after surgery (Fig. 4), but the patient did not complain of any discomfort and was able to walk independently. Hematuria and dysuria occurred 1 year and 10 months after surgery, and the patient visited the urology department. Cystoscopy revealed a screw head. Therefore, after 1 week, under general anesthesia, implant removal and partial

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**Fig. 1.** Initial radiograph showing anterior posterior compression type III pelvic ring injury. (A) A three-dimensional reconstruction view of the pelvis, (B) anteroposterior view of the pelvis, and (C, D) computed tomography axial view. The red circle indicates the crescent fracture. The patient provided written informed consent for publication of the research details and clinical images.
Fig. 2. (A) Eight days after damage control surgery using an external fixator, (B) definitive surgery was performed using a symphyseal plate. The patient provided written informed consent for publication of the research details and clinical images.

Fig. 3. After 6 weeks of external fixation, the external fixator was removed. (A) Anteroposterior view of the pelvis, (B) pelvis inlet view, and (C) pelvis outlet view. The patient provided written informed consent for publication of the research details and clinical images.

Fig. 4. Symphyseal plate breakage and screw loosening and breakage were observed on (A) pelvis anteroposterior and (B) outlet images 17 months after surgery. The patient provided written informed consent for publication of the research details and clinical images.
cystectomy were performed by an orthopedic surgeon and urology surgeon (Fig. 5). During the procedure, it was found that the symphysis pubis and the bladder were adhered, and an inflammatory reaction was observed. After surgery, hematuria improved, and the patient was able to walk independently.

**DISCUSSION**

To the best of our knowledge, only three cases of delayed bladder perforation due to orthopedic implants after pelvic ring injury have been reported worldwide, and this is the first reported case in Korea.

Fridman et al. [2] previously reported a patient with spontaneous voiding of an implant after fixation of the pubic symphysis, which was similar to our case. In the case of Peled et al. [4], there was a bladder injury at the time of injury; therefore, the possibility that the screw entered the injured area could not be excluded. Hosseini et al. [3] also reported a case of delayed bladder perforation due to screw loosening 7 weeks after pelvic surgery, which was treated with cystoscopic screw removal. Unlike the above cases, our case was accompanied by breakage of the symphyseal plate and loosening of the screw, and the presence of a screw in the bladder was confirmed by a cystoscope. Using the previous incision, the broken plate and screws were removed, and the bladder was repaired.

The pubic symphysis is a fibrous joint that connects the pubis, and micromotion occurs during walking. Therefore, when a symphyseal plate is fixed to the anterior pelvic ring, screw loosening, screw breakage, and plate breakage are common [6]. In addition, in this case, a long plate was used because of the diastasis and pubic ramus fracture that caused the unbalanced fixation and likely promoted screw loosening and breakage of the plate. Therefore, we suggest using a 2- or 4-hole-longer plate on the left side to balance the fixation and a dual plate or a ramus screw to increase the strength of fixation.

Although clear timing and indications for symphyseal plate removal have not been established [7], in our case, it is thought that bladder perforation could have been avoided if the plate had been removed at an early stage when screw loosening was observed.

According to the European Association of Urology guidelines [8], hematuria, dysuria, and recurrent urinary tract infections (UTIs) have been suggested as symptoms of unrecognized bladder injury. Kaldenbach and Roth [9] reported hematuria and pain as the main symptoms of delayed bladder injury, which are similar to the symptoms of lower UTIs. The patients in the present case and those in the three cases described above complained of hematuria and dysuria. Therefore, if urinary symptoms appear after orthopedic pelvic surgery, it is necessary to pay close attention to the diagnosis rather than dismiss it as a simple lower UTI.

We report the rare complication of delayed bladder perforation after pelvic ring surgery using a symphyseal plate and suggest that if screw loosening is observed, attention should be paid to urinary symptoms.
NOTES

Ethical statement
Informed consent was obtained from the patient.

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

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All authors read and approved the final copy of the manuscript.

