Aims and Scope

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

JTI aims to provide education and training in the field of trauma and to promote communication and information exchange among medical staff, ultimately helping to save the lives of injured patients.

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

The regional scope is mainly Korea, but JTI welcomes submissions from researchers worldwide.

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INTRODUCTION

Pediatric carpal fractures are clinically rare due to anatomical factors and diagnostic challenges. The carpal bones develop via secondary ossification, meaning that at birth, the ossification centers are surrounded by spherical growth plates, which act as protective barriers against injury. The lunate has no calcification until after the age of 2 years. As a child reaches adolescence, the critical bone to cartilage ratio is attained, resulting in an increased risk of carpal bone fractures. These injuries are difficult to detect due to the low sensitivity of radiographs in the cartilaginous immature skeleton, potential obscuration with physeal lines, and incompletely ossified carpal bones; therefore, subtle pathology may be easily missed. Furthermore, this particular patient group may struggle to express and localize pain, and may be difficult to examine.

Pediatric carpal fractures are commonly seen in combination with other fractures or dislocations [1,2], particularly distal radius fractures; therefore, the initial assessment requires a thorough review for secondary injuries. Damage to pediatric bones, particularly around the physeal plates and growth centers, may have long-term consequences with the potential for delayed complications [3]. The most appropriate management pathway in pediatric patients remains elusive, as does the understanding of the long-term sequelae of carpal delayed unions or nonunions in this cohort, due to their rarity.
This paper reviews the current literature on pediatric carpal fractures, utilizing our own case report as an example of delayed complications after nonoperative management. It highlights the need for long-term follow-up and vigilance for possible complications resulting from injury to the immature bones.

**CASE REPORT**

A 12-year-old boy presented following a fall onto his dominant hand from his bicycle with a closed right wrist injury (Figs. 1, 2). Radiographs demonstrated a dorsally displaced Salter-Harris type III fracture of the distal radius associated with a displaced lunate (equivalent to type IV in the Teisen classification) and ulnar styloid fracture. The patient complained of reduced sensation and “tingling” in the median nerve territory; however, the motor power remained Medical Research Council grade 5 in all muscle groups. The wrist was placed in a dorsal back-slab, after which computed tomography (CT) scanning further delineated the fracture pattern.

The following morning, the patient underwent manipulation under anesthesia with reapplication of a dorsal plaster as demonstrated in Fig. 3. Satisfactory reduction of the distal radius fracture was achieved; however, the lunate and ulnar styloid fractures remained displaced. Sensation started to return to normal the next day, but it did not settle completely.

Ten days postoperation, radiographs demonstrated maintained reduction of the distal radius (Fig. 4); therefore, the patient was switched to a lightweight cast for 5 further weeks. At 7 weeks, radiographs demonstrated satisfactory union of the distal radius but no signs of healing of the ulnar styloid or lunate fractures.

---

**Fig. 1.** Wrist x-ray images at presentation. Salter-Harris III fracture of distal radius dorsally displaced, ulnar styloid fracture, and lunate fracture. (A) Anteroposterior view. (B) Lateral view.

**Fig. 2.** Coronal computed tomography image of wrist confirming distal radius and lunate fracture.

**Fig. 3.** Intraoperative fluoroscopy demonstrating reduction of distal radius.

**Fig. 4.** Wrist x-ray images at 6 weeks, demonstrating union of distal radius fracture with no evidence of healing of lunate and ulnar styloid fractures. (A) Anteroposterior view. (B) Lateral view.
The median nerve sensory symptoms had completely resolved. The cast was removed, and range of motion exercises began. The wrist was initially stiff, with no tenderness to palpation over the distal radius, ulnar or lunate and movements were pain-free. The patient and parents declined physiotherapy input.

Eight weeks postinjury, magnetic resonance imaging demonstrated a nonunited fracture of the lunate without signs of avascular necrosis (Fig. 5). At 6 months the patient had no symptoms, with a full, pain-free range of motion at the wrist, without tenderness. The patient returned to sports without any functional deficit. Radiographs were deemed unnecessary due to the absence of any symptoms.

Three years following the injury, the patient developed pain in the ipsilateral wrist. His Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire score was 8.3 and his Mayo Wrist Score was 90, with moderate pain in the arm and hand, mild difficulty during recreational activities requiring force or impact through bone, and slight limitation to social activities. His range of movement was limited in flexion and extension compared to the noninjured side. Pronation and supination were unaffected. These results are demonstrated in Table 1.

Radiographs revealed abnormal posttraumatic morphology (Fig. 6): partial closure of the distal radial physeal plate or posttraumatic bony bridging with evidence of distal radius growth arrest resulting in a (new) positive ulnar variance.

It should be noted that the case we present was additionally complex due to the presence of a concomitant distal radius fracture. The standard management of distal radius fractures was described by Carson et al. in 2006, who stated that “fractures of the distal radial physis … heal quickly … requiring only 3 to 4 weeks of immobilization” [4,5]. In addition, the evidence suggests that 4 to 8 weeks of immobilization is appropriate for conservative scaphoid fracture management [4,6]. There is very sparse further research available to recommend how to manage other carpal fractures in the pediatric population; therefore, we used this evidence. Furthermore, a clinical examination is preferred to a radiographic evaluation in young children with hand and wrist injuries for two reasons: (1) reducing exposure of the patient to ionizing radiation; and (2) incomplete ossification of the carpal bones, which makes fracture assessment difficult on plain radiographs. Thus, we provided immobilization until clinical union (i.e., the absence of pain at the fracture site on palpation, stressing of the fracture, or during range of motion exercises).

**Ethics statement**

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

**Table 1. Range of movement in the noninjured limb versus the injured limb, 3 years after injury**

<table>
<thead>
<tr>
<th>Movement</th>
<th>Range of movement (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left (noninjured)</td>
</tr>
<tr>
<td>Flexion</td>
<td>85</td>
</tr>
<tr>
<td>Extension</td>
<td>70</td>
</tr>
<tr>
<td>Pronation</td>
<td>90</td>
</tr>
<tr>
<td>Supination</td>
<td>90</td>
</tr>
</tbody>
</table>

**Fig. 6.** Wrist x-ray images showing early closure of the distal radial growth plate and consequent ulnar variance. (A) Anteroposterior view. (B) Lateral view.

**Fig. 5.** Coronal magnetic resonance imaging of the wrist confirming no evidence of healing of lunate fracture.
The lunate’s anatomical position and surrounding structures may explain why lunate fractures are often associated with other bony and soft tissue injuries, and may result in instability and pain. The lunate is the central carpal bone in the proximal row, and its position makes it difficult to view radiographically as there is significant overlap with other carpals on many radiographic views [7]. It is crescent-shaped, with a convex articular facet facing the radius, and a concave single or dual articular surface distally, facing the capitate. Along with the triquetrum and scaphoid, the lunate forms the distal articular surface of the radiocarpal joint and it articulates with the triangular fibrocartilage complex. Multiple ligamentous attachments of the lunate, including the scapholunate and lunotriquetral ligaments, indicate dislocation as an inherently severe injury. One proposed mechanism of lunate fracture is direct axial compression, driving the capitate into the lunate. There are few evidence-supported risk factors for lunate fractures, but one appears to be positive ulnar variance [8].

Adult lunate fractures are categorized using the Teisen classification system, based on the anatomic orientation of fracture patterns [9]; however, these do not provide prognostic value. They can be recognized by disruption of the radius-lunate-capitate axis on a lateral radiograph (normal axis demonstrated in Fig. 7), if it is not clear on the anteroposterior view [10].

In adults, the lunate is mainly covered in cartilage, and it is therefore relatively insensate [11]. Its vascular supply is often twofold, with dorsal and palmar surfaces supplied by the radiocarpal and intercarpal arch; however, 20% of all lunates have a single-vessel supply [12]. This means that missed lunate fractures may lead to avascular necrosis and resulting chronic pain, which is termed Kienböck disease [13]. Only one case report [14] thus far has documented the progression of a pediatric lunate fracture to Kienböck disease, with unclear original pathology. However, there may be reporting bias regarding this possibility due to a lack of thorough follow-up.

Pediatric fractures involve a growth plate in 15% to 30% of cases [15], often at the distal radius. The most commonly fractured carpal bone in children is the scaphoid, with an incidence of 0.4% of all pediatric fractures [16]. Of carpal bone fractures, scaphoid fractures are the most common (73.5%), followed by triquetral fractures (18.0%), with lunate fractures making up a significantly smaller proportion of the total (0.5%) [9].

Pediatric lunate fractures are rare, and as a result, little high-level evidence has been published. The evidence found in a literature search is presented in Table 2 [14,17–27]. Current management is often based on case series and reports of other carpal fractures, often in adult populations.

Nonunion of pediatric carpal fractures is extremely rare, with the first reported nonunion of a pediatric scaphoid fracture described by Southcott and Rosman [28] in 1977. Despite their scarcity in the literature, more recently, Rodriguez-Alejandro et al. [27] reported the case of a hook of hamate nonunion in a 12-year-old baseball player. This case likely resulted in nonunion due to repeated misdiagnoses on sequential plain radiographs by multiple healthcare professionals. The definitive and successful management involves surgical excision of the hook of hamate. That case report described a full return of function and no patient complaints 2 years after operation.

Previous case reports have demonstrated good long-term results from both nonoperative and operative management of pediatric carpal fractures, but the length of follow-up has often been a limitation. Most reports only have a 3-year follow-up, which may not be sufficient to understand the long-term consequences of these injuries.
<table>
<thead>
<tr>
<th>Study</th>
<th>Carpal</th>
<th>Displacement</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Detection</th>
<th>Imaging</th>
<th>Mechanism of injury</th>
<th>Management</th>
<th>Outcome</th>
<th>X-ray finding</th>
<th>Range of motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adler and Shaftan [17] (1962)</td>
<td>Capitate</td>
<td>None</td>
<td>17</td>
<td>Male</td>
<td>Immediate</td>
<td>X-ray</td>
<td>Fall</td>
<td>C</td>
<td>Union</td>
<td>Full</td>
<td></td>
</tr>
<tr>
<td>Young [18] (1986)</td>
<td>Capitate</td>
<td>None</td>
<td>10</td>
<td>Male</td>
<td>Immediate</td>
<td>X-ray</td>
<td>Fall (from 2 m)</td>
<td>C</td>
<td>3 mo</td>
<td>Union</td>
<td>Full</td>
</tr>
<tr>
<td>Gibbon and Jackson [19] (1989)</td>
<td>Capitate</td>
<td>None</td>
<td>9</td>
<td>Male</td>
<td>Delay of 24 day</td>
<td>X-ray</td>
<td>FOOSH</td>
<td>C</td>
<td>3.5 wk</td>
<td>Sclerosis</td>
<td>-</td>
</tr>
<tr>
<td>Wulff and Schmidt [20] (1998)</td>
<td>Capitate</td>
<td>None</td>
<td>13</td>
<td>Female</td>
<td>Immediate</td>
<td>-</td>
<td>MTC</td>
<td>C</td>
<td>6 wk</td>
<td>Union</td>
<td>-</td>
</tr>
<tr>
<td>Wulff and Schmidt [20] (1998)</td>
<td>Triquetrum</td>
<td>None</td>
<td>12</td>
<td>Female</td>
<td>Immediate</td>
<td>-</td>
<td>Fall (from 1 m)</td>
<td>C</td>
<td>4 wk</td>
<td>Union</td>
<td>-</td>
</tr>
<tr>
<td>Wulff and Schmidt [20] (1998)</td>
<td>Trapezoid</td>
<td>None</td>
<td>14</td>
<td>Female</td>
<td>Immediate</td>
<td>-</td>
<td>MTC</td>
<td>C</td>
<td>4 wk</td>
<td>Union</td>
<td>-</td>
</tr>
<tr>
<td>Wulff and Schmidt [20] (1998)</td>
<td>Hamate</td>
<td>None</td>
<td>16</td>
<td>Male</td>
<td>Immediate</td>
<td>-</td>
<td>MTC</td>
<td>C</td>
<td>3 wk</td>
<td>Union</td>
<td>-</td>
</tr>
<tr>
<td>Sawant and Miller [21] (2000)</td>
<td>Capitate</td>
<td>-</td>
<td>12</td>
<td>Male</td>
<td>Delay of 24 hr</td>
<td>X-ray</td>
<td>MTC</td>
<td>S</td>
<td>3 yr</td>
<td>Union</td>
<td>Flexion, 70° (vs. 90°), Extension, 85° (vs. 95°), Normal grip strength</td>
</tr>
<tr>
<td>Ferlic et al. [14] (2003)</td>
<td>Lunate</td>
<td>None</td>
<td>13</td>
<td>Male</td>
<td>Delayed presentation (6 mo)</td>
<td>X-ray + MRI</td>
<td>Nontraumatic</td>
<td>S</td>
<td>30 mo</td>
<td>Union</td>
<td>Flexion, 68° Extension, 45°</td>
</tr>
<tr>
<td>Kuniyoshi et al. [22] (2005)</td>
<td>Capitate</td>
<td>None</td>
<td>6</td>
<td>Male</td>
<td>Delayed presentation (3 mo)</td>
<td>X-ray + MRI</td>
<td>Wrist caught in iron gates</td>
<td>C</td>
<td>14 mo</td>
<td>Union</td>
<td>Full</td>
</tr>
<tr>
<td>Horras et al. [23] (2012)</td>
<td>Triquetrum</td>
<td>Yes</td>
<td>14</td>
<td>Male</td>
<td>Immediate</td>
<td>MRI</td>
<td>FOOSH</td>
<td>C</td>
<td>6 wk</td>
<td>Union</td>
<td>Full</td>
</tr>
<tr>
<td>Cooney and Stuart [24] (2013)</td>
<td>Capitate</td>
<td>Minimal</td>
<td>16</td>
<td>Male</td>
<td>Delayed presentation (2 mo)</td>
<td>X-ray + CT</td>
<td>FOOSH</td>
<td>C + delayed S + bone graft</td>
<td>18 wk⁴</td>
<td>Delayed union post-ORIF</td>
<td>-</td>
</tr>
<tr>
<td>Hurni et al. [25] (2015)</td>
<td>Pisiform</td>
<td>Yes</td>
<td>11</td>
<td>Male</td>
<td>Immediate</td>
<td>CT</td>
<td>MTC</td>
<td>S</td>
<td>3 mo</td>
<td>Union</td>
<td>Full</td>
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<tr>
<td>Covelli et al. [26] (2018)</td>
<td>Pisiform</td>
<td>Yes</td>
<td>13</td>
<td>Male</td>
<td>Delayed presentation (3 mo)</td>
<td>MRI</td>
<td>Nontraumatic</td>
<td>C</td>
<td>No mention of follow-up</td>
<td>Nonunion (excised hook of hamate)</td>
<td>Full</td>
</tr>
<tr>
<td>Rodriguez-Alejandro et al. [27] (2021)</td>
<td>Hamate</td>
<td>None</td>
<td>12</td>
<td>Male</td>
<td>Delayed presentation (3 mo)</td>
<td>MRI</td>
<td>Hitting ball with a baseball bat</td>
<td>S</td>
<td>No union mentioned</td>
<td>Excision of hook of hamate after non-union detected</td>
<td>Full</td>
</tr>
</tbody>
</table>

C, conservative; FOOSH, fall on an outstretched hand; MTC, motor traffic collision; S, surgical; MRI, magnetic resonance imaging; CT, computed tomography; ORIF, open reduction and internal fixation.

⁴Sclerosis only; delayed ORIF + bone grafting to union, 38 weeks postfixation union + wrist flexion to 80°, wrist extension to 60°.
A case report by Bhatnagar et al. [29] highlighted a good clinical outcome following nonoperative management of an active 11-year-old boy with multiple carpal fractures. They demonstrated asymptomatic full range of motion of the wrist at a 3-year follow-up, despite CT scanning at this stage showing nonunion of the hamate fracture.