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Foot drop is defined as a significant weakness of ankle and toe dorsiflexion caused by weakness or paralysis of the tibialis anterior muscles. The most common cause of foot drop is lumbar degenerative disc herniation, particularly at L4/5. We present a rare case of spinal cord injury accompanied by a thoracolumbar lesion that presented with bilateral foot drop. A 69-year-old male patient presented with sudden-onset severe bilateral leg pain and bilateral foot drop. Radiologic findings revealed T12 spondylitis compressing the conus medullaris. He had undergone vertebroplasty for a T12 compression fracture after a fall 6 months before. A physical examination showed bilateral foot drop, paresthesia of both L5 dermatomes, increased deep tendon reflex, and a positive Babinski sign. An acute bilateral L5 root lesion and a conus medullaris lesion were suspected based on electromyography. A surgical procedure was done for decompression and reconstruction. After the operation, bilateral lower extremity muscle strength recovered to a good grade from the trace grade, and the patient could walk without a cane. The current case is a very rare report of bilateral foot drop associated with T12 infectious spondylitis after vertebroplasty. It is essential to keep in mind that lesions of the thoracolumbar junction can cause atypical neurological symptoms. Furthermore, understanding the conus medullaris and nerve root anatomy at the T12–L1 level will be helpful for treating patients with atypical neurological symptoms.

**Keywords:** Foot drop; Compression fractures; Spondylitis; Electromyography

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**INTRODUCTION**

Foot drop is defined as a significant weakness of ankle and toe dorsiflexion caused by weakness or paralysis of the tibialis anterior muscles. The most common cause of foot drop is an impairment of the peroneal nerve or L5 nerve root. However, bilateral foot drop is rare in peripheral lesions, and central nervous lesions should be considered in such cases [1–3].

The thoracolumbar junction is anatomically composed of the spinal cord, epiconus, conus medullaris, and cauda equina. Therefore, lesions in the thoracolumbar spine (T12–L1) can also present upper motor neuron signs and nonspecific neurological symptoms of the lower extremities [3]. In addition, middle column fracture can cause significant compression of the spinal
canal, leading to substantial neurological symptoms, including foot drop.

Infectious spondylitis after vertebroplasty has been reported in rare instances [4]. Severe neurological deficits are also rare in cases of spondylitis induced by spine fractures, with a prevalence of 3% [5]. Herein, we report a very rare case of bilateral foot drop caused by a T12 vertebral compression fracture accompanied by infectious spondylitis after vertebroplasty and suggest a possible mechanism.

CASE REPORT

A 69-year-old male patient was admitted with complaints of gait disturbance, paralysis of both legs, and leg pain for 2 weeks. Six months prior to admission, he had undergone vertebroplasty for T12 compression fracture, after he fell on his buttocks. On admission, he had no signs of infection such as fever, malaise, night sweat, or weight loss. He had been diagnosed with pulmonary tuberculosis 3 months before and was on antituberculosis drugs.

Neurological examination revealed severe leg pain (visual analogue scale, 7 points) and bilateral foot drop with upper motor neuron signs, including ankle clonus and the Babinski sign. Neurogenic bladder and bowel symptoms were also reported. Although bilateral foot drop was predominantly documented (motor grade, 1/5–2/5), knee flexion and ankle plantar flexion were mildly affected (motor grade, 3/5–4/5).

Computed tomography and magnetic resonance imaging revealed infectious spondylitis with abscess formation and bony destruction at the T12 vertebral body, resulting in severe compression of the conus medullaris. There was no lesion that could cause L5 radiculopathy at the L4–5 and L5–S1 levels (Figs. 1, 2). However, a bilateral L5 root lesion and conus medullaris lesion were revealed by electromyography (EMG).

Surgical resection of the bony fragment compressing the spinal cord was performed using a posterior approach. After pedicle screw fixation from T9 to L2, modified pedicle subtraction osteotomy was performed to decompress and correct the affected vertebrae. A mesh cage filled with autogenous bone was inserted between the lower end plate of T12 and the osteotomy surface of L1. After placement of an L2 laminar hook and rod,

Fig. 1. (A) T2-weighted sagittal and (B) axial magnetic resonance imaging reveal a compression fracture at T12 with spinal cord compression. The L5–S1 disc is relatively preserved on the patient’s magnetic resonance imaging. The patient provided written informed consent for the publication of the research details and clinical images.
Posterolateral bone grafting in the fixation region was performed with an autogenous bone graft (Fig. 3).

Postoperatively, improvements were observed in radiating pain (visual analogue scale, 3 points) and motor weakness. Bilateral lower extremity muscle strength recovered to a good grade, and foot drop also improved immediately after surgery. The presence of a T12 fracture-induced bilateral L5 root lesion was verified.

In addition, for more quantitative measurements of preoperative and postoperative motor recovery, active range of motion (ROM) angles of ankle dorsiflexion during knee flexion and extension were measured (Fig. 4). Surface EMG was used to measure the percent reference voluntary contraction (%RVC) values of ankle dorsiflexion (Table 1). A remarkable increment in the %RVC of the bilateral tibialis anterior muscles was observed postoperatively. Consequently, we were able to objectively confirm not only manual muscle test results of ankle dorsiflexion, but also the postoperative improvement in active ROM and %RVC values.

The causative pathogen was not identified in microbiological specimens, and al granuloma was not found in the biopsy sample. Empirical antibiotics and an antituberculosis regimen were administrated. On day 53, the patient was discharged with a good motor grade in both lower extremities, without bladder or bowel symptoms. The antituberculosis medication continued for 40 days.

**DISCUSSION**

The incidence of infectious spondylitis after percutaneous augmentation, including vertebroplasty, is low (0.46%), and the mean interval between the completion of augmentation and revision operation is 118.4 days [6]. In general, although severe back pain is a common symptom of infectious spondylitis [7,8], in our case, weakness due to cord compression first developed...
Fig. 4. In order to obtain quantitative measurements of preoperative and postoperative motor recovery, active range of motion angles of ankle dorsiflexion during (A) knee extension and (B) flexion were measured. POD, postoperative day.

Table 1. The percent reference voluntary contraction values of bilateral TA and GCM during ankle dorsiflexion

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preoperative</th>
<th>POD 14</th>
<th>POD 28</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>TA</td>
<td>22.30</td>
<td>0.71</td>
<td>17.79</td>
</tr>
<tr>
<td>GCM</td>
<td>14.11</td>
<td>0.75</td>
<td>11.19</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>18.20</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Max (%)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preoperative</th>
<th>POD 14</th>
<th>POD 28</th>
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<tbody>
<tr>
<td></td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>TA</td>
<td>23.88</td>
<td>0.79</td>
<td>21.41</td>
</tr>
<tr>
<td>GCM</td>
<td>20.40</td>
<td>0.81</td>
<td>12.21</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>22.14</td>
<td>0.80</td>
</tr>
</tbody>
</table>

TA, tibialis anterior muscle; GCM, gastrocnemius muscle; POD, postoperative day.

164 days after vertebroplasty.

Neurological symptoms may vary according to the level of the lesion. Symptoms may manifest as paraplegia due to spinal cord compression, various sensory or motor deficits associated with cauda equina or root compression, and rectal or urinary incontinence [9]. The thoracolumbar junction (T12–L1), which is the site of cord termination, anatomically consists of the spinal cord, epiconus, conus medullaris, and cauda equina. A compressive lesion at the thoracolumbar junction causes various nonspecific neurological symptoms, including foot drop [3]. However, bilateral root paralysis is a rare pathologic condition.

Miwa et al. [3] reported that foot drop caused by a thoracolumbar spine lesion recovered much better than foot drop caused by a lumbar spine lesion. This suggests that the pathogenesis of paralysis in the 2 lesions may be different.

According to Wall et al. [10], the axial cross-section of T12–L1 shows that the spinal cord is surrounded by the L1 to L5 roots, and among these, the L5 ventral root is medially located (Fig. 5). Based on this anatomy, we further verified how a compression fracture at the T12 level caused an L5 root lesion, subsequently leading to bilateral foot drop.

It has been reported that an L5 root lesion resulting from thoracolumbar spine fracture is anatomically possible [3,11], but this patient’s clinical presentation was very rare, as it was due to infectious spondylitis in a T12 compression fracture after vertebroplasty. To the best of our knowledge, no similar case has been reported before.