Clarke et al. [30] reported a case of an 11-year-old boy with spontaneous union 2 years following a conservatively managed waist-of-scaphoid fracture. This caused persistent wrist pain between 18 and 24 months, prior to radiographic evidence of union. This may highlight the need to review the pediatric definition of healing timelines when defining delayed union and nonunion in children.

Similarly, there have been good clinical outcomes with operative management. Kamano et al. [31] showed effective results in a child with multiple carpal fractures treated with wire fixation and followed for 29 months. In 2009, Foley and Patel [32] also demonstrated similar outcomes in a 10-year-old boy treated with Kirschner wires for scaphoid, capitate, and triquetrum fractures. In this patient, bone union was achieved and there was pain-free full range of movement of the wrist at a 1-year follow-up. DeCoster et al. [33] also reported initial good clinical outcomes following open reduction with internal fixation of distal radius, scaphoid, lunate, and triquetral fractures with gross displacement in a 10-year-old boy at 1 year, but described delayed abnormal carpal development. Ferlic et al. [14] operatively managed a delayed presentation of Kienböck disease with radial shortening.

There is evidence for management of other carpal injuries, with established protocols for scaphoid nonunion in the pediatric population to be anatomically reduced with stable fixation, with or without bone grafting. The management of other types of carpal nonunion in children, and particularly the lunate, is much less clear. Wyrick et al. [34] advocated for open reduction and internal fixation in all displaced pediatric carpal fractures.

In our case, the patient was nonoperatively managed following the initial reduction of the distal radius fracture. However, the following questions remain: (1) What follow-up time is appropriate for pediatric carpal fractures to identify delayed consequences of injury, and delayed union? (2) Should lunate fixation be performed at the primary operation? (3) Is lunate nonunion detrimental to wrist function and does it cause chronic pain? (4) Should delayed open reduction with internal fixation, with or without bone grafting, be performed simply to achieve union or only in the presence of symptoms?

CONCLUSIONS

Pediatric carpal fractures are rare and easily missed, and their long-term impact remains unknown. A high index of suspicion is required in order to make an accurate diagnosis and ensure that occult injuries are not missed. No evidence exists regarding the specific management of pediatric lunate fractures, and good outcomes have been reported in both operatively and nonoperatively managed cases. The rate of Kienböck disease is unclear in the pediatric population. We present a case of nonoperative management based on the patient’s symptoms. Although successful in the short to mid-term, this has resulted in some limitation of function after 3 years. We are still unable to comment on the long-term prognosis of this injury, but will continue to follow his progress. If a nonoperative approach is to be taken, we recommend immobilization in a cast for a minimum of 4 weeks and a maximum of 8 weeks.

ARTICLE INFORMATION

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

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

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Data availability
Data sharing is not applicable as no new data were created or analyzed in this study.

REFERENCES


Perceptions regarding the multidisciplinary treatment of patients with severe trauma in Korea: a survey of trauma specialists

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2 Trauma Center, Seoul National University Hospital, Seoul, Korea
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Purpose: Patients with multiple trauma necessitate assistance from a wide range of departments and professions for their successful reintegration into society. Historically, the primary focus of trauma treatment in Korea has been on reducing mortality rates. This study was conducted with the objective of evaluating the current state of multidisciplinary treatment for patients with severe trauma in Korea. Based on the insights of trauma specialists (i.e., medical professionals), we aim to suggest potential improvements.

Methods: An online questionnaire was conducted among 871 surgical specialists who were members of the Korean Society of Traumatology. The questionnaire covered participant demographics, current multidisciplinary practices, perceived challenges in collaboration with rehabilitation, psychiatry, and anesthesiology departments, and the perceived necessity for multidisciplinary treatment.

Results: Out of the 41 hospitals with which participants were affiliated, only nine conducted multidisciplinary meetings or rounds with nonsurgical departments. The process of transferring patients to rehabilitation facilities was not widespread, and delays in these transfers were frequently observed. Financial constraints were identified by the respondents as a significant barrier to multidisciplinary collaboration. Despite these hurdles, the majority of respondents acknowledged the importance of multidisciplinary treatment, especially in relation to rehabilitation, psychiatry, and anesthesiology involvement.

Conclusions: This survey showed that medical staff specializing in trauma care perceive several issues stemming from the absence of a multidisciplinary system for patient-centered care in Korea. There is a need to develop an effective multidisciplinary treatment system to facilitate the recovery of trauma patients.

Keywords: Wounds and injuries; Multidisciplinary; Rehabilitation; Psychiatry; Pain management
INTRODUCTION

Background
A survey carried out by the Ministry of Health and Welfare demonstrated a significant decrease in the national average preventable trauma mortality rate, from 30.5% in 2015 to 15.7% in 2019 [1]. The establishment of regional trauma centers in Korea has improved trauma treatment, and the nationwide preventable trauma mortality rate has declined.

To date, trauma treatment in Korea has primarily focused on reducing mortality rates. The indicators used to evaluate regional trauma centers and the parameters of the Korean Trauma Database (KTDB) are limited to resuscitation, acute-phase outcomes, and mortality. Although a multidisciplinary system is implemented in Korea, it primarily comprises surgical departments.

However, patients with multiple trauma necessitate the involvement of numerous departments and professions until they can be successfully reintegrated into society. As such, trauma care must span all stages of recovery, forming a continuous process. Ideally, enhancements in acute care quality should be seamlessly integrated with those in rehabilitation and recovery. A multidisciplinary approach is of the utmost importance in facilitating survivors’ functional recovery, improving their quality of life, and re-integrating into society.

Objectives
As a preliminary step toward establishing a foundation for multidisciplinary treatment in trauma care, this study aimed to investigate the current state and problems regarding multidisciplinary treatment for patients with severe trauma in Korea, obtain insights into ways of improving the system by conducting a perception survey among trauma specialists (medical professional), and generate more interest in this subject.

METHODS

Ethics statement
This study was approved by the Institutional Review Board of the Seoul National University Hospital (No. 2112-129-1284). Written informed consent was obtained from the respondents. An online questionnaire-based survey was conducted following the CHERRIES (Checklist for Reporting Results of Internet E-Surveys) statement [2].

Study design
In total, 871 surgical specialists from 1,500 members of the Korean Society of Traumatology were selected as the target population. The questionnaire was created using Google Forms (Google) and sent via email. Only those who indicated their willingness to participate were included in the study. The survey was launched at the end of November 2021, and remained open until December 2021.

The questionnaire consisted of 43 items, which could be categorized into the following: (1) the characteristics of the survey participants (major subject, hospital size, and location); (2) the current status of multidisciplinary meetings and rounds; (3) perceptions of problems with the Department of Rehabilitation Medicine; (4) perceptions of problems with the Department of Psychiatry; (5) perceptions of problems with the Department of Anesthesiology and Pain Medicine; (6) perceptions of medical staff on the need for multidisciplinary treatment; (7) status of medical care after discharge; and (8) comments. A combined total, with each section consisting of a minimum of 4 to a maximum of 16, was considered (Table S1). Categories 3 through 7 only included answers from staff of regional trauma centers and final treatment centers. Final treatment centers are designated by the Seoul Metropolitan Government (Seoul, Korea), and a total of four final treatment centers are responsible for treating severe trauma patients in the Seoul area.

RESULTS

Characteristics of the survey participants
Among the 41 hospitals with which participants were affiliated, there were 16 regional trauma centers (39.0%, only Mokpo Hanyook Hospital [Mokpo, Korea] was not included), three final treatment centers in Seoul (7.3%), 15 certified tertiary hospitals (36.6%), and seven other hospitals (17.1%). Medical staff working at regional trauma and final treatment centers in Seoul accounted for 68.1% of the sample. Specialists in surgery (or trauma surgery), neurosurgery, orthopedic surgery, and cardiothoracic surgery participated in the study in decreasing order.

Among the survey respondents, a duration of work experience in the trauma field of more than 5 years was the most common (71.6%), followed by 2 to 5 years (16.4%) and < 2 years (12.1%). Most participants worked in Seoul, followed by southern Gyeonggi Province, Daegu, northern Gyeonggi Province, Gangwon Province, and North Jeolla Province (Table S2).

Multidisciplinary meetings and rounds
Multidisciplinary meetings consisting of only surgical departments were excluded from the questionnaire analysis. Among
the 41 hospitals with which participants were affiliated, only nine trauma centers had a multidisciplinary system (Table 1). Among the regional trauma and final treatment centers, only four held regular multidisciplinary meetings with the Department of Rehabilitation Medicine or the Department of Anesthesiology and Pain Medicine. Only Seoul National University Hospital, one of the final treatment centers in Seoul, held multidisciplinary meetings with the Departments of Rehabilitation Medicine, Psychiatry, Anesthesiology and Pain Medicine, and Family Medicine. Only one regional trauma center conducted periodic multidisciplinary rounds among all hospitals. However, it should be kept in mind that, given the study design, it was not possible to gather information pertaining to hospitals other than those with which the study participants were affiliated.

### Status and issues of multidisciplinary treatment for trauma patients

The analysis of the status and problems of multidisciplinary treatment for trauma patients only included responses from the medical staff of regional centers and the final treatment centers in charge of treating severely injured patients. Respondents from only six hospitals answered that they could transfer patients to the Department of Rehabilitation Medicine within the hospital if specialized rehabilitation was deemed necessary. In-hospital transfers to the Department of Rehabilitation Medicine also seemed possible in the other two hospitals. However, respondents’ answers were inconsistent within a single hospital, leading to the inference that such transfers may not always be feasible (Table 2).

**Table 1. Survey on the presence of multidisciplinary meetings and rounds**

<table>
<thead>
<tr>
<th>Hospital</th>
<th>Surgical department</th>
<th>Other departments participating in multidisciplinary meetings</th>
<th>Multidisciplinary rounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional trauma centers and final treatment center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pusan National University Hospital (Busan, Korea)</td>
<td>Trauma surgery</td>
<td>Rehabilitation medicine</td>
<td>Exists</td>
</tr>
<tr>
<td>Seoul National University Hospital (Seoul, Korea)</td>
<td>Trauma surgery</td>
<td>Rehabilitation medicine</td>
<td>None</td>
</tr>
<tr>
<td>Ajou University Hospital (Suwon, Korea)</td>
<td>Trauma surgery</td>
<td>Psychiatry, Anesthesiology and pain medicine, Family medicine</td>
<td>None</td>
</tr>
<tr>
<td>Chungbuk National University Hospital (Cheongju, Korea)</td>
<td>Trauma surgery</td>
<td>Anesthesiology and pain medicine</td>
<td>None</td>
</tr>
<tr>
<td>Gachon University Gil Medical Center (Incheon, Korea)</td>
<td>Trauma surgery</td>
<td>Anesthesiology and pain medicine</td>
<td>None</td>
</tr>
<tr>
<td>Other hospital</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seoul National University Bundang Hospital (Seongnam, Korea)</td>
<td>Orthopedic surgery</td>
<td>Rehabilitation medicine</td>
<td>None</td>
</tr>
<tr>
<td>Konkuk University Chungju Hospital (Chungju, Korea)</td>
<td>Thoracic surgery</td>
<td>Rehabilitation medicine</td>
<td>None</td>
</tr>
<tr>
<td>Seoul St. Mary’s Hospital (Seoul, Korea)</td>
<td>Plastic surgery</td>
<td>Rehabilitation medicine</td>
<td>None</td>
</tr>
<tr>
<td>Hanyang University Guri Hospital (Guri, Korea)</td>
<td>Neurosurgery</td>
<td>Rehabilitation medicine</td>
<td>None</td>
</tr>
</tbody>
</table>

If the answers differed within one hospital, the answers of the majority were accepted. Since the participants were only affiliated with some hospitals, the results of the survey were not exhaustive.

**Table 2. List of hospitals that can transfer patients to the Department of Rehabilitation Medicine within the hospital if specialized rehabilitation is deemed necessary**

<table>
<thead>
<tr>
<th>Response (yes)</th>
<th>Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>From all respondents</td>
<td>Chonnam National University Hospital (Gwangju, Korea)</td>
</tr>
<tr>
<td></td>
<td>Gyeongsang National University Hospital (Jinju, Korea)</td>
</tr>
<tr>
<td></td>
<td>Korea University Guro Hospital (Seoul, Korea)</td>
</tr>
<tr>
<td></td>
<td>Pusan National University Hospital (Busan, Korea)</td>
</tr>
<tr>
<td></td>
<td>Wonju Severance Christian Hospital (Wonju, Korea)</td>
</tr>
<tr>
<td></td>
<td>Wonkwang University Hospital (Iksan, Korea)</td>
</tr>
<tr>
<td>From some respondents</td>
<td>Gachon University Gil Medical Center (Incheon, Korea)</td>
</tr>
<tr>
<td></td>
<td>Kyungpook National University Hospital (Daegu, Korea)</td>
</tr>
</tbody>
</table>
The most common response (40.5%) for the average time required for in-hospital transfer to the Department of Rehabilitation Medicine or for transfer to a rehabilitation hospital was 1 to 2 weeks (Table 3).

Furthermore, 57.0%, 31.7%, and 45.5% of responses indicated that there were always, frequently, or fairly often problems, respectively, due to the lack of support from the Departments of Rehabilitation Medicine, Psychiatry, and Anesthesiology and Pain Medicine (Table 4).

Perceptions of the possible causes of lack of multidisciplinary support
Based on the multiple responses received regarding the causes of lack of support from the Department of Rehabilitation Medicine, respondents perceived the causes as shortage of staff in rehabilitation medicine (21.3%), a lack of network or protocol for multidisciplinary treatment for trauma patients (17.0%), a lack of specialized (certified) rehabilitation hospitals nearby that can accept transfers (16.5%), a shortage of beds at the Department of Rehabilitation Medicine (13.9%), a lack of or excessively cheap insurance fees or reimbursements (13.5%), a lack of interest or enthusiasm the Department of Rehabilitation Medicine for trauma patients (9.6%), and a lack of information on rehabilitation hospitals that can accept transfers (7.8%) (Table 5).

Regarding the lack of psychiatric support, a lack of a network or protocol for multidisciplinary treatment for trauma patients (20.6%) was the most common answer, followed by a shortage of hospitals that could accept transfers of patients with psychiatric problems (16.1%), a shortage of staff in the Department of Psychiatry (14.6%), and a lack of interest or enthusiasm in the Department of Psychiatry for trauma patients (14.1%) (Table 6).

Perceptions of the need for multidisciplinary treatment
Based on the responses on the need for multidisciplinary treatment in collaboration with the Departments of Rehabilitation Medicine, Psychiatry, and Anesthesia and Pain Medicine, 89.8%,

#### Table 3. Survey of the average time required for in-hospital transfer to the Department of Rehabilitation Medicine or transfer to a rehabilitation hospital (n=79)

<table>
<thead>
<tr>
<th>Response</th>
<th>No. of responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–2 day</td>
<td>0</td>
</tr>
<tr>
<td>3–7 day</td>
<td>31 (39.2)</td>
</tr>
<tr>
<td>1–2 wk</td>
<td>32 (40.5)</td>
</tr>
<tr>
<td>&gt;2 wk</td>
<td>6 (7.6)</td>
</tr>
<tr>
<td>Poorly transferred</td>
<td>3 (3.8)</td>
</tr>
<tr>
<td>Highly variable</td>
<td>7 (8.9)</td>
</tr>
</tbody>
</table>

#### Table 4. Survey on whether problems occurred due to a lack of support from related departments (n=79)

<table>
<thead>
<tr>
<th>Response</th>
<th>Lack of support from</th>
<th>Lack of support from</th>
<th>Lack of support from</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Department of Medicine</td>
<td>Department of Psychiatry</td>
<td>Department of Anesthesiology and Pain Medicine</td>
</tr>
<tr>
<td>Always</td>
<td>6 (7.6)</td>
<td>0</td>
<td>2 (2.5)</td>
</tr>
<tr>
<td>Frequently</td>
<td>13 (16.5)</td>
<td>4 (5.1)</td>
<td>9 (11.4)</td>
</tr>
<tr>
<td>Fairly often</td>
<td>26 (32.9)</td>
<td>21 (26.6)</td>
<td>25 (31.6)</td>
</tr>
<tr>
<td>Occasionally</td>
<td>23 (29.1)</td>
<td>36 (45.5)</td>
<td>27 (34.2)</td>
</tr>
<tr>
<td>Never</td>
<td>10 (12.6)</td>
<td>18 (22.8)</td>
<td>16 (20.3)</td>
</tr>
<tr>
<td>No response</td>
<td>1 (1.3)</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Values are presented as number (%).