Moreover, by using a wireless EMG system (Delsys Inc., Boston, MA, USA) for motor recovery measurements, we were able to obtain more objective data. Notably, the recovery of the soleus and gastrocnemius muscles was differentiated by presenting active ROM angles of ankle dorsiflexion during knee extension and knee flexion. This aspect of the present case also bears some significance. As more cases are gathered in the future, further evaluation of motor recovery patterns is required.
In conclusion, it is essential to keep in mind that lesions of the thoracolumbar junction can present with atypical neurological symptoms, including bilateral foot drop. Understanding the conus medullaris and nerve root anatomy, as well as performing EMG, will be helpful in treating patients with atypical neurological symptoms.

**NOTES**

**Ethical statement**
Informed consent was obtained from the patient.

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

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**Author contributions**
Conceptualization: KHN, YBS; Data curation: DHK; Formal analysis: YBS, DHK; Project administration: KHN; Visualization: DHK, YBS; Writing—original draft: DHK, KHN; Writing—review & editing: KHN, YBS, MJH, BCK, IHH. All authors read and approved the final copy of the manuscript.

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Case Report

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Euisung Jeong, MD ©, Hyunseok Jang, MD ©, Younggoun Jo, MD, PhD ©, Yunchul Park, MD ©, Naa Lee, MD ©, Jungchul Kim, MD, PhD ©
Division of Trauma, Department of Surgery, Chonnam National University Hospital, Chonnam National University Medical School, Gwangju, Korea

Traumatic abdominal wall hernia is a very rare clinical entity. Herein, we report the case of a patient who was transferred from a local clinic to the emergency department because of left lower abdominal pain. Initially, an intra-abdominal hematoma was observed on computed tomography and no extravasation was noted. Conservative treatment was initiated, and the patient’s symptoms were slightly relieved. However, though abdominal pain was relieved during the hospital stay, bowel herniation was suspected in the left periumbilical area. Follow-up computed tomography showed traumatic abdominal wall hernia with hemoperitoneum in the abdomen. We performed a laparoscopic exploration of the injury site and hernia lesion. The anterior abdominal wall hernia was successfully closed.

Keywords: Nonpenetrating wounds; Abdominal injuries; Contusions; Traumatic diaphragmatic hernia

INTRODUCTION

Traumatic abdominal wall hernia (TAWH) is a very rare clinical entity. The defect is caused by the blunt injury of the abdominal wall, and intestinal prolapse occurs through this site. In such a situation, TAWH is often difficult to evaluate through a bedside physical examination because intra-abdominal muscle rupture occurs without skin penetration, and bruising and abdominal tenderness are often found when examining the area near the injury.

In patients with TAWH, the presence of other accompanying intra-abdominal injuries should be evaluated, and if any injury is suspected, either conservative or surgical treatment should be considered. However, decision-making might be challenging.

Herein, we report the case of a patient with a traumatic abdominal wall hernia with hemoperitoneum caused by a blunt injury. Initially, an intra-abdominal hematoma was observed on computed tomography (CT). On re-examination by interventional angiography, no extravasation was observed. Conservative treatment was initiated, the patient’s symptoms were slightly relieved, and the results of laboratory investigations showed improvement. However, although the abdominal pain was relieved during the hospital stay, bowel herniation was suspected in the left periumbilical area. On follow-up CT, a TAWH with slight he-
moperitoneum was seen in the abdomen. We performed laparoscopic exploration of the injury site and the anterior abdominal wall hernia was successfully closed. This case demonstrated the feasibility of a laparoscopic approach and intervention in cases of TAWH to detect suspected injuries.

CASE REPORT

A 64-year-old male patient was transferred from a local clinic to the emergency department because of left lower quadrant abdominal pain. The patient had been struck on the abdomen with rebar 5 hours ago. His initial vital signs were stable. On physical examination, there was pain in the left lower quadrant and mild rigidity throughout the abdomen. He had underlying hypertension and diabetes mellitus, and was not on any anticoagulant medications. The laboratory findings were as follows: white blood cell count 17.7 × 10³/μL (normal reference range, 4.8–10.8 × 10³/μL); hemoglobin, 12.2 g/dL; aspartate aminotransferase, 23 IU/L; alanine aminotransferase, 14 IU/L; total bilirubin level, 0.59 mg/dL; and C-reactive protein, 0.6 mg/dL (normal reference range, 0.0–0.3 mg/dL). An abdominal CT scan showed suspected mesenteric injury with a small amount of hemoperitoneum in the descending portion of the aorta and lateral aspect of the left common iliac artery with a contusion injury on the anterior abdominal wall (Fig. 1).