#### Table 5. Perceptions of the causes of the lack of rehabilitation medical support (n=79, multiple responses)

<table>
<thead>
<tr>
<th>Cause</th>
<th>No. of responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortage of staff at the Department of Medicine</td>
<td>49 (21.3)</td>
</tr>
<tr>
<td>Lack of network or protocol for multidisciplinary medicine for trauma patients</td>
<td>39 (17.0)</td>
</tr>
<tr>
<td>Lack of specialized (certified) rehabilitation hospitals nearby that can accept transfers</td>
<td>38 (16.5)</td>
</tr>
<tr>
<td>Shortage of beds at the Department of Medicine</td>
<td>32 (13.9)</td>
</tr>
<tr>
<td>Lack of or sufficiently cheap insurance fees or reimbursements</td>
<td>31 (13.5)</td>
</tr>
<tr>
<td>Lack of interest or enthusiasm the Department of Medicine for trauma patients</td>
<td>22 (9.6)</td>
</tr>
<tr>
<td>Lack of information on rehabilitation hospitals that can accept transfers</td>
<td>18 (7.8)</td>
</tr>
<tr>
<td>Other (absence of programs that can solve spontaneous breathing problems in patients with upper spinal cord injuries)</td>
<td>1 (0.4)</td>
</tr>
<tr>
<td>Total</td>
<td>230 (100)</td>
</tr>
</tbody>
</table>
Table 6. Perceptions of the causes of the lack of psychiatric support (n=79, multiple responses)

<table>
<thead>
<tr>
<th>Cause</th>
<th>No. of responses (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of network or protocol for multidisciplinary treatment for trauma patients</td>
<td>41 (20.6)</td>
</tr>
<tr>
<td>Shortage of hospitals that can accept transfers of patients with psychiatric problems</td>
<td>32 (16.1)</td>
</tr>
<tr>
<td>Shortage of staff in the Department of Psychiatry</td>
<td>29 (14.6)</td>
</tr>
<tr>
<td>Lack of interest or enthusiasm of the Department of Psychiatry for trauma patients</td>
<td>28 (14.1)</td>
</tr>
<tr>
<td>Shortage of beds in the Department of Psychiatry</td>
<td>24 (12.1)</td>
</tr>
<tr>
<td>Lack of or excessively cheap insurance fees or reimbursements</td>
<td>22 (11.0)</td>
</tr>
<tr>
<td>Problems of social perception in the Department of Psychiatry</td>
<td>13 (6.5)</td>
</tr>
<tr>
<td>Lack of information on specialized psychiatric medical institutions</td>
<td>9 (4.5)</td>
</tr>
<tr>
<td>None</td>
<td>1 (0.5)</td>
</tr>
<tr>
<td>Total</td>
<td>199 (100)</td>
</tr>
</tbody>
</table>

74.7%, and 56.9% of respondents who were medical staff of regional trauma centers and final treatment centers, respectively, answered that it was “very much needed” or “needed.” Including the answer “fairly needed,” the percentages increased to 97.4%, 93.7%, and 89.8%, respectively, which indicates that most of the medical staff treating patients with severe trauma had positive views on the necessity of multidisciplinary treatment (Table 7). Regarding the need for multifaceted evaluations of patients who have completed acute trauma treatment, 98.7% responded “very needed,” “needed,” or “fairly needed.”

Comments and suggestions from the respondents
Most respondents pointed to financial issues in their comments and suggestions. Respondents suggested that there must be financial support, such as insurance reimbursement and incentives, for the multidisciplinary treatment of patients with trauma. One respondent suggested that the provision of multidisciplinary treatment for severe trauma should be a mandatory criterion for the designation of a regional trauma center (Fig. 1).

DISCUSSION

The treatment of patients with multiple traumas cannot be confined solely to the surgical field. Moreover, trauma care should encompass a continuum that spans from resuscitation to postdischarge management. According to the Victorian State Trauma Registry [3], disability remains common 24 months after a traumatic injury, and 30% of patients could not return to work. Post-traumatic stress disorder (45%), psychiatric disorders (31%), alcoholism (26%), moderate-to-severe chronic pain (23%), and depression (18%) were commonly observed 1 year after injury [4,5]. Poor health-related quality of life, such as pain or physical discomfort (72%) and difficulties in self-care (31%) were also commonly observed [4].

There is evidence that multidisciplinary treatment improves outcomes in patients with trauma, especially in the older adult population. Multidisciplinary teams described in the literature include nurses, rehabilitation therapists, respiratory therapists, nutritionists, and palliative care staff, in addition to specialists such as trauma surgeons, orthopedic surgeons, and internists [6–9]. There is research reporting that shorter hospital stays and faster transfers to specialized trauma rehabilitation units, along with early initiation of multidisciplinary treatments and “nonweight bearing” mobilization, were achieved through integrated coordination between trauma surgeons and rehabilitation physicians, providing a “fast track” rehabilitation service for patients with an Injury Severity Score (ISS) > 15 [10]. In another study [11], early physical medicine and rehabilitation consultation within 8 days of admission demonstrated a shorter length of stay in acute care, fewer complications, and reduced use of benzodiazepines and antipsychotics.

In this study, trauma specialists in Korea perceived a lack of multidisciplinary support and collaboration in trauma care. Only nine trauma centers had a multidisciplinary system with nonsurgical departments. The respondents highlighted financial issues as one of the most significant potential causes of the lack of multidisciplinary support. A systematic review of multidisciplinary rehabilitation in patients with multiple traumas listed the reasons for the limited access to optimal rehabilitation programs, including a lack of political commitment to reform, inadequate financial support for infrastructure, and fragmented healthcare systems [12–14].

Multidisciplinary treatment may become widely established with reasonable fees and national support. For example, in the United Kingdom, a best practice tariff is applied based on data collected by the Trauma Audit and Research Network (TARN), wherein incentives are paid to trauma care institutions whose performance is rated as excellent, and its calculation is reflective
of the severity of trauma in patients treated by each center [15].

The indicators used to evaluate regional trauma centers in Korea are limited to the initial stages of trauma treatment. The United Kingdom emphasizes the importance of rehabilitation for the recovery of trauma patients; hence, the process of identifying patients’ rehabilitation needs and timely rehabilitation are included in the performance evaluation [15]. UK standards dictate that all patients with an ISS ≥ 9 should receive a standardized rehabilitation prescription. Rehabilitation needs must be assessed within 10 days of referral, and patients should be transferred to specialist rehabilitation within 6 weeks of being fit for transfer. Measurements of functional improvement and discharge destination were also recorded for quality control purposes [15]. In Australia and New Zealand, quality indicators include the time taken for rehabilitation from referral and the patient’s discharge destination [16].

Currently, quantitative data regarding recovery, long-term outcomes, and reintegration into society of trauma patients in Korea are lacking. The Victorian State Trauma Registry collects information on patient-reported health-related quality of life, time required to return to work, residential status, and healthcare utilization 6, 12, and 24 months after discharge [3]. This type of post-discharge patient-centered data is invaluable for identifying patients who recover, when they recover, and to what extent. It enables quantification of the burden of major trauma, which in turn aids in the planning of medical services [17].

Limitations
This study had certain limitations owing to the exclusion of certain medical staff from regional trauma centers, potentially resulting in missing information. Furthermore, as this survey primarily dealt with perceptions, it presents subjective information. Nonetheless, this study holds significance in confirming the necessity of a multidisciplinary system and offers important suggestions for subsequent phases of developing trauma treatment in Korea.

Conclusions
Drawing from this survey and the existing literature, the following suggestions can be put forth to enhance the quality of trauma treatment in Korea. Financial support should be provided through measures such as insurance reimbursement and incentives for multidisciplinary treatment involving various medical and surgical departments, rehabilitation-related indicators should be included in the quality assessment of regional trauma centers, and parameters for recovery and long-term outcomes should be incorporated into the KTDB.
**ARTICLE INFORMATION**

**Author contributions**
Conceptualization: YRC; Data curation: SAL, YRC; Formal analysis: YJJ, YRC; Funding acquisition: YRC; Investigation: YJJ; Methodology: SAL, YRC; Project administration: SAL, YRC; Visualization: YJJ; Writing--original draft: SAL, YRC; Writing--review & editing: all authors. All authors read and approved the final manuscript.

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

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**Data availability**
Data analyzed in this study are available from the corresponding author upon reasonable request.

**Supplementary materials**
Table S1. Questionnaire
Table S2. Number of survey respondents by region (n = 116)
Supplementary materials are available from https://doi.org/10.20408/jti.2023.0045.

**REFERENCES**

Clinical characteristics and mortality risk factors among trauma patients by age groups at a single center in Korea over 7 years: a retrospective study

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Purpose: In this study, we aimed to compare the characteristics of patients with trauma by age group in a single center in Korea to identify the clinical characteristics and analyze the risk factors affecting mortality.

Methods: Patients aged ≥18 years who visited the Chungbuk National University Hospital Regional Trauma Center between January 2016 and December 2022 were included. The accident mechanism, severity of the injury, and outcomes were compared by classifying the patients into group A (18–64 years), group B (65–79 years), and group C (≥80 years). In addition, logistic regression analysis was performed to identify factors affecting death.

Results: The most common injury mechanism was traffic accidents in group A (40.9%) and slipping in group B (37.0%) and group C (56.2%). Although group A had the highest intensive care unit admission rate (38.0%), group C had the highest mortality rate (9.5%). In the regression analysis, 3 to 8 points on the Glasgow Coma Scale had the highest odds ratio for mortality, and red blood cell transfusion within 24 hours, intensive care unit admission, age, and Injury Severity Score were the predictors of death.

Conclusions: For patients with trauma, the mechanism, injured body region, and severity of injury differed among the age groups. The high mortality rate of elderly patients suggests the need for different treatment approaches for trauma patients according to age. Identifying factors affecting clinical patterns and mortality according to age groups can help improve the prognosis of trauma patients in the future.

Keywords: Aged; Wounds and injuries; Transfusion; Trauma centers
INTRODUCTION

Background
Trauma is the leading cause of death for people of different age groups in Korea. According to the 2021 statistics, traffic accidents are the ninth most common cause of death for men, especially for young people under the age of 40 years. In contrast, the rate of the causes of death by trauma in the elderly is low, but it is steadily increasing as the elderly population increases [1].

The variations in the type of trauma or mechanism of injury can be attributed to the differences in the areas of activity or occupation according to age. Therefore, various clinical characteristics can be observed according to patient age. In particular, in the elderly patient group, physiological changes occur in and affect various body systems [2]. Age is a predictor of poor prognosis in patients [3–5] and increases mortality, especially among those over 65 years of age [6]. However, the prognosis of elderly patients who experience trauma is still controversial [7,8]. It is necessary to identify the characteristics of trauma patients according to age in order to provide appropriate treatment. In addition, the prognosis can be improved, and the mortality rate can be lowered through aggressive initial treatment.

Objectives
This study aimed to analyze the mortality rates of trauma patients who visited a single regional trauma center for 7 years. The patients were stratified by age group to identify the clinical characteristics and factors related to mortality.

METHODS

Ethics statement
This study was approved by the Institutional Review Board of Chungbuk National University Hospital (No. 2023-03-011-001). The requirement for informed consent was waived due to the retrospective nature of the study.

Patients and data collection
This retrospective study included trauma patients who visited the Chungbuk National University Hospital Regional Trauma Center and Regional Emergency Medical Center (Cheongju, Korea) from January 2016 to December 2022. Data from the medical records of the patients admitted to this hospital and registered in the Korean Trauma Database (KTDB) were collected and analyzed.

Those who were aged below 17 years at the time of hospital visit, had already died at the time of arrival in the emergency room, or did not survive after CPR were excluded. The patients were classified into the following groups: group A (18–64 years), group B (65–79 years), and group C (≥ 80 years). The clinical characteristics were compared among the groups. Patients whose systolic blood pressure at the time of visiting the emergency room was < 90 mmHg were considered hypotensive.

The distribution of patients according to the Abbreviated Injury Scale (AIS) score were comparatively analyzed; areas with an AIS of 3 or more were classified as having undergone severe damage. Based on the Injury Severity Score (ISS), an indicator of the severity of damage, the patients were classified into severe (3–8 points), moderate (9–12 points), and mild (13–15 points) groups. The Trauma and Injury Severity Score (TRISS), and Geriatric Trauma Outcome Score (GTOS) [9–11] were used to determine the patient’s prognosis, and the GTOS was calculated using the following formula:

GTOS = age+(2.5 × ISS)+22 (if given packed red blood cells)

Statistical analysis
Statistical analyses were performed using R ver. 4.2.2 (R Foundation for Statistical Computing). Continuous variables that did not satisfy normality were expressed as median with an interquartile range (IQR). Categorical variables were expressed as percentage. Chi-square test or Fisher exact test was used for nominal variables, and one-way analysis of variance or the Kruskal-Wallis test was used for continuous variables depending on their normality. Logistic regression analysis was performed to analyze risk factors for death, and the Hosmer-Lemeshow goodness-of-fit test was performed to confirm the suitability of the test. A P-value of < 0.05 was considered statistically significant.

RESULTS

Demographics
Among the trauma patients who visited the hospital during the study period, 7,843 were analyzed. There were 4,573 patients in group A, 2,041 in group B, and 1,229 in group C. Since 2020, there has been an overall decrease in the numbers of patients with COVID-19 pandemic; however, the proportion of elderly patients has been steadily increasing (Fig. 1). Men accounted for 62.9% of the total sample, but as the age increased, the proportion of women increased. In group C, the proportion of men ac-
counted for 37.7%. Most of the injury was blunt trauma and increased with age. Most injuries were the result of traffic accidents (36.2%), including pedestrian injuries, falls (18.2%), and slips (27.3%), and the proportion of falls and slips tended to increase steeply with age. The lowest incidence of trauma was observed in winter in all age groups (Table 1).

**Injured body region and injury severity**

Except for the facial and external areas, pelvis and extremities (55.1%) were the most frequently injured areas in all age groups, followed by the head and neck (31.1%), chest (29.1%), and abdomen (20.4%). As age increased, injuries to the head, neck, thorax, and abdomen decreased frequently, and only injuries to the pelvic and limb areas tended to increase with age. In particular, the incidence of severe injury (AIS score, > 3) in the pelvis and extremities was the highest in group C (49.1%). Multiple injuries were observed in 3,420 patients (43.6%), and the frequency decreased with age (Table 2).

The median ISS was 9 (IQR, 4–16), and the difference in the scores among the groups was not significant. The ISS was the highest in group A (30.4%) and decreased significantly with age (group B, 26.5%; group C, 20.1%). The GCS score severity showed no significant difference among the groups; however, TRISS and GTOS showed significant differences among the groups (Table 3).

**Clinical parameters and outcomes**

At the time of visiting the emergency room, the incidence rate of low blood pressure and red blood cell transfusion within 4 hours of visiting the hospital were the highest in group A. However, the proportion of patients requiring red blood cell transfusions within 24 hours after visiting the hospital, group C was 19.6%, higher than the rates in both group A (17.8%) and group B (18.4%). The proportion of patients requiring surgery or interventions was the highest in group A (25.7%) compared to that in group B (18.2%) and group C (12.8%) (Table 4).

The rate of intensive care unit (ICU) hospitalization was the highest in group A; the length of ICU stay was the longest in group C. The in-hospital mortality rate was 5.4% for the entire study group; group C had the highest in-hospital mortality rate of 9.5%. When calculated only for patients admitted to the ICU, the mortality rates were 9.4%, 16.7%, and 26.6% for groups A, B, and C, respectively (Table 4).

**Predictors of mortality**

Logistic regression analysis was performed using sex, age, ISS, red blood cell transfusion, hypotension, ICU admission, GCS score, surgery, and intervention as independent variables (Table 5). The GCS score had the highest odds ratio (12.04; 95% confidence interval, 8.23–17.61; P < 0.001). Transfusion within 24 hours, admission to the ICU, age, and ISS were the other predictors (Fig. 2). When logistic regression analysis was conducted on
Table 1. Patient characteristics and injury profile

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (n=7,843)</th>
<th>Group A (n=4,573)</th>
<th>Group B (n=2,041)</th>
<th>Group C (n=1,229)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>61 (46–75)</td>
<td>49 (35–58)</td>
<td>73 (69–76)</td>
<td>84 (81–87)</td>
<td>-</td>
</tr>
<tr>
<td>Male sex</td>
<td>4,931 (62.9)</td>
<td>3,394 (74.2)</td>
<td>1,074 (52.6)</td>
<td>463 (37.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Blunt injury</td>
<td>7,370 (94.0)</td>
<td>4,178 (91.4)</td>
<td>1,983 (97.2)</td>
<td>1,209 (98.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Injury mechanism</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Traffic accident</td>
<td>2,138 (27.3)</td>
<td>1,488 (32.6)</td>
<td>487 (23.9)</td>
<td>163 (13.3)</td>
<td></td>
</tr>
<tr>
<td>Pedestrian injury</td>
<td>695 (8.9)</td>
<td>381 (8.3)</td>
<td>215 (10.5)</td>
<td>99 (8.1)</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>1,429 (18.2)</td>
<td>962 (21.0)</td>
<td>319 (15.6)</td>
<td>148 (12.0)</td>
<td></td>
</tr>
<tr>
<td>Slip</td>
<td>2,142 (27.3)</td>
<td>694 (15.1)</td>
<td>757 (37.1)</td>
<td>691 (56.2)</td>
<td></td>
</tr>
<tr>
<td>Stuck by object</td>
<td>557 (7.1)</td>
<td>421 (9.2)</td>
<td>97 (4.7)</td>
<td>39 (3.2)</td>
<td></td>
</tr>
<tr>
<td>Stab wound</td>
<td>348 (3.4)</td>
<td>305 (6.7)</td>
<td>36 (1.8)</td>
<td>7 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>534 (6.8)</td>
<td>322 (7.0)</td>
<td>130 (6.4)</td>
<td>82 (6.6)</td>
<td></td>
</tr>
<tr>
<td>Season of injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.164</td>
</tr>
<tr>
<td>Spring</td>
<td>1,998 (25.5)</td>
<td>1,131 (24.7)</td>
<td>565 (27.7)</td>
<td>302 (24.6)</td>
<td></td>
</tr>
<tr>
<td>Summer</td>
<td>2,017 (25.7)</td>
<td>1,168 (25.5)</td>
<td>515 (25.2)</td>
<td>334 (27.2)</td>
<td></td>
</tr>
<tr>
<td>Autumn</td>
<td>2,087 (26.6)</td>
<td>1,229 (26.9)</td>
<td>530 (26.0)</td>
<td>328 (26.7)</td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>1,741 (22.2)</td>
<td>1,045 (22.9)</td>
<td>431 (21.1)</td>
<td>265 (21.5)</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as median (interquartile range) or number (%). Patients were classified based on age: group A (18–64 years), group B (65–79 years), and group C (≥80 years).

Table 2. Injured region

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n=7,843)</th>
<th>Group A (n=4,573)</th>
<th>Group B (n=2,041)</th>
<th>Group C (n=1,229)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injured body region(^a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head and neck</td>
<td>2,443 (31.1)</td>
<td>1,426 (31.2)</td>
<td>680 (33.3)</td>
<td>337 (27.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Face</td>
<td>999 (12.7)</td>
<td>713 (15.7)</td>
<td>219 (10.7)</td>
<td>67 (5.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chest</td>
<td>2,282 (29.1)</td>
<td>1,455 (31.8)</td>
<td>588 (28.8)</td>
<td>239 (19.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Abdomen</td>
<td>1,601 (20.4)</td>
<td>1,168 (25.5)</td>
<td>334 (16.4)</td>
<td>99 (8.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pelvis and extremities</td>
<td>4,318 (55.1)</td>
<td>2,360 (51.6)</td>
<td>1,139 (55.8)</td>
<td>819 (66.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>External</td>
<td>2,401 (30.6)</td>
<td>1,615 (35.3)</td>
<td>561 (27.5)</td>
<td>225 (18.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Severely injured region(^a),(^b)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head and neck</td>
<td>1,789 (22.8)</td>
<td>993 (21.7)</td>
<td>524 (25.7)</td>
<td>272 (22.1)</td>
<td>0.002</td>
</tr>
<tr>
<td>Face</td>
<td>54 (0.7)</td>
<td>41 (0.9)</td>
<td>12 (0.6)</td>
<td>1 (0.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Chest</td>
<td>1,639 (20.9)</td>
<td>990 (21.6)</td>
<td>472 (23.1)</td>
<td>177 (14.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Abdomen</td>
<td>781 (10.0)</td>
<td>584 (12.8)</td>
<td>156 (7.6)</td>
<td>41 (3.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pelvis and extremities</td>
<td>2,062 (26.3)</td>
<td>821 (18.0)</td>
<td>638 (31.3)</td>
<td>603 (49.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>External</td>
<td>7 (0.1)</td>
<td>7 (0.2)</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>No. of injured region</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>2</td>
<td>1,635 (20.8)</td>
<td>1,054 (23.0)</td>
<td>412 (20.2)</td>
<td>169 (13.8)</td>
<td></td>
</tr>
<tr>
<td>≥3</td>
<td>1,785 (22.8)</td>
<td>1,218 (26.6)</td>
<td>419 (20.5)</td>
<td>148 (12.0)</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as number (%). Patients were classified based on age: group A (18–64 years), group B (65–79 years), and group C (≥80 years).
\(^a\)The sum may exceed the total due to the presence of injuries in multiple regions.
\(^b\)Abbreviated Injury Scale score, >3.

age ≥ 65 years, the GCS score was the strongest predictor, and sex was a predictor compared with the entire age group. Male sex was a predictor of high mortality rates in the elderly population (odds ratio, 1.58; 95% confidence interval, 1.10–2.28; P < 0.05) (Fig. 3).

**DISCUSSION**

This study is meaningful in that the results can improve the treatment of trauma patients by identifying the characteristics, severity of injury of trauma patients by age group. It can also contribute to the appropriate distribution of equipment, manpower, and costs at regional trauma centers by identifying the causes of acci-
Table 3. Injury scores

<table>
<thead>
<tr>
<th>Score</th>
<th>Total (n=7,843)</th>
<th>Group A (n=4,573)</th>
<th>Group B (n=2,041)</th>
<th>Group C (n=1,229)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISS</td>
<td>9 (4–16)</td>
<td>9 (4–17)</td>
<td>9 (8–16)</td>
<td>9 (9–11)</td>
<td>0.004</td>
</tr>
<tr>
<td>Mild (1–15)</td>
<td>5,668 (72.3)</td>
<td>3,185 (69.6)</td>
<td>1,501 (73.5)</td>
<td>982 (79.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Severe (16–75)</td>
<td>2,175 (27.7)</td>
<td>1,388 (30.4)</td>
<td>540 (26.5)</td>
<td>247 (20.1)</td>
<td></td>
</tr>
</tbody>
</table>

GCS score

| Mild (13–15) | 6,927 (88.3)    | 4,012 (87.7)      | 1,816 (89.0)      | 1,099 (89.4)      | 0.358   |
| Moderate (9–12) | 388 (5.0)       | 232 (5.1)         | 97 (4.7)          | 59 (4.8)          |         |
| Severe (3–8)  | 528 (6.7)       | 329 (7.4)         | 128 (6.3)         | 71 (5.8)          |         |

TRISS

| 0.953 (0.953–0.993) | 0.982 (0.953–0.993) | 0.953 (0.953–0.953) | 0.953 (0.953–0.953) | <0.001 |

GTOS

| 91.5 (69.5–110.0) | 74.0 (58.0–96.5) | 99.5 (89.0–118.0) | 108.0 (104.0–126.0) | <0.001 |

Values are presented as median (interquartile range) or number (%). Patients were classified based on age: group A (18–64 years), group B (65–79 years), and group C (≥80 years).

ISS, Injury Severity Score; GCS, Glasgow Coma Scale; TRISS, Trauma and Injury Severity Score; GTOS, Geriatric Trauma Outcome Score.

Table 4. Clinical parameters and outcomes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n=7,843)</th>
<th>Group A (n=4,573)</th>
<th>Group B (n=2,041)</th>
<th>Group C (n=1,229)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension</td>
<td>370 (4.7)</td>
<td>231 (5.1)</td>
<td>97 (4.8)</td>
<td>42 (3.4)</td>
<td>0.042</td>
</tr>
<tr>
<td>Transfusion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within 4 hr</td>
<td>971 (12.5)</td>
<td>607 (13.3)</td>
<td>241 (11.8)</td>
<td>123 (10.0)</td>
<td>0.006</td>
</tr>
<tr>
<td>Within 24 hr</td>
<td>1,432 (18.3)</td>
<td>815 (17.8)</td>
<td>376 (18.4)</td>
<td>241 (19.6)</td>
<td>0.346</td>
</tr>
<tr>
<td>Surgery or intervention</td>
<td>1,702 (21.7)</td>
<td>1,174 (25.7)</td>
<td>371 (18.2)</td>
<td>157 (12.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICU admission</td>
<td>2,727 (35.0)</td>
<td>1,727 (37.8)</td>
<td>692 (33.9)</td>
<td>308 (25.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of stay (day)</td>
<td>3 (1–7)</td>
<td>3 (1–6)</td>
<td>3 (2–8)</td>
<td>3 (2–13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mortality</td>
<td>362 (13.3)</td>
<td>164 (9.5)</td>
<td>116 (16.8)</td>
<td>82 (26.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td>422 (5.4)</td>
<td>170 (3.7)</td>
<td>135 (6.6)</td>
<td>117 (9.5)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are presented as number (%) or median (interquartile range). Patients were classified based on age: group A (18–64 years), group B (65–79 years), and group C (≥80 years).

ICU, intensive care unit.

Table 5. Predictors of mortality

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Univariate analysis</th>
<th>Multivariate analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>P-value</td>
</tr>
<tr>
<td>Sex</td>
<td>0.86 (0.66–1.13)</td>
<td>0.278</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>1.05 (1.04–1.06)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>1.11 (1.10–1.13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Transfusion within 24 hr</td>
<td>6.17 (4.49–8.40)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hypotension</td>
<td>3.87 (2.54–5.90)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICU admission</td>
<td>7.67 (5.71–10.31)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>GCS score</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate (9–12)</td>
<td>6.52 (4.32–9.86)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Severe (3–8)</td>
<td>29.49 (22.0–39.48)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Surgery or intervention</td>
<td>1.66 (1.26–2.18)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Hosmer-Lemeshow goodness-of-fit test: P=0.853.

OR, odds ratio; CI, confidence interval; ICU, intensive care unit; GCS, Glasgow Coma Scale.
Predictors according to age. In particular, it can be helpful in the treatment of super-aged trauma patients by separately presenting the characteristics of super-aged trauma patients.

In this study, injuries caused by traffic accidents (36.2%) were the most common among all age groups. In groups A and B, which were socially active, the rate of accidents caused by falls and impaled objects, in addition to traffic accidents, was higher than that in group C. This is thought to be due to the high rate of movement or occupational activity in groups A and B, and the difference in the mechanism of injury appears to be due to a difference in the area or degree of injury. In contrast, in group C, which was a super-aged group, the damage caused by falls was 56.2%, significantly higher than that in the other groups. Owing to the difference in the mechanism of injury, the rate of injury to the head and neck, pelvis, and extremities was high in group C. In addition, osteoporosis is often present in the elderly, so the frequency or severity of fractures in the pelvis or extremities is higher than that in the young, even with low-energy trauma [12,13]. In this study, 73.6% of pelvic fractures in patients aged 80 years or older showed severe damage of 3 AIS. Older patients with pelvic fractures show a fourfold increase in mortality and a higher rate of prolonged hospitalization or other complications than their younger counterparts. In addition, patients aged 60 years or older are reported to have a high risk of intrapelvic bleeding; therefore, interventional procedures, such as angiography or embolization, are often needed early [14]. For elderly patients, even if the frequency of multiple injuries from low-energy trauma is low, active treatment and attention are needed in cases of pelvic injury.

ISS is useful for predicting the morbidity and mortality of patients with trauma, estimating the length of recovery after trauma, and predicting resource demands in regional trauma centers. ISS was higher in the younger age group, probably due to differ-
ences in the mechanism of injury. Several indicators can determine the severity of trauma and predict mortality or survival rates. In this study, GCS scores showed no significant differences among the three age groups. However, TRISS and GTOS showed significant differences. GTOS is a scoring system [9] that can easily predict the possibility of death in elderly patients, and its effectiveness has been verified in several studies [15–17].

The frequency of low blood pressure, requirement for red blood cell transfusion, and requirement for ICU admission were higher in the younger age group; however, the duration of hospitalization and mortality rate in the ICU were higher in the elderly. In addition, the number of patients who needed red blood cell transfusion within 24 hours was higher in the elderly group than in the younger age group, possibly because of the presence of underlying diseases and systemic conditions that are not explained by injury scores or hypotension immediately after injury and because the elderly have different degrees of physiological responses to acute injuries. Perdue et al. [16] reported that the mortality rate was twice as high in elderly patients, despite having the same injury mechanism and similar damage scores as the younger patients, because they more often have comorbid diseases and complications. Therefore, in the case of elderly patients who visit the hospital for trauma, a detailed treatment approach involving a detailed medical history taking and evaluation of the overall condition is needed.

Recently, the increase in traffic accidents has led to an increase in the incidence of multiple traumas. A study by van Breugel et al. [17] reported that the overall mortality rate of trauma patients has decreased over the past decade and that the main cause of death has shifted from multiple organ failure to brain damage. In the study by Chang et al. [18], the cause of accidents in patients in severe specialized trauma centers in Korea was traffic accidents, and the main cause of death was brain damage. In this study, similar to previous studies, severe brain injury was the major cause of death. Mock et al. [19] reported that the mortality rate of patients aged 80 years and above admitted to the ICU was 22%, similar to the 26.6% reported in this study. In this study, the mortality rate increased with age and the mortality rate was higher among patients requiring ICU admission.

Factors affecting posttraumatic mortality vary depending on the study design, but older age, high ISS, and low GCS score have been reported to be some common predictors [20,21]. In this study, low GCS score was also the strongest predictor, followed by blood transfusion, ICU admission, age, and ISS. The odds ratios of low GCS score tended to be lower in the elderly patient group than in the entire age group. Considering that there is no difference in the distribution of GCS score according to the age group, it can be estimated that underlying diseases or frailty affect death in the elderly group. In particular, in the group of elderly patients aged 65 years or older, women had a lower mortality rate than men, probably due to the mechanism of injury in elderly women, mainly slipping.

Limitations
This study has several limitations. First, this was a retrospective study and may have been affected by selection bias and unreliable data. Second, this study was based on data from a single center, and the results may not be generalizable to all trauma patients. Third, by excluding patients who died during transport or in the emergency room, the data may not have reflected the mechanism of a severe injury that could cause death at the time of injury.

Conclusions
Trauma patients experience different mechanisms, injured body regions, and severities of injury, and the prognosis differs according to age group. Despite the low ICU admission rate among older patients, the high mortality rate suggests that different strategies are required for older trauma patients. For most patients, low GCS score and transfusion within 24 hours were predictors of death. The survival rate of trauma patients can be improved by providing appropriate and aggressive treatment according to the age and characteristics of the patients visiting the emergency department for trauma.