Abdominal aortography was initially performed in the emergency department. The left common iliac artery and both lumbar arteries were also examined through abdominal angiography, and no evidence of active bleeding was found.

The patient was admitted and received conservative treatment. On day 4 of admission, slight abdominal tenderness persisted in the left lower quadrant, but the rigidity of the abdomen and the results of laboratory tests showed improvement. The white blood cell count was 7.2 × 10³/μL (normal reference range, 4.8–10.8 × 10³/μL) and the C-reactive protein level was < 0.6 mg/dL (normal reference range, 0.0–0.3 mg/dL). However, although the symptoms had subsided, a reducible bowel herniation lesion was palpable near the area of contusion over the left lower part of the abdomen when the patient was in an upright position. When herniation occurred, the patient had severe splanchnic pain; hence, a CT examination was performed again. A slight focal defect was found in the left anterior abdominal wall, and a small amount of hemoperitoneum persisted in the intra-abdominal cavity without evidence of active bleeding (Fig. 2).

Due to the recurrence of symptoms of herniation and intra-abdominal fluid collection, immediate repair of the abdominal hernia was planned. As the CT scan showed hemoperitoneum, we decided to perform a laparoscopic exploration of the intra-abdominal cavity and herniation site. The laparoscopic examination showed a small amount of hemoperitoneum throughout the entire abdominal cavity without injuries to the other intra-abdominal organs.

Fig. 1. (A) Hematoma (white arrow) is seen on the initial computed tomographic scan. (B) The Hounsfield unit values of the hematoma lesions, ranging from 27 to 35, suspected mesenteric injury (white arrows) with a small amount of hemoperitoneum in the descending part of the aorta and lateral aspect of the left common iliac artery. Written informed consent for the publication of the images was obtained from the patient.
On the left side of the umbilicus, a 5 × 4 cm defect in the abdominal wall was found. The defect showed loss of fascia and peritoneum, and muscle was exposed (Fig. 3). After locating and marking the abdominal wall defect externally, closure was performed layer-by-layer with non-absorbable suture material (Fig. 4). The patient was discharged 8 days after surgery with no other complications. Abdominal CT follow-up was performed 1 month after discharge and showed an improvement of hemothorax at the herniation site.

DISCUSSION

TAWH is a rare occurrence in patients with trauma, although some cases caused by bicycle or motorcycle handlebar injuries have been reported. Reports have indicated that it accounts for fewer than 1% of blunt trauma injuries [1,2].

In events with blunt trauma, injuries often result in bruising of the skin and bulging of the abdominal wall with hematoma. The surrounding muscles, tendons, and bones are often involved. This might lead to a delay in diagnosing the wall defects or other organ injuries due to masking of the symptoms [3,4].

Fig. 2. A focal defect (white arrow) was found in the left anterior abdominal wall on the follow-up computed tomographic scan. Written informed consent for the publication of the image was obtained from the patient.

Fig. 3. Laparoscopic finding of the hernia sac in the anterior abdominal wall. Written informed consent for the publication of the image was obtained from the patient.

Fig. 4. (A) After locating the defect internally, the area was marked externally. (B) A minimal laparotomy incision was made for the herniation site and closure was performed. Written informed consent for the publication of the images was obtained from the patient.
Patients with anterior TAWH on clinical examination are more likely to have an associated intra-abdominal injury requiring surgical intervention. Hence, patients with abdominal wall hernias following trauma should receive a CT scan to rule out intra-abdominal injury [2,5]. Most TAWHs on the anterior abdominal wall do not show skin defects due to the elastic features of the skin, and the herniation defects occur on the rectus abdominus sheaths [6,7].

However, in our case, anterior TAWH was not clearly identified on the initial examination. Conservative treatment was administered following abdominal angiography. Upon the later onset of TAWH symptoms, CT was performed again, and it showed persistent hemoperitoneum in the abdominal cavity and a clear anterior abdominal wall defect. Based on these findings, it was decided to check for other accompanying intra-abdominal injuries.