ARTICLE INFORMATION

Author contributions
Conceptualization: JHH, SYY; Data curation: JHH, JS, JYL, JSL, JBY, YS, SK, HRK; Formal analysis: JHH; Methodology: JHH; Project administration: YS; Supervision: SYY; Writing–original draft: JHH; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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

Funding
The authors received no financial support for this study.

Data availability
Data analyzed in this study are available from the corresponding author upon reasonable request.
REFERENCES

Determining the appropriate resting energy expenditure requirement for severe trauma patients using indirect calorimetry in Korea: a retrospective observational study

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Division of Acute Care Surgery, Department of Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

Purpose: This study aimed to compare the resting energy expenditure (REE) measured using indirect calorimetry with that estimated using predictive equations in severe trauma patients to determine the appropriate caloric requirements.

Methods: Patients admitted to the surgical intensive care unit between January 2020 and March 2023 were included in this study. Indirect calorimetry was used to measure the patients’ REE values. These values were subsequently compared with those estimated using predictive equations: the weight-based equation (rule of thumb, 25 kcal/kg/day), Harris-Benedict, Ireton-Jones, and the Penn State 2003 equations.

Results: A total of 27 severe trauma patients were included in this study, and 47 indirect calorimetric measurements were conducted. The weight-based equation (mean difference [MD], –28.96±303.58 kcal) and the Penn State 2003 equation (MD, –3.56±270.39 kcal) showed the closest results to REE measured by indirect calorimetry. However, the REE values estimated using the Harris-Benedict equation (MD, 156.64±276.54 kcal) and Ireton-Jones equation (MD, 250.87±332.54 kcal) displayed significant differences from those measured using indirect calorimetry. The concordance rate, which the predictive REE differs from the measured REE value within 10%, was up to 36.2%.

Conclusions: The REE values estimated using predictive equations exhibited substantial differences from those measured via indirect calorimetry. Therefore, it is necessary to measure the REE value through indirect calorimetry in severe trauma patients.

Keywords: Wounds and injuries; Indirect calorimetry; Nutritional requirements; Energy metabolism

INTRODUCTION

Background

Proper nutritional support plays a crucial role in the recovery of critically ill patients. Overfeeding and underfeeding are potentially associated with mortality [1,2]. Overfeeding can lead to complications such as infection, hyperglycemia, and ventilation weaning failure. Underfeeding can have some complications...
such as infection, skeletal muscle loss, impaired immune function, and delayed wound healing. Several studies have reported the importance of determining and supplying the appropriate amount of calories [2–6]. The American Society for Parenteral and Enteral Nutrition (ASPEN) and European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines recommend indirect calorimetry use to measure patients’ appropriate caloric intakes [7,8]. However, using indirect calorimetry in the clinical setting is challenging due to the associated costs and required resources. Therefore, the ASPEN guidelines recommend that a published predictive equation or simplistic weight-based equation (25 to 30 kcal/kg/day) be used to determine energy requirements [7].

Notwithstanding, several studies have reported that these predictive equations are not sufficiently accurate [2,4,9,10]. Since calculations involving predictive equations are based on parameters such as patient height, weight, sex, and age, they do not accurately reflect a patient’s actual condition. In particular, severe trauma potentially leads to a cascade of metabolic responses. In addition to primary traumatic injury, various metabolic responses occur due to secondary injury, such as massive transfusion, resuscitation, generalized inflammation, and infection [11,12]. Although most trauma patients have normal nutritional statuses before hospital admission, these metabolic responses increase the risk of malnutrition. Therefore, determining the appropriate caloric requirements for trauma patients is imperative.

Objectives
This study aims to compare the resting energy expenditure (REE) measured by indirect calorimetry in severe trauma patients with the value obtained through the predictive equations.

**METHODS**

**Ethics statement**
This study was approved by the Institutional Review Board of Asan Medical Center (No. 2023-0355). The requirement for informed consent was waived due to the retrospective nature of the study.

**Study setting and patients**
This study retrospectively investigated trauma patients admitted to the surgical intensive care unit (ICU) between January 2020 and March 2023. Severe trauma patients with an Injury Severity Score (ISS) ≥ 15 who had undergone mechanical ventilation for more than 3 days were included in this study. Patients aged < 18 years who were unable to undergo indirect calorimetric measurement (fraction of inspired oxygen >0.6, bronchopleural fistula, and/or persistent air leakage) were excluded. Patient-related data were retrospectively collected from electrical medical records and analyzed. Nutritional status at the ICU admission was classified according to the ASPEN malnutrition criteria [13].

**Indirect calorimetric measurement**
Indirect calorimetry was performed using a CARESCAPE Monitor B650 (GE Healthcare). REE was measured by three well-experienced critical care nurses. Measurements were conducted under the following strict conditions to obtain accurate results: (1) prohibition of interventions, such as positioning, suctioning, or hemodialysis that may stimulate the patients; (2) indirect calorimetric calibration for ≥ 10 minutes before each measurement; and (3) rest for ≥ 30 minutes before each measurement. Oxygen consumption and CO₂ production were measured, and the respiratory quotient and REE were calculated using the Weir equation.

**Predictive equations**
REE was estimated using four predictive methods: the weight-based equation [14], Harris-Benedict equation [15], Ireton-Jones equation [16] (for ventilated patients), and Penn State 2003 equation [17].

**Table 1. Predictive equations for REE**

<table>
<thead>
<tr>
<th>Name</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight-based equation [14]</td>
<td>REE=25×W</td>
</tr>
<tr>
<td>Ireton-Jones equation [16] (for ventilated patients)</td>
<td>Male: REE=2028–11(A)+5(W)+239(T)+804(B) Female: REE=1,784–11(A)+5(W)+239(T)+804(B)</td>
</tr>
<tr>
<td>Penn State 2003 equation [17]</td>
<td>REE=0.85×HBE+175×Tmax+33×VE–6433</td>
</tr>
</tbody>
</table>

REE, resting energy expenditure; W, actual body weight (kg); H, height (cm); A, age (yr); T, trauma; B, burn; HBE, Harris-Benedict equation; Tmax, maximum body temperature (°C); VE, expired minute volume.
based equation (rule of thumb, 25 kcal/kg/day) [14], Harris-Benedict equation [15], Ireton-Jones equation (for ventilated patients) [16], and the Penn State 2003 equation [17] (Table 1).

**Outcomes**
The primary outcome was the comparison between indirect calorimetry–measured and predictive equation–derived REE values. The secondary outcome was the concordance rate between the measured and predicted REE values. The concordance rate was defined as the value of the predictive equation–estimated REE that was within the 90% to 110% range of the indirect calorimetry–measured REE value.

**Statistical analysis**
Continuous, normally distributed variables are presented as mean ± standard deviation. Measurements were compared using the paired t-test. Bland-Altman method was used to calculate the mean difference (MD) between predicted and measured REE values. Statistical significance was set at P < 0.05. Statistical analyses were conducted using R ver. 4.2.3 (R Foundation for Statistical Computing).

**RESULTS**
A total of 47 indirect calorimetric measurements were performed on 27 trauma patients whose mean age was 55.6 ± 18.3 years (Fig. 1). Traffic accidents, the most common cause, accounted for 15 patients (55.6%). The average ISS was 28.6 ± 11.1, and 25 patients (92.6%) had normal nutritional statuses before ICU admission.

The average length of stay in the ICU was 30.4 ± 15.7 days, and the average length of hospital stay was 53.4 ± 27.9 days (Table 2).

The mean indirect calorimetry–measured REE value was 1,613.0 ± 382.2 kcal, and the respiratory quotient was 0.73 ± 0.06. Among the four predictive equations, the weight-based equation (MD, –28.96 ± 303.58 kcal) and the Penn State 2003 equation (MD, –3.56 ± 270.39 kcal) yielded the closest results, while Harris-Benedict and Ireton-Jones equations exhibited differences of 156.64 ± 276.53 kcal (P = 0.024) and 250.87 ± 332.54 kcal (P = 0.001), respectively. However, the concordance rate deviated from 27.6% to 36.2% (Table 3). Bland-Altman analysis revealed that each predictive equation–derived REE value differed significantly from the indirect calorimetry–measured REE value (Fig. 2).

**Table 2.** Characteristics of enrolled patients (n=27)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>20 (74.1)</td>
</tr>
<tr>
<td>Female</td>
<td>7 (25.9)</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>55.6±18.3</td>
</tr>
<tr>
<td>Underlying disease</td>
<td></td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>3 (11.1)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>6 (22.2)</td>
</tr>
<tr>
<td>Liver cirrhosis</td>
<td>2 (7.4)</td>
</tr>
<tr>
<td>Chronic kidney disease</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>8 (29.6)</td>
</tr>
<tr>
<td>Cause of trauma</td>
<td></td>
</tr>
<tr>
<td>Traffic accident</td>
<td>15 (55.6)</td>
</tr>
<tr>
<td>Fall</td>
<td>11 (40.7)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (3.7)</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>28.6±11.1</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>23.8±3.4</td>
</tr>
<tr>
<td>Nutritional status at ICU admission</td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>25 (92.6)</td>
</tr>
<tr>
<td>Moderate</td>
<td>1 (3.7)</td>
</tr>
<tr>
<td>Severe</td>
<td>1 (3.7)</td>
</tr>
<tr>
<td>Continuous renal replacement therapy</td>
<td>1 (3.7)</td>
</tr>
<tr>
<td>Median number of measurements in indirect calorimetry</td>
<td>2 (1–2)</td>
</tr>
<tr>
<td>Enteral nutrition at the indirect calorimetric measurement</td>
<td>18 (38.3)</td>
</tr>
<tr>
<td>Time from ICU admission to indirect calorimetric measurement (day) (n=47)</td>
<td>18.8±14.6</td>
</tr>
<tr>
<td>Mean fraction of inspired oxygen (n=47)</td>
<td>35.1±6.2</td>
</tr>
<tr>
<td>Length of ICU stay (day)</td>
<td>30.4±15.7</td>
</tr>
<tr>
<td>Length of hospital stay (day)</td>
<td>53.4±27.9</td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>0</td>
</tr>
</tbody>
</table>

Values are presented as number (%), mean ± standard deviation, or median (interquartile range).

ICU, intensive care unit.
Table 3. Comparison of measured REE with prediction equation–estimated REE values (n=47)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean±SD (kcal)</th>
<th>MD between measured and predicted REE values (kcal)</th>
<th>P-value</th>
<th>Concordance rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indirect calorimetry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measured REE</td>
<td>1,613±382.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Respiratory quotient</td>
<td>0.73±0.06</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Weight-based equation (25 kcal/kg)</td>
<td>1,584±226.7</td>
<td>-28.96±303.58</td>
<td>0.656</td>
<td>27.6</td>
</tr>
<tr>
<td>Harris-Benedict equation</td>
<td>1,770±270.5</td>
<td>156.6±276.53</td>
<td>0.024</td>
<td>36.2</td>
</tr>
<tr>
<td>Ireton-Jones equation</td>
<td>1,864±265.6</td>
<td>250.87±332.54</td>
<td>0.001</td>
<td>27.6</td>
</tr>
<tr>
<td>Penn State 2003 equation</td>
<td>1,609.9±293.4</td>
<td>-3.56±270.39</td>
<td>0.959</td>
<td>36.2</td>
</tr>
</tbody>
</table>

REE, resting energy expenditure; SD, standard deviation; MD, mean difference.

**DISCUSSION**

When treating severe trauma patients, proper nutritional therapy is important for their recovery. It is important to supply appropriate caloric requirements according to the patient's recovery progress. Nevertheless, determining these values in actual clinical settings proves challenging. Therefore, although several guidelines recommend indirect calorimetry use for critically ill patients, using this technique is difficult due to various limitations. In particular, few hospitals use indirect calorimetry in Korea due to challenges such as insurance fees.

Therefore, this study analyzed the concordance of predictive equations in comparison to that of indirect calorimetry. Four predictive equations typically used for critically ill and trauma patients were compared with the measured REE of indirect calorimetry. Among the four predictive equations, the simple weight-based equation and the Penn State 2003 equation yielded results that were most consistent with the indirect calorimetry–measured REE value. Several studies have reported that the Penn State 2003 equation showed the best results among several predictive equations. In a study by Kwon et al. [18], the Penn State equation produced the highest r-value (0.742; 95% confidence interval, 0.636 to 0.821) and least MD (54.8 kcal; range: −595.9 to 705.5). A study by Lee et al. [19], which targeted liver transplant patients, also found the Penn State equation showed the closest result to the measure REE. Kamel et al. [20] and Zusman et al. [21] reported that the Harris-Benedict equation yielded the closest REE value to that measured using indirect calorimetry; nevertheless, our study revealed a vast difference between the Harris-Benedict equation–derived REE value and that measured via indirect calorimetry. In contrast, our study found the REE value estimated using the weight-based equation to be most consistent with that measured using indirect calorimetry.

However, when the concordance rate was analyzed to ascertain whether the error between the measured and predictive equation–derived REE values was within 10%, considerable disparities were obtained. Several studies have reported differences between predictive equation–derived and indirect calorimetry–measured REE values [4,20,21]. In a study by Zusman et al. [21], which retrospectively analyzed a large cohort of 1,440 critically ill patients, the concordance rate was analyzed based on an error of 15%. Moreover, the Harris-Benedict equation generated the best result, with a concordance rate of 15%, and other predictive equations yielded low concordance rates. In a study by Kamel et al. [20] on critically ill surgical patients, including trauma patients, the Harris-Benedict equation exhibited the highest concordance rate (65.2%). However, most of the other predictive equations yielded low concordance rates of 40% to 50%. In our study, which exclusively included severe trauma patients, all four predictive equations produced concordance rates within the 27.6% to 36.2% range, and they were lower than those in other studies. This means that it is more difficult to evaluate the appropriate caloric requirement through a predictive equation in severe trauma patients. Bland-Altman analysis revealed that each predictive equation's REE value drastically deviated from the mean indirect calorimetry–measured REE value. Therefore, it is necessary to evaluate an appropriate caloric requirement through IC for severe trauma patients with complicated metabolic responses.

**Limitations**

This study has several limitations. First, the number of samples was small. The number of enrolled patients was small because it was limited to patients with severe trauma. Second, since the time points at which indirect calorimetric measurements were performed varied, the effect of measurement time points could not be compensated for. Finally, this was a single-center retrospective study; thus, selection bias might have arisen. A prospective large cohort study is required in the future.
Fig. 2. Bland-Altman analyses of measured and predicted resting energy expenditure (REE) values. The blue solid line represents the mean difference, and the dashed lines indicate the limits of agreement (mean±1.96 standard deviation of the differences). (A) Weight-based equation (rule of thumb). (B) Harris-Benedict equation. (C) Ireton-Jones equation. (D) Penn State 2003 equation.

Conclusions
The simplistic weight-based equation and the Penn State 2003 equation showed the similar results to the REE values measured through indirect calorimetry. However, this study’s findings suggest that the predictive equation–estimated energy expenditure of critically ill trauma patients deviates significantly from that measured using indirect calorimetry. Therefore, indirect calorimetry should be used to measure the REE values of severe trauma patients.

ARTICLE INFORMATION

Author contributions
Conceptualization: HJL, SKH; Data curation: HJL, SBA, JHL, JYK, SY; Formal analysis: SBA, JYK, SWY; Visualization: HJL; Methodology: HJL, JHL, SKH; Writing–original draft: HJL; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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

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Data availability
Data analyzed in this study are available from the corresponding author upon reasonable request.
REFERENCES

Comparison of pediatric injury patterns before and during the COVID-19 pandemic in Korea: a retrospective study

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1Department of Emergency Medicine, Gachon University Gil Medical Center, Incheon, Korea
2Department of Emergency Medicine, Gachon University College of Medicine, Incheon, Korea

Purpose: The COVID-19 pandemic led to significant changes in the lifestyle patterns of children and affected the patterns of pediatric injuries. This study analyzed the changing patterns of pediatric injury overall and by age groups, based on the datasets before and during the COVID-19 pandemic.

Methods: This study is based on the data of patients who presented with injuries at 23 hospital emergency departments participating in the Emergency Department-based Injury In-depth Surveillance (EDIIS) conducted by the Korea Disease Control and Prevention Agency. The surveillance data was categorized by injury mechanism, location, activity, and severity. We analyzed the injury patterns of pediatric patients aged 0 to 15 years. Subgroup analysis was conducted by age group in children aged 7 to 15 years, 1 to 6 years, and <1 year.

Results: When comparing the COVID-19 pandemic period to the pre–COVID-19 period, the total number of pediatric patients with injuries decreased by 38.7%, while the proportions of in-home injuries (57.9% vs. 67.9%), and minor injuries (38.9% vs. 39.7%) increased. In the 7 to 15 years group, bicycle riding injuries (50.9% vs. 65.6%) and personal mobility device injuries (2.4% vs. 4.6%) increased. The 1 to 6 years group also showed an increase in bicycle accident injuries (15.8% vs. 22.4%). In the <1 year group, injuries from falls increased (44.5% vs. 49.9%). Self-harm injuries in the 7 to 15 years group also increased (1.6% vs. 2.8%).

Conclusions: During the COVID-19 pandemic period, the overall number of pediatric injuries decreased, while injuries occurring at home and during indoor activities increased. Traffic accidents involving bicycles and personal mobility devices and self-harm injuries increased in the 7 to 15 years group. In the <1 year group, the incidence of falls increased. Medical and societal preparedness is needed so that we might anticipate these changes in the patterns of pediatric injuries during future infectious disease pandemics.

Keywords: COVID-19; Pandemics; Pediatrics; Wounds and injuries
INTRODUCTION

Background
COVID-19 was first reported in Wuhan, Hubei Province, China at the end of 2019. In the United States, the number of COVID-19 cases gradually increased between January and February 2020, and significantly increased in March 2020 [1]. On March 11, 2020, COVID-19 was declared a pandemic by the World Health Organization (WHO) [2]. On January 20, 2020, the first confirmed case of COVID-19 imported from Wuhan was reported in Korea. By March 31, 2020, Korea had a total of 9,786 confirmed cases of COVID-19, with 162 deaths and 4,216 individuals under non-hospital isolation [3]. To avoid overwhelming healthcare systems with the continuing increase in confirmed cases, home quarantine and social distancing measures were implemented worldwide. These COVID-19 containment measures led to significant changes in the lifestyle patterns of both adults and children, as well as shifts in the mechanism of traumatic injuries being seen in emergency departments [4].

Previous studies reported that activities in schools and childcare facilities decreased while activities at home increased during the COVID-19 pandemic. This shift in activities led to changes in the patterns of injuries observed in emergency departments before and after the COVID-19 outbreak [5]. Specifically, it was found that blunt trauma and exercise-related injuries decreased, while penetrating injuries and intentional injuries increased [6]. However, most studies focused on adults, and those studies that targeted pediatric populations were limited to patients from a single hospital or high-severity institutions such as trauma centers.

Objectives
The purpose of this study was to analyze the changing patterns of pediatric injuries overall and by age groups, based on a large dataset from 23 hospital emergency departments, before and during the COVID-19 pandemic.

METHODS

Ethics statement
The study protocol was reviewed and approved by the Institutional Review Board of Gachon University Gil Medical Center (No. GBIRB2023-177). The requirement for informed consent was waived due to the retrospective nature of the study. The study was conducted in compliance with the principles of the Declaration of Helsinki.

Study design and patients
This study was based on the data of patients who presented with injuries at 23 hospital emergency departments participating in the Emergency Department-based Injury In-depth Surveillance (EDIIS) conducted by the Korea Disease Control and Prevention Agency (KDCA; Cheongju, Korea). The study included 21 university hospitals and two general hospitals that were involved in the in-depth surveillance. Among them, 13 hospitals were in metropolitan areas, while the remaining 10 hospitals were distributed in various regions, with one or two hospitals per region. Each hospital was assigned a dedicated coordinator to collect the data. The collected data underwent primary verification by analyzing data integrity, including checking for duplicates and missing essential items. If errors were identified, the responsible researchers were asked to make corrections, and iterative quality management was performed to minimize error rates.

Data collection
The surveillance data included date of visit, age, sex, mode of arrival, mechanism of injury, location of injury, activity at the time of injury, emergency department treatment outcome, and the excess mortality ratio–adjusted Injury Severity Score (EMR-ISS). The mechanism of injury was classified into categories such as traffic accidents, slips, falls, blunt trauma, penetrating injuries, burns, intoxication, overexertion, foreign body insertion, and others. The location of injury was classified as home, schools/education facilities, sports facilities, roads and transportation facilities, commercial facilities, and others. The activity at the time of injury was surveyed and classified into categories including school activities, exercise, leisure activities, basic daily activities, and others.

The EMR-ISS was calculated using the S and T codes of the International Classification of Diseases (ICD). Each diagnosis was assigned a severity score ranging from 1 to 5. The EMR-ISS was calculated by squaring the three highest scoring codes, regardless of the body region, and adding them together [7]. To assess the severity of trauma, the EMR-ISS was used and scores were classified as mild (<9), moderate (9–24), and severe (25–74) [8]. To analyze treatment outcomes, they were categorized as discharge after emergency department treatment, admission, intensive care unit (ICU) admission, surgery, and death.

Statistical analysis
The collected data were analyzed using SPSS ver. 24.0 (IBM Corp.). The chi-square test was employed to compare the frequencies of categorical variables between groups. The
Mann-Whitney U-test was used for univariate analysis of continuous variables. A P-value of < 0.05 was considered statistically significant.

RESULTS

The total number of injured patients treated in the 23 hospital emergency departments in Korea during the pre–COVID-19 period (March 12, 2018, to December 31, 2019) and the COVID-19 pandemic period (March 12, 2020, to December 31, 2021) was 873,149, of whom 222,304 were ≤ 15 years old. Among them, 14,526 patients (6.5%) were < 1 year, 137,425 patients (61.8%) were 1 to 6 years, and 70,353 patients (31.7%) were 7 to 15 years (Fig. 1). Characteristics of the patients and their injuries are shown in Table 1.

The number of pediatric patients 0 to 15 years old who were treated in the emergency department decreased by 38.7%, from 137,880 during the pre–COVID-19 period to 84,424 during the COVID-19 pandemic period. In both periods, the proportion of boys was higher (62.1% vs. 61.3%, P < 0.001), and 1 to 6 years had the highest number of visits to the emergency department (61.3% vs. 62.7%, P < 0.001). When comparing the pre–COVID-19 period to the COVID-19 pandemic period for mechanism of injury, blunt trauma decreased by 2.4 percentage points (30.9% vs. 28.5%), while falls increased by 1.3 percentage points (15.0% vs. 16.3%), foreign body insertion increased by 2.3 percentage points (7.7% vs. 10.0%), and traffic accidents decreased by 0.3 percentage points (6.5% vs. 6.2%). There were statistically significant differences in injury mechanisms between the two periods (P < 0.001).

During the COVID–19 pandemic, injuries occurred predominantly at home during the pandemic, a 14.6 percentage points increase over the pre–COVID–19 period (32.6% vs. 47.2%). Injuries that occurred in education facilities showed a 10.5 percentage points decrease (18.7% vs. 8.2%), indicating a decrease in the occurrence of injuries associated with school-related outdoor activities.

In terms of activity at the time of injury, in the COVID-19 pandemic there was a 5.7 percentage points decrease in injuries during educational activities compared to the pre–COVID–19 period (9.6% vs. 3.9%). Exercise-related injuries decreased by 5.7 percentage points (15.2% vs. 9.5%), while injuries during leisure activities increased by 5.2 percentage points (25.1% vs. 30.3%). Injuries during daily activities increased by 6.1 percentage points (42.3% vs. 48.4%). Regarding injury intention, self-harm increased by 1.2 percentage points (1.6% vs. 2.8%). Analysis of the EMR-ISS showed that severe injuries (3.6% vs. 3.5%) and moderate injuries (49.0% vs. 47.1%) decreased, while minor injuries increased (38.9% vs. 46.5%).

When considering location, injuries occurred predominantly at home during the pandemic, a 14.6 percentage points increase over the pre–COVID–19 period (32.6% vs. 47.2%). Injuries that occurred in education facilities showed a 10.5 percentage points decrease (18.7% vs. 8.2%), indicating a decrease in the occurrence of injuries associated with school-related outdoor activities.

In terms of activity at the time of injury, in the COVID–19 pandemic there was a 5.7 percentage points decrease in injuries during educational activities compared to the pre–COVID–19 period (9.6% vs. 3.9%). Exercise-related injuries decreased by 5.7 percentage points (15.2% vs. 9.5%), while injuries during leisure activities increased by 5.2 percentage points (25.1% vs. 30.3%). Injuries during daily activities increased by 6.1 percentage points (42.3% vs. 48.4%). Regarding injury intention, self-harm increased by 1.2 percentage points (1.6% vs. 2.8%). Analysis of the EMR-ISS showed that severe injuries (3.6% vs. 3.5%) and moderate injuries (49.0% vs. 47.1%) decreased, while minor injuries increased (46.5% vs. 48.5%).

In the subgroup analysis of patients aged 1 to 6 years who presented to the emergency departments with injuries (Table 3), the number of patients decreased by 37.3%, with 84,477 in the pre–COVID–19 period and 52,948 in the COVID–19 pandemic period. Blunt injuries decreased (31.2% vs. 30.6%), traffic accidents decreased (3.6% vs. 2.5%), and foreign body insertion increased by 2.2 percentage points (8.8% vs. 11.0%). During the COVID–19 pandemic period, injuries occurred predominantly at home, with a 7.3 percentage points increase compared to the pre–COVID–19 period (68.1% vs. 75.4%). Education facilities showed a 0.8 percentage points decrease (5.1% vs. 4.3%), reflecting a statistically significant decrease in injury rates associated with outdoor activities (P < 0.001). In terms of the EMR-ISS, severe injuries (2.1% vs. 1.9%) and moderate injuries (60.4% vs. 60.8%) de-
### Table 1. Demographics of pediatric trauma patients and their injuries before and during the COVID-19 pandemic (n=222,304)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre–COVID-19 (n=137,880)</th>
<th>COVID-19 (n=84,424)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male</td>
<td>85,684 (62.1)</td>
<td>51,759 (61.3)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>52,196 (37.9)</td>
<td>32,665 (38.7)</td>
<td></td>
</tr>
<tr>
<td><strong>Age (yr)</strong></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&lt;1</td>
<td>8,788 (6.4)</td>
<td>5,738 (6.8)</td>
<td></td>
</tr>
<tr>
<td>1–6</td>
<td>84,477 (61.3)</td>
<td>52,948 (62.7)</td>
<td></td>
</tr>
<tr>
<td>7–15</td>
<td>44,615 (32.3)</td>
<td>25,738 (30.5)</td>
<td></td>
</tr>
<tr>
<td><strong>Injury mechanism</strong></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Traffic accident</td>
<td>8,950 (6.5)</td>
<td>5,194 (6.2)</td>
<td></td>
</tr>
<tr>
<td>Slip and fall</td>
<td>32,125 (23.3)</td>
<td>19,494 (23.1)</td>
<td></td>
</tr>
<tr>
<td>Fall from a height</td>
<td>20,625 (15.0)</td>
<td>13,749 (16.3)</td>
<td></td>
</tr>
<tr>
<td>Blunt force</td>
<td>42,549 (30.9)</td>
<td>24,040 (28.5)</td>
<td></td>
</tr>
<tr>
<td>Penetrating</td>
<td>9,653 (7.0)</td>
<td>6,287 (7.4)</td>
<td></td>
</tr>
<tr>
<td>Overexertion/overuse</td>
<td>7,040 (5.1)</td>
<td>3,599 (4.3)</td>
<td></td>
</tr>
<tr>
<td>Burn</td>
<td>3,272 (2.4)</td>
<td>1,597 (1.9)</td>
<td></td>
</tr>
<tr>
<td>Poisoning</td>
<td>1,818 (1.3)</td>
<td>1,320 (1.6)</td>
<td></td>
</tr>
<tr>
<td>Insertion of foreign objects</td>
<td>10,668 (7.7)</td>
<td>8,430 (10.0)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1,180 (0.8)</td>
<td>714 (0.7)</td>
<td></td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Home</td>
<td>79,882 (57.9)</td>
<td>57,319 (67.9)</td>
<td></td>
</tr>
<tr>
<td>Education facility</td>
<td>12,659 (9.2)</td>
<td>4,425 (5.2)</td>
<td></td>
</tr>
<tr>
<td>Sports facility</td>
<td>6,331 (4.6)</td>
<td>2,718 (3.2)</td>
<td></td>
</tr>
<tr>
<td>Transportation facility</td>
<td>17,518 (12.7)</td>
<td>9,543 (11.3)</td>
<td></td>
</tr>
<tr>
<td>Social facility</td>
<td>16,540 (12.0)</td>
<td>7,625 (9.0)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>4,950 (3.6)</td>
<td>2,794 (3.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Activity</strong></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Indoor (daily activity)</td>
<td>92,222 (66.9)</td>
<td>59,175 (70.1)</td>
<td></td>
</tr>
<tr>
<td>Outdoor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>7,095 (5.1)</td>
<td>2,315 (2.7)</td>
<td></td>
</tr>
<tr>
<td>Exercise</td>
<td>7,673 (5.6)</td>
<td>2,867 (3.4)</td>
<td></td>
</tr>
<tr>
<td>Leisurea)</td>
<td>25,574 (18.5)</td>
<td>17,436 (20.7)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>5,316 (3.9)</td>
<td>2,631 (3.1)</td>
<td></td>
</tr>
<tr>
<td><strong>Transportation by ambulance</strong></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Intention</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Unintentional</td>
<td>135,595 (98.3)</td>
<td>82,701 (98.0)</td>
<td></td>
</tr>
<tr>
<td>Self-harm</td>
<td>696 (0.5)</td>
<td>736 (0.9)</td>
<td></td>
</tr>
<tr>
<td>Violence</td>
<td>1,482 (1.2)</td>
<td>937 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>107 (0.1)</td>
<td>50 (0.0)</td>
<td></td>
</tr>
<tr>
<td><strong>Time of injury</strong></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>00:00–0:8:00</td>
<td>6,640 (4.8)</td>
<td>4,114 (4.9)</td>
<td></td>
</tr>
<tr>
<td>08:00–16:00</td>
<td>50,178 (36.4)</td>
<td>28,423 (33.7)</td>
<td></td>
</tr>
<tr>
<td>16:00–24:00</td>
<td>80,774 (58.7)</td>
<td>51,766 (61.3)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>288 (0.2)</td>
<td>121 (0.1)</td>
<td></td>
</tr>
<tr>
<td><strong>ED disposition</strong></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Discharge</td>
<td>131,870 (95.6)</td>
<td>80,049 (94.8)</td>
<td></td>
</tr>
<tr>
<td>Admission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General ward</td>
<td>4,518 (3.3)</td>
<td>3,123 (3.7)</td>
<td></td>
</tr>
<tr>
<td>Intensive care unit</td>
<td>695 (0.5)</td>
<td>522 (0.6)</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>739 (0.5)</td>
<td>683 (0.8)</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>58 (0.1)</td>
<td>47 (0.1)</td>
<td></td>
</tr>
</tbody>
</table>

(Continued on the next page)
### Table 2. Subgroup analysis of changes in pediatric trauma among children aged 7 to 15 years, before and during the COVID-19 pandemic (n=70,353)