There have been debates regarding local wound exploration versus midline exploratory laparotomy to rule out intraabdominal injuries, and Yegane et al. [6] insisted on the need for exploratory laparotomy.

In this patient, because a mesenteric injury with a small amount of hemoperitoneum was suspected, exploration of the injury site by local wound exploration might have been difficult, so midline exploratory laparotomy might have been considered to rule out intraabdominal injuries. Instead of midline laparotomy, we decided to perform laparoscopic exploration with mini-laparotomy repair.

In the laparoscopic view, the defect at the TAWH site was well visualized. After locating the entire hernial sac through an intra-abdominal view, a minimal incision was made. Due to the large size of the hernia sac and defect itself, we approached it by minimal incision in case mesh insertion would be necessary. However, the fascia was fairly firm, and TAWH was successfully repaired by primary repair without mesh insertion.

Several reports of TAWH have raised questions about whether urgent laparotomy is necessary; instead, the possibility of delayed repair of herniation or non-surgical treatment has been discussed. It is difficult to consider urgent laparotomy as a standard treatment method because of its invasiveness and the possibility of recurrence of the hernia [8,9]. However, in some cases, the defect can grow and muscle atrophy might progress, making direct repair difficult.

Standard methods of laparotomy directly approach the herniation site through incisions directly in the weak layers where herniation has occurred; this direct approach might aggravate the hernia. Furthermore, several cases have been reported suggesting that direct access and immediate hernia repair may increase the rate of surgical site infection and recurrence. Some clinicians recommend delaying hernia repair, as delayed closure allows the tissue and hematoma of the surrounding injury site to resolve, after which the margins of the muscle can be easily located and the developed hernia sac can be easily found [10,11].

In situations where an intra-abdominal injury cannot be completely excluded, such as in this case, it may be insufficient to check the intra-abdominal cavity by open laparotomy, and diagnosis could be missed through a direct approach due to a limited view and cavity.

With recent technical improvements, herniation lesions can be repaired and intra-abdominal examinations can also be easily performed through a laparoscopic approach. Therefore, exploration and laparoscopic interventions, such as repair, can be considered. Even in cases of delayed hernia, minimally invasive laparoscopic surgery could be an alternative treatment option. The conventional treatment for hernia repair has mostly focused on the repair of the hernia itself [12]. However, in traumatic blunt injuries, it is often difficult to rule out a hollow viscus organ injury.

Since there may be cases in which detection of an accompanying injury is also necessary, intraperitoneal identification should be considered [13–15]. In such situations, if the patient’s vital signs are stable, a minimally invasive intervention using the laparoscopic approach is required.

Laparoscopic treatment must be selected cautiously. Depending on the location of the blunt injury, the degree of herniation, and the hernia’s content and symptoms, conservative treatment is often feasible and safe. Since there have been several cases of observation without repair, the range of indications should be maintained at an appropriate level [6]. In conclusion, in cases of TAWH, a laparoscopic approach can be helpful for herniation repair site visualization and further exploration of other injuries.

NOTES

Ethical statement
Informed consent was obtained from the patient.

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

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All authors read and approved the final copy of the manuscript.

REFERENCES

Very large haematoma following the nonoperative management of a blunt splenic injury in a patient with preexisting liver cirrhosis: a case report

Euisung Jeong, MD, Younggoun Jo, MD, PhD, Yunchul Park, MD, PhD, Jungchul Kim, MD, PhD, Hyunseok Jang, MD, PhD, Naa Lee, MD

Division of Trauma, Department of Surgery, Chonnam National University Hospital, Gwangju, Korea

INTRODUCTION

The spleen is the most commonly injured organ after blunt abdominal trauma. Nonoperative management (NOM) is the standard treatment for blunt splenic injuries in haemodynamically stable patients without peritonitis. Complications of NOM include rebleeding, new pseudoaneurysm formation, splenic abscess, and symptomatic splenic infarction. These complications hinder the NOM of patients with blunt splenic injuries. We report a case in which a very large haemorrhagic fluid collection that occurred after angio-embolisation was resolved by percutaneous drainage in a patient with liver cirrhosis who experienced a blunt spleen injury.