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of patients (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre–COVID-19 (n=44,615)</td>
<td>COVID-19 (n=25,738)</td>
</tr>
<tr>
<td>Injury mechanism</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traffic accident</td>
<td>5,695 (12.8)</td>
<td>3,759 (14.6)</td>
</tr>
<tr>
<td>Slip and fall</td>
<td>9,652 (21.6)</td>
<td>5,513 (21.4)</td>
</tr>
<tr>
<td>Fall from a height</td>
<td>4,047 (2.9)</td>
<td>2,273 (2.8)</td>
</tr>
<tr>
<td>Blunt force</td>
<td>14,640 (32.8)</td>
<td>6,913 (26.9)</td>
</tr>
<tr>
<td>Penetrating</td>
<td>3,798 (8.5)</td>
<td>2,530 (9.8)</td>
</tr>
<tr>
<td>Overexertion/overuse</td>
<td>2,459 (5.5)</td>
<td>1,056 (4.1)</td>
</tr>
<tr>
<td>Burn</td>
<td>800 (1.8)</td>
<td>439 (1.7)</td>
</tr>
<tr>
<td>Poisoning</td>
<td>638 (1.4)</td>
<td>539 (2.1)</td>
</tr>
<tr>
<td>Insertion of foreign objects</td>
<td>2,543 (5.7)</td>
<td>2,127 (8.3)</td>
</tr>
<tr>
<td>Other</td>
<td>351 (0.8)</td>
<td>232 (0.9)</td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home</td>
<td>14,572 (32.6)</td>
<td>12,153 (47.2)</td>
</tr>
<tr>
<td>Education facility</td>
<td>8,344 (18.7)</td>
<td>2,120 (8.2)</td>
</tr>
<tr>
<td>Sports facility</td>
<td>5,211 (11.7)</td>
<td>2,239 (8.7)</td>
</tr>
<tr>
<td>Transportation facility</td>
<td>8,817 (19.8)</td>
<td>5,293 (20.6)</td>
</tr>
<tr>
<td>Social facility</td>
<td>5,708 (12.8)</td>
<td>2,798 (10.9)</td>
</tr>
<tr>
<td>Other</td>
<td>1,963 (4.4)</td>
<td>1,135 (4.4)</td>
</tr>
<tr>
<td>Activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indoor (daily activity)</td>
<td>18,869 (42.3)</td>
<td>12,467 (48.4)</td>
</tr>
<tr>
<td>Outdoor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>4,285 (9.6)</td>
<td>995 (3.9)</td>
</tr>
<tr>
<td>Exercise</td>
<td>6,767 (15.2)</td>
<td>2,451 (9.5)</td>
</tr>
<tr>
<td>Leisure a)</td>
<td>11,230 (25.1)</td>
<td>7,800 (30.3)</td>
</tr>
<tr>
<td>Other</td>
<td>3,464 (7.8)</td>
<td>2,025 (7.9)</td>
</tr>
<tr>
<td>Intention</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unintentional</td>
<td>42,551 (95.4)</td>
<td>24,170 (93.9)</td>
</tr>
<tr>
<td>Self-harm</td>
<td>693 (1.5)</td>
<td>733 (2.8)</td>
</tr>
<tr>
<td>Violence</td>
<td>1,323 (3.0)</td>
<td>817 (3.3)</td>
</tr>
<tr>
<td>Other</td>
<td>48 (0.1)</td>
<td>18 (0.0)</td>
</tr>
<tr>
<td>EMR-ISS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild (&lt;9)</td>
<td>20,767 (46.5)</td>
<td>12,486 (48.5)</td>
</tr>
<tr>
<td>Moderate (9–24)</td>
<td>21,851 (49.0)</td>
<td>12,122 (47.1)</td>
</tr>
<tr>
<td>Severe (&gt;24)</td>
<td>1,595 (3.6)</td>
<td>911 (3.5)</td>
</tr>
<tr>
<td>Unknown</td>
<td>402 (0.9)</td>
<td>219 (0.9)</td>
</tr>
</tbody>
</table>

**EMR-ISS, excess mortality ratio–adjusted Injury Severity Score.**

a) Leisure activities included dog walking, children’s play, watching a movie, watching a sports game, going to the cinema, having a party, going camping, and dancing.
increased, while minor injuries increased (36.3% vs. 36.8%).

In the subgroup analysis of infants < 1 year who presented to the emergency department (Table 4), there were 8,788 patients in the pre–COVID-19 period and 5,738 patients in the COVID-19 pandemic period, representing a decrease of 37.3%. In terms of injury mechanism, falls increased by 5.4 percentage points (44.5% vs. 49.9%), while blunt injuries decreased (17.7% vs. 15.8%). Regarding location, there was a 2.6 percentage points increase in injuries at home (89.0% vs. 91.5%). In terms of activity at the time of injury, daily activities increased by 1.0 percentage points (93.4% vs. 94.4%). The EMR-ISS showed that severe injuries (8.1% vs. 6.4%) and moderate injuries (65.9% vs. 65.3%) decreased, while minor injuries increased (25.1% vs. 27.6%).

For detailed analysis of the mechanism of traffic accidents across all age groups, further subgroup analysis was performed comparing traffic accidents during the pre–COVID-19 and COVID-19 pandemic periods (Fig. S1). In infants under 1 year, vehicle accidents decreased by 1.2 percentage points (95.7% vs. 94.5%).

Table 3. Subgroup analysis of changes in pediatric trauma among children aged 1 to 6 years before and during the COVID-19 pandemic (n=137,425)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre–COVID-19 (n=84,477)</th>
<th>COVID-19 (n=52,948)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury mechanism</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Traffic accident</td>
<td>3,024 (3.6)</td>
<td>1,344 (2.5)</td>
<td></td>
</tr>
<tr>
<td>Slip and fall</td>
<td>21,631 (25.6)</td>
<td>13,497 (25.5)</td>
<td></td>
</tr>
<tr>
<td>Fall from a height</td>
<td>12,675 (15.0)</td>
<td>8,258 (15.6)</td>
<td></td>
</tr>
<tr>
<td>Blunt force</td>
<td>26,350 (31.2)</td>
<td>16,217 (30.6)</td>
<td></td>
</tr>
<tr>
<td>Penetrating</td>
<td>5,446 (6.4)</td>
<td>3,506 (6.6)</td>
<td></td>
</tr>
<tr>
<td>Overexertion/overuse</td>
<td>4,223 (5.0)</td>
<td>2,318 (4.4)</td>
<td></td>
</tr>
<tr>
<td>Burn</td>
<td>2,018 (2.4)</td>
<td>936 (1.8)</td>
<td></td>
</tr>
<tr>
<td>Poisoning</td>
<td>981 (1.2)</td>
<td>663 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Insertion of foreign objects</td>
<td>7,418 (8.8)</td>
<td>5,818 (11.0)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>711 (0.8)</td>
<td>391 (0.7)</td>
<td></td>
</tr>
<tr>
<td>Location</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Home</td>
<td>57,492 (68.1)</td>
<td>39,913 (75.4)</td>
<td></td>
</tr>
<tr>
<td>Education facility</td>
<td>4,290 (5.1)</td>
<td>2,285 (4.3)</td>
<td></td>
</tr>
<tr>
<td>Sports facility</td>
<td>1,116 (1.3)</td>
<td>478 (0.9)</td>
<td></td>
</tr>
<tr>
<td>Transportation facility</td>
<td>8,186 (9.7)</td>
<td>4017 (7.6)</td>
<td></td>
</tr>
<tr>
<td>Social facility</td>
<td>10,541 (12.5)</td>
<td>4,677 (8.8)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2,852 (3.3)</td>
<td>1,578 (3.0)</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Indoor (daily activity)</td>
<td>65,149 (77.1)</td>
<td>41,292 (78.0)</td>
<td></td>
</tr>
<tr>
<td>Outdoor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>2,798 (3.3)</td>
<td>1,310 (2.5)</td>
<td></td>
</tr>
<tr>
<td>Exercise</td>
<td>905 (1.1)</td>
<td>416 (0.8)</td>
<td></td>
</tr>
<tr>
<td>Leisure a)</td>
<td>13,935 (16.5)</td>
<td>9,393 (17.7)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>1,690 (2.0)</td>
<td>537 (1.0)</td>
<td></td>
</tr>
<tr>
<td>Intention</td>
<td></td>
<td></td>
<td>0.584</td>
</tr>
<tr>
<td>Unintentional</td>
<td>84,275 (99.7)</td>
<td>52,814 (99.8)</td>
<td></td>
</tr>
<tr>
<td>Self-harm</td>
<td>3 (0.0)</td>
<td>3 (0.0)</td>
<td></td>
</tr>
<tr>
<td>Violence</td>
<td>145 (0.2)</td>
<td>103 (0.2)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>54 (0.1)</td>
<td>28 (0.0)</td>
<td></td>
</tr>
<tr>
<td>EMR-ISS</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mild (&lt;9)</td>
<td>30,694 (36.3)</td>
<td>19,471 (36.8)</td>
<td></td>
</tr>
<tr>
<td>Moderate (9–24)</td>
<td>51,053 (60.4)</td>
<td>32,205 (60.8)</td>
<td></td>
</tr>
<tr>
<td>Severe (&gt;24)</td>
<td>1,740 (2.1)</td>
<td>998 (1.9)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>990 (1.2)</td>
<td>274 (0.5)</td>
<td></td>
</tr>
</tbody>
</table>

EMR-ISS, excess mortality ratio–adjusted Injury Severity Score.

a)Leisure activities included dog walking, children's play, watching a movie, watching a sports game, going to the cinema, having a party, going camping, and dancing.
94.5%). In the 1 to 6 years group, there was an increase in bicycle accidents (15.8% vs. 22.4%) and pedestrian accidents (32.0% vs. 35.9%), as well as a 0.2 percentage points increase in personal mobility device accidents (4.2% vs. 4.4%), whereas, vehicle accidents decreased (47.1% vs. 35.8%). In the 7 to 15 years group, pedestrian accidents decreased by 8.8 percentage points (25.6% vs. 16.8%), and vehicle accidents decreased by 8.0 percentage points (18.9% vs. 10.9%). However, there was an increase of 14.7 percentage points in bicycle accidents (50.9% vs. 65.6%) and a 2.2 percentage points increase in personal mobility device accidents (2.4% vs. 4.6%).

**DISCUSSION**

The COVID-19 pandemic resulted in significant changes in the lifestyle patterns of children, including their home environment, educational institutions, and outdoor activities. These changes also affected the injury patterns of pediatric trauma patients pre-
senting to the emergency department. This study investigated the changes in pediatric trauma before and during the COVID-19 pandemic. Given that lifestyle patterns and types of injuries vary among different age groups, the analysis was conducted separately for children < 1 year, 1 to 6 years, and 7 to 15 years, focusing on injury mechanisms, activities and locations at the time of injury, intent, and severity. An additional detailed analysis of traffic accidents was conducted.

Incidence of injuries

Other studies have analyzed the changes in pediatric trauma following the COVID-19 pandemic. Sheridan et al. [9] reported a significant decrease in the number of admissions and procedures related to acute pediatric trauma care at a level I trauma center (Cork University Hospital, Cork, Ireland) during the COVID-19 pandemic. Haddadin et al. [10] compared 30,289 infants seen in a single level I pediatric trauma center for acute respiratory illness and trauma between March and May from 2018 to 2020 and reported a 34% decrease in cases due to trauma. Bessoff et al. [11] investigated 8,772 patients across five level I and one level II pediatric trauma centers in the United States and found a 13% decrease in trauma-related cases in 2020. In our study, the pre-COVID-19 period included 137,880 patients, while the COVID-19 pandemic period included 84,424 patients, representing a decrease of 38.7% in pediatric injuries seen in the emergency department. This decrease can be attributed to various factors such as reduced outdoor activities and the closure of schools and commercial facilities, resulting in a decrease in factors that contribute to the incidence of trauma. Specifically, the frequency of blunt trauma, slipping, and falls decreased significantly, indicating an overall decrease in pediatric trauma mechanisms that account for a significant proportion of trauma cases (Table 1). This result is consistent with the significant reduction in sports-related injuries (e.g., blunt trauma and slipping) during the COVID-19 pandemic period, as reported by Fahy et al. [5].

Increased injuries at home

A decrease in the number of injuries does not necessarily mean that children were safer during the COVID-19 pandemic period. Fahy et al. [5] reported a 17% increase in trauma cases resulting from accidents within the home during the COVID-19 pandemic. In addition, Malige et al. [12] conducted a retrospective review of all injuries (1,112 patients) recorded in 42 hospitals from 2017 to 2020, and reported a higher proportion of injuries occurring at home during the COVID-19 pandemic compared to the pre-COVID-19 period (54.9% vs. 44.7%, P = 0.01). In the present study, the frequency of blunt trauma, slipping, and falls decreased significantly (Table 1). However, injuries occurring in education facilities, sports facilities, and commercial facilities all decreased. In all age groups except those under 1 year, there was a decrease in the frequency of injuries during educational and exercise activities conducted outside the home, particularly a significant decrease in the 7 to 15 years group (Table 2). However, injuries during daily activities and leisure activities increased across all age groups. The increased frequency of leisure activities can be attributed to personal activities such as dog walking, children’s play, watching movies, watching sports games, going to the cinema, having parties, going camping, and dancing. These findings indicate that homes have become a new risk environment for pediatric injuries during the era of infectious disease pandemics, emphasizing the need for preventive measures against the types of injuries that can occur at home and during indoor activities.

Increased minor injuries

Bessoff et al. [11] reported an increase in the proportion of severely injured patients (ISS, ≥ 25) based on analysis of hospital admissions in five level I and one level II pediatric trauma centers in the United States. Similarly, Malige et al. [12] reported higher ICU admission rates and higher mortality rates during the pandemic. However, in contrast to these overseas findings, our study showed a decrease in the proportion of moderate injuries and an increase in the proportion of mild injuries (Table 1). This trend of decreased severity can be attributed to the reduction in mechanisms such as blunt trauma, slipping, and falls, which can cause fractures and multiple injuries. Furthermore, the previously mentioned studies focused mainly on trauma centers, and primarily targeted the early stages of the COVID-19 pandemic. In contrast, our study included the initial isolation period from 2020 to 2021, encompassing the entire pandemic period, which may account for the differences observed. In addition, Sanford et al. [13] included penetrating injuries such as gunshot wounds/pellet gun injuries, as did Bessoff et al. [11] who included an analysis of penetrating injuries such as firearm injuries. However, firearm possession is illegal in Korea, making gunshot wounds rare. Therefore, cultural factors related to firearm use can be considered a contributing factor to the differences in severity between this study and previous studies.

Increased injuries while riding a bicycle or personal mobility device

According to Rajput et al. [14], there was a 73% decrease in the number of drivers and a consequent 46.6% decrease in the fre-
frequency of traffic accidents in March 2020 compared to the pre-COVID-19 pandemic period. Similarly, our study showed a decrease in the overall frequency of traffic accidents. However, when conducting a detailed analysis of the frequency and types of traffic accidents by age group, the frequency of traffic accidents for children aged <7 years decreased, but there was an increase observed in the group aged 7 to 15 years (Table 2). When conducting a subgroup analysis of traffic accidents in the 7 to 15 years group (Table 5), it was found that the proportion of bicycle accidents increased. There was also an increase in accidents involving personal mobility vehicles (Fig. S1). Consequently, although the overall rate of traffic accidents in the 7 to 15 years group increased, this was attributed to an increase in accidents involving bicycles and personal mobility devices rather than an increase in vehicle accidents. The increase in bicycle-related accidents among the 7 to 15 years group can be attributed to increased leisure time resulting from the decrease in structured activities and supervision during the COVID-19 pandemic period. In addition, the culture of avoiding public transportation and minimizing contact with others may have contributed to the increased use of bicycles. In fact, a study by Ko et al. [15] reported a significant increase in bicycle sales following the COVID-19 outbreak.