Keywords: Hematoma; Spleen; Wounds and injuries

The spleen is the most commonly injured organ after blunt abdominal trauma, mainly because of its highly vascularised parenchyma and anatomic location. Nonoperative management (NOM) is currently the standard treatment for blunt splenic injuries (BSIs) in haemodynamically stable adults and children with no signs of peritonitis [1–3]. NOM includes serial physical examinations, frequent haematocrit measurements, bed rest, and limited oral intake, and it aims to avoid unnecessary surgery and decrease the risk of overwhelming post-splenectomy sepsis [4,5]. With advances in NOM, angio-embolisation (AE) has been introduced to help reduce the need for splenectomy, especially in patients with severe spleen injuries [6,7]. The complications of NOM with AE include rebleeding, new pseudoaneurysm formation, splenic abscess, and symptomatic splenic infarction; the occurrence of these complications may necessitate late splenectomy or radiological intervention [8]. Patients with BSIs who have liver cirrhosis (LC) have higher risks of NOM failure and mortality than those without LC [9]. We report a case in which a very large haematoma occurred in a patient with BSI and alcohol-associated cirrhosis undergoing NOM with AE. The patient was successfully treated with percutaneous drainage alone and did not require surgical intervention.
CASE REPORT

A 42-year-old male patient was transferred to Chonnam National University Hospital via a local hospital 6 hours after a car accident. He had been receiving medication for diabetes and alcohol-associated hepatitis for the last 8 years and had Child-Turcotte-Pugh class A cirrhosis. On arrival, he was alert and his blood pressure was 80/40 mmHg, heart rate was 116 beats per minute, respiratory rate was 20 breaths per minute, body temperature was 36.7°C, and peripheral oxygen saturation was 97%. Transfusion of two units of packed red blood cells had been performed at another hospital. After resuscitation, his blood pressure was 120/80 mmHg. On palpation, the abdomen was soft but mildly distended. He had no concomitant abdominal injury, abdominal tenderness, or signs of peritonitis. Focused assessment with sonography in trauma showed fluid collection in the Morrison’s pouch, splenorenal pouch, and pelvis. Abdominal computed tomography (CT) showed a laceration injury with extravasation of contrast material from the spleen and a large haemoperitoneum (Fig. 1). Celiac arteriography revealed active bleeding in the spleen. The splenic artery branches were embolized using micro-coils and gelatin sponges (Fig. 2). Subsequently, he was admitted to the intensive care unit for close observation. After 3 days in intensive care unit, he was transferred to the general ward because all his vital signs were stable and there were no changes in the laboratory test results and physical examination findings.

Abdominal CT performed after 2 weeks of hospitalization showed a very large collection of liquefied haemorrhagic fluid (17 × 10 cm) in the left subphrenic area that extended up to the area of the splenic injury (Fig. 3). There were no changes in haematocrit levels and abdominal physical examination findings, and the patient’s vital signs were stable. Therefore, we performed percutaneous drainage on the following day, and a significant amount of old blood was drained. Subsequently, a considerable amount of bloody fluid continued to be drained. Abdominal ultrasonography performed after 5 weeks of hospitalization showed improvement of the haematoma in the left subphrenic area, and the percutaneous drain was removed. The patient was discharged on the following day.

DISCUSSION

Over the past 2 decades, NOM has been shown to be an effective option for the management of blunt abdominal injuries in haemodynamically stable patients [1,2]. Recent studies have shown that approximately 65% of adult patients with BSIs received NOM, with the failure rate ranging from 4.2% to 13.0% in appropriately selected cases [10,11]. The predictors of NOM failure include older age, a higher Injury Severity Score, a higher splenic injury grade (grades 4 and 5), need for blood transfusion, CT findings of contrast extravasation or “blush,” and hypotension on admission [12,13]. With the evolution of NOM, AE has been
used instead of observation alone in selected patients, especially those with high-grade splenic injuries, to increase the rate of splenic salvage [6,7]. AE seems to be an effective treatment option for patients with CT findings of pseudoaneurysm or contrast extravasation, who have been reported to have the highest risk of ongoing bleeding or subsequent rebleeding. There have been reports of patients developing splenic abscess or symptomatic splenic infarction and requiring late splenectomy or percutaneous intervention [8].

Our patient experienced a grade 3 BSI and showed contrast extravasation on abdominal CT. We performed NOM after AE because the patient became haemodynamically stable after transfusion and resuscitation and had no concomitant extra-abdominal injuries. Abdominal CT performed 2 weeks later showed a large amount of liquefied haemorrhagic fluid in the left subphrenic area. Despite the possibility of rebleeding, the haematoma and necrotic tissue of the spleen seemed to have changed after AE. If abdominal CT had been performed 1 week after AE, this process would have been better seen. Our patient had preexisting alcohol-associated LC (Child-Turcotte-Pugh class A).

Fig. 2. (A) The angiography show active bleeding in the spleen. (B) Embolization of the splenic artery branches using micro-coils and a gelatine sponge was done. Written informed consent for the publication of the images was obtained from the patient.

Fig. 3. Follow-up computed tomography of (A) axial and (B) coronal view after 2 weeks of hospitalization, showing a large liquefied haemorrhagic fluid collection in the left subphrenic area communicating with the splenic injury. Written informed consent for the publication of the images was obtained from the patient.
Splenomegaly occurs in patients with LC due to portal hypertension-induced venous engorgement, reticuloendothelial cell hyperplasia, fibrogenesis, and increased blood flow through the spleen accompanied by an increased number of peripheral arterioles. Furthermore, most patients with LC have thrombocytopenia and coagulopathy, which have been shown to promote bleeding in both surgical and medical conditions. Moreover, malnutrition, hypoalbuminemia, and hyperbilirubinemia, which are commonly observed in patients with LC, adversely affect the outcomes of patients with various diseases. The effects of LC on patient management and outcomes have not been sufficiently studied. A report published in 2003 analysing 12 patients with BSIs and cirrhosis stated that LC adversely affected both NOM and survival rates, and the NOM salvage rate was only 8% [14]. Another study of 20 patients with BSIs found that LC was associated with high operative rates, low NOM salvage rates (30%), and high surgical morbidity and mortality rates [15]. A recent study (n = 160) demonstrated that BSI patients with LC had higher risks of NOM failure (17% vs. 10%) and mortality (23% vs. 6%) than those without LC [9]. Although patients with LC have higher NOM failure rates than those without LC and our patient's haematoma was very large, considering the benefits of spleen preservation and the risks associated with surgery in patients with LC, we performed percutaneous drainage and collected a large amount of liquefied haemorrhagic fluid. Although the patient was hospitalized for a prolonged time, he recovered and was discharged without any other complications.

In conclusion, clinicians should pay particular attention to NOM failure when performing NOM in patients with LC, even in patients who have low-grade spleen injuries and undergo AE. In the event of complications such as the above case, the risks associated with surgical treatment in patients with LC should be carefully considered.

NOTES

Ethical statement
Informed consent was obtained from the patient.

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

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Author contributions
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REFERENCES


GENERAL INFORMATION

The Journal of Trauma and Injury (J Trauma Inj, JTI) is an official publication of the Korean Society of Traumatology and an international, peer-reviewed open access journal. This journal is published four times per year, on the last day of March, June, September, and December. JTI was launched in June 1988 with publications in the Korean and English languages and was eventually converted to an English-only journal.

JTI aims to contribute to saving lives of patients who underwent traumatic events through active communication and exchange of study information on trauma and provision of education and training on trauma. Thus, the journal publishes original basic and clinical research on trauma-associated medical fields, such as surgeries (which include general surgery, chest surgery, orthopedic surgery, neurosurgery, plastic surgery, and head and neck surgery), gynecology and ophthalmology, emergency medicine, anesthesiology, neuro-psychiatrics, rehabilitation medicine, and radiology (which include interventional radiology). Due to the special circumstances Korea is under with North Korea, JTI also publishes basic and clinical research on battlefield trauma unique in Korea and has established ties with the Armed Forces Medical Command and Armed Forces Capital Hospital. Furthermore, this journal includes all items closely associated with medicine, disaster and department of emergency, emergency medical technicians and nurses, social infrastructures and systems, and government policies and supports.

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• Contributors: Any researcher who does not meet all four ICMJE criteria for authorship discussed above but contributes substantively to the study in terms of idea development, manuscript writing, conducting research, data analysis, and financial support should have their contributions listed in the Acknowledgments section of the article.
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