Self-harm injuries
Regarding self-harm injuries during the COVID-19 pandemic, Flynn-O’Brien et al. [16] reported an increase in intentional injuries among children based on socioeconomic status during the pandemic. de Oliveira et al. [17] also reported a significant increase in self-harm cases due to substance abuse or overdose among female adolescents who were more vulnerable to violence and self-neglect during the COVID-19 pandemic. In our study, there was an increase in self-harm injuries among children aged 7 to 15 years (Table 2). The subgroup analysis of injured 7- to 15-year patients who attempted self-harm showed a 1.7 percentage points increase in self-injury (28.6% vs. 30.3%) and a 5.7 percentage points increase in falls (6.9% vs. 12.6%). Substance abuse decreased (54.0% vs. 49.5%). Flynn-O’Brien et al. [16] reported an increase in firearm injuries among children under 12 years old, mainly during the first 6 months of the pandemic. However, firearm possession is not allowed in Korea, resulting in a low incidence of penetrating injuries related to firearms. These results may be associated with the stress and psychological distress experienced by children during the COVID-19 pandemic. Children in this age group are particularly vulnerable to the impact of social isolation and disruption in their daily lives, which can lead to loneliness, anxiety, and depression. School closures and reduced supervision compromised the important functions of social support and positive reinforcement, which exacerbated negative emotions. Lewit et al. [18] reported that the economic downturn caused by the COVID-19 pandemic increased the rate of self-harm among children. Consequently, the increase in pediatric self-harm injuries in our study may have also been affected by family conflicts, financial stress, and the economic difficulties faced by families during the COVID-19 pandemic.

**Infant fall injuries**
Shi et al. [19] reported an increase in falls among the pediatric population (average age, 7 years) in New Hampshire in the United States. In our study, the proportion of falls among all injuries was analyzed for each age group. The results showed a relatively significant increase in the proportion of falls in the under 1 year group (Table 4, Fig. S1). This could be attributed to the COVID-19 pandemic, which led to working at home and the closure of daycares and educational institutions. This newly increased telecommuting environment resulted in an increased workload for parents in households with children. Parents performed the roles of caregivers and day workers, all within the confines of their home. This significantly increased workload inevitably affected the likelihood of accidents, especially the increased rate of injuries from falls in children < 1 year old.

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**Table 5. Subgroup analysis of the mechanisms of traffic accidents in different age groups before and during COVID-19**

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>&lt;1 yr (n=322)</th>
<th>Pre-COVID-19</th>
<th>COVID-19</th>
<th>1–6 yr (n=4,316)</th>
<th>Pre-COVID-19</th>
<th>COVID-19</th>
<th>7–15 yr (n=9,245)</th>
<th>Pre-COVID-19</th>
<th>COVID-19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian</td>
<td>6 (2.6)</td>
<td>4 (4.4)</td>
<td>967 (32.0)</td>
<td>483 (35.9)</td>
<td>1,457 (25.6)</td>
<td>630 (16.8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycle</td>
<td>2 (0.9)</td>
<td>0</td>
<td>477 (15.8)</td>
<td>301 (22.4)</td>
<td>2,900 (50.9)</td>
<td>2,467 (65.6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal mobility device*</td>
<td>2 (0.9)</td>
<td>1 (1.1)</td>
<td>127 (4.2)</td>
<td>59 (4.4)</td>
<td>134 (2.4)</td>
<td>173 (4.6)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle</td>
<td>221 (95.6)</td>
<td>86 (94.5)</td>
<td>1,424 (47.1)</td>
<td>478 (35.8)</td>
<td>1,075 (18.9)</td>
<td>409 (10.9)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Personal mobility devices include electric scooters, Segways (Segway Inc), electric wheelchairs, carriages, rickshaws, animal rides, all-terrain vehicles, handcarts, etc.

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https://doi.org/10.20408/jti.2023.0053
Limitations
This study had some limitations. First, although 24 hospitals participated, they were mainly located in metropolitan and urban areas, and the survey focused on university hospitals, making it difficult to generalize the results to the entire country. Second, the study primarily targeted tertiary hospitals and did not include pediatric patients visiting primary or secondary healthcare facilities. Conducting a survey primarily in tertiary hospitals may introduce a selection bias since it includes patients with more severe conditions or injuries that may not accurately reflect the injury trends in the general pediatric population. Third, there was a limitation in the data collection of ISS; this study analyzed injury severity based on the EMR-ISS, which may less accurately reflect the severity of injuries.

Conclusions
During the COVID-19 pandemic period, the overall number of pediatric injuries decreased, while injuries occurring at home and during indoor activities increased. Traffic accidents involving bicycles and personal mobility devices increased among the 7 to 15 years, as did self-harm injuries. In the <1 year group, the incidence of falls increased. Medical and societal preparedness is needed to anticipate these changes in the patterns of pediatric injuries in future infectious disease pandemics.

ARTICLE INFORMATION

Author contributions
Conceptualization: WSC, JSC; Data curation: GPN, JSC; Formal analysis: GPN, WSC, JYC, YSL; Methodology: GPN, YSL, JYC, JHW; Project administration: GPN, WSC, JHJ, JSC; Visualization: WSC, JHW, JHJ; Writing– original draft: GPN; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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

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Data availability
Data analyzed in this study are available from the corresponding author upon reasonable request.

Supplementary materials
Supplementary materials are available from https://doi.org/10.20408/jti.2023.0053.

REFERENCES

Outcomes and physiologic responses associated with ketamine administration after traumatic brain injury in the United States and Canada: a retrospective analysis

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Purpose: Ketamine has historically been contraindicated in traumatic brain injury (TBI) due to concern for raising intracranial pressure. However, it is increasingly being used in TBI due to the favorable respiratory and hemodynamic properties. To date, no studies have evaluated whether ketamine administered in subjects with TBI is associated with patient survival or disability.

Methods: We performed a retrospective analysis of data from the multicenter Prehospital Tranexamic Acid Use for Traumatic Brain Injury trial, comparing ketamine-exposed and ketamine-unexposed TBI subjects to determine whether an association exists between ketamine administration and mortality, as well as secondary outcome measures.

Results: We analyzed 841 eligible subjects from the original study, of which 131 (15.5%) received ketamine. Ketamine-exposed subjects were younger (37.3 ± 16.9 years vs. 42.0 ± 18.6 years, P=0.037), had a worse initial Glasgow Coma Scale score (7 ± 3 vs. 8 ± 4, P=0.003), and were more likely to be intubated than ketamine-unexposed subjects (88.5% vs. 44.2%, P<0.001). Overall, there was no difference in mortality (12.2% vs. 15.5%, P=0.391) or disability measures between groups. Ketamine-exposed subjects had significantly fewer instances of elevated intracranial pressure (ICP) compared to ketamine-unexposed subjects (56.3% vs. 82.3%, P=0.048). In the very rare outcomes of cardiac events and seizure activity, seizure activity was statistically more likely in ketamine-exposed subjects (3.1% vs. 1.0%, P=0.010). In the intracranial hemorrhage subgroup, cardiac events were more likely in ketamine-exposed subjects (2.3% vs. 0.2%, P=0.025). Ketamine exposure was associated with a smaller increase in TBI protein biomarker concentrations.

Conclusions: Ketamine administration was not associated with worse survival or disability despite being administered to more severely injured subjects. Ketamine exposure was associated with reduced elevations of ICP, more instances of seizure activity, and lower concentrations of TBI protein biomarkers.

Keywords: Ketamine; Traumatic brain injuries; Biomarkers; Intracranial pressure; Glial fibrillary acidic protein
INTRODUCTION

Background
Ketamine is a dissociative anesthetic with unique pharmacologic effects compared to other anesthetic induction agents [1]. Early studies of ketamine’s physiology identified potentially harmful side effects associated with its administration including increased intracranial pressure (ICP) [2,3], increased cerebral blood flow [4], and increased cerebral metabolic rate [5]. Based on these reports, use of ketamine for traumatic brain injury (TBI) has traditionally been discouraged.

Despite these initial concerns, ketamine’s favorable hemodynamic, analgesic, and respiratory sparing effects have led to its increasingly being utilized in trauma patients including those with TBI [6]. Ketamine’s effects on ICP have been directly investigated in small-scale studies which found either no effect on ICP or reduced ICP when ketamine was prospectively administered to TBI subjects. In addition to its potential impact on ICP, ketamine has also been proposed as a neuroprotective agent in TBI based on its reduction in postinjury glutamate toxicity [7,8] and inhibition of cortical spreading depressions [9]. Notably, none of these studies explored subject outcomes and thus, there is a lack of clarity related to ketamine’s ICP effects and patient outcomes.

Objectives
The TXA for TBI (Prehospital Tranexamic Acid Use for Traumatic Brain Injury) trial was a large, multinational, multicenter, randomized controlled trial that provided the opportunity to evaluate an extensive sample of TBI subjects and associated outcomes [10]. Using the dataset from this study, we examined the characteristics of ketamine administration in the TBI population to analyze ketamine’s association with morbidity and mortality, as well as physiologic responses including ICP and longitudinal TBI biomarker trajectories. We hypothesized that ketamine exposure would not be associated with worse survival or disability after TBI, and that the physiologic responses and TBI-related biomarker responses would not be different between ketamine-exposed and ketamine-unexposed TBI subjects in the TXA for TBI trial population.

METHODS

Ethics statement
The original study [10] was approved by the Institutional Review Board for the study’s associated Resuscitation Outcomes Consortium Clinical Trials Center at the University of Washington. Informed consent was not possible for all participants initially and therefore enrollment was conducted under US regulations for Exception from Informed Consent Requirements for Emergency Research as well as the Canadian Tri-County Policy Statement 2, and informed consent was obtained as soon as feasible. The original study is registered on ClinicalTrials.gov (identifier: NCT01990768).

Study design
The TXA for TBI trial was a multicenter, North American randomized, controlled trial that enrolled subjects from May 2015 until November 2017 [10]. Subjects with moderate-to-severe TBI were randomized to placebo bolus prehospital and 8-hour placebo infusion in-hospital, a 2-g tranexamic acid (TXA) prehospital bolus followed by an 8-hour placebo infusion in the hospital, or a 1-g prehospital bolus followed by a 1-g in-hospital 8-hour infusion. In the primary trial, there were no significant differences in mortality or morbidity between groups overall, however, in the subset of subjects with intracranial hemorrhage (ICH), prehospital administration of a 2-g bolus of TXA bolus was associated with decreased mortality [8,10].

Participants
We performed a retrospective analysis of the TXA for TBI trial dataset for ketamine exposure to examine the associations between ketamine and clinical and laboratory outcomes in subjects with TBI. Ketamine exposure was defined as recorded ketamine administration by emergency medical services in the prehospital setting; exact dosing and timing of the ketamine administration was not available. Subjects without ketamine exposure data were excluded.

Demographic measures
Demographics variables included age, sex, body mass index (BMI), weight, initial Glasgow Coma Scale (GCS) score, initial Injury Severity Score (ISS), history of seizure, intubation status, presence of ICH, and TXA study group allocation.

Death and disability outcome measures
The primary outcome assessed was death within 6 months of injury; secondary outcomes included the Glasgow Outcome Scale Extended (GOSE) and Disability Rating Scale (DRS) scores at discharge and 6 months postinjury, as well as incidences of seizure activity, cardiac events (cardiac arrest or heart failure), and surgical interventions.
Physiologic outcome measures
Physiologic outcome measures included the following: systolic blood pressure (SBP), heart rate and temperature, PaO₂, and ICP. Measurements were taken from the first 24 hours following hospital presentation. ICP was measured with either a Camino (Natus Medical Inc) intracranial pressure and temperature monitor or an external ventricular drain pressure monitor. ICP elevation was defined as ICP > 20 cmH₂O; bradycardia was defined as heart rate < 60 beats per minute (bpm) and tachycardia as heart rate > 100 bpm; hypoxia was defined as PaO₂ < 80 mmHg; hypotension was defined as SBP < 90 mmHg and hypertension defined as SBP > 180 mmHg; hypothermia was defined as < 35 °C and hyperthermia as > 38 °C.

TBI protein biomarker measures
The TXA for TBI trial performed longitudinal biomarker measurements of the TBI-related biomarkers glial fibrillary acidic protein (GFAP), microtubule-associated protein 2 (MAP2), and ubiquitin C-terminal hydrolase L1 (UCHL1) [8]. Serum concentration measurements of GFAP, MAP2, and UCHL1 were compared between the ketamine-exposed and ketamine-unexposed groups at admission, 6-, 12-, 24-, and 48-hours following hospital admission [11]. Biomarkers were compared using the change in measured serum concentration from admission to each subsequent time point, as well as a comparison of biomarker concentrations at each time point.

ICH subgroup
Based on the decreased mortality observed in the original TXA for TBI trial [10] in the ICH subgroup of the 2-g TXA arm, we performed a subgroup analysis of ICH subjects comparing ketamine exposure groups.

Statistical analysis
Demographic variables were assessed for their association with outcomes including our primary outcome of death within 6 months of injury. The P-value for significance of variables was set at P < 0.05. A multivariate mixed-effects logistic regression model was created using the variables age, sex, race, BMI, seizure history, intubation status, and TXA study arm; final P-values in this model were adjusted for multiple comparisons using Bonferroni correction. All results are provided as mean ± standard deviation unless otherwise specified. TBI was stratified into severe (GCS ≤ 8), moderate (GCS 9–12) and mild (GCS 13–15); ISS was stratified into severe (> 25), moderate (16–25), and mild (≤ 15); GOSE was stratified into poor recovery (1–4) and good recovery (5–8); DRS was stratified into mild (0–1), moderate (2–6), severe (7–11), and vegetative or worse (≥ 12). Statistical analyses were completed using Stata ver. 17.0 (Stata Corp).

RESULTS
Demographics and clinical characteristics
Of the 966 subjects included in the primary analysis in the original TXA for TBI trial, 910 had complete data collected and were analyzed for ketamine exposure; 69 subjects lacked ketamine administration information and were excluded, leaving 841 subjects for our analysis. Of these subjects, 131 (15.6%) received ketamine and 710 (84.4%) did not receive ketamine (Fig. 1).

Demographic and clinical characteristics of the ketamine-exposed and ketamine-unexposed subjects are listed in Table 1. Overall, the ketamine-exposed group was younger (37.3 ± 16.9 years vs. 42.0 ± 18.6 years, P = 0.037); the groups otherwise had similar sex- and race-distribution, BMI, and TXA study allocations. Ketamine-exposed subjects had a worse initial GCS (7 ± 3 vs. 8 ± 4, P = 0.003) and were more likely to be intubated (88.5% vs. 84.2%, P < 0.001); initial ISS and ICH status were not different between groups.

Death and disability
In our primary outcome of death at any time, there was no difference between the ketamine-exposed and the ketamine-unexposed groups (mortality rate: ketamine exposed, 12.2% vs. ketamine unexposed, 15.5%; P = 0.391) (Table 2).

For our secondary outcomes, there was similarly no difference in disability scores for GOSE at discharge (ketamine exposed,
966 Subjects screened for inclusion and enrolled (TXA for TBI study)
910 Subjects evaluated for ketamine exposure
841 Subjects included in retrospective analysis
131 Ketamine exposed
710 Ketamine unexposed
502 ICH subgroup
86 Ketamine exposed
416 Ketamine unexposed
56 Excluded (lack of overall data)
69 Excluded (lack of ketamine administration data)
339 Excluded (no ICH)

Fig. 1. Participant flow diagram. CONSORT (Consolidated Standards of Reporting Trials) style diagram of subject inclusion, exclusion, and group allocation in the overall study analysis and in the intracranial hemorrhage (ICH) subgroup analysis. TXA for TBI, Prehospital Tranexamic Acid Use for Traumatic Brain Injury.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ketamine exposure</th>
<th>P-value (n=131)</th>
<th>P-value (n=710)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death at any time</td>
<td>Exposed</td>
<td>Unexposed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16 (12.2)</td>
<td>110 (15.5)</td>
<td>0.391</td>
</tr>
<tr>
<td>Seizure activity</td>
<td>4 (3.1)</td>
<td>7 (1.0)</td>
<td>0.010a</td>
</tr>
<tr>
<td>Cardiac events</td>
<td>2 (1.5)</td>
<td>6 (0.8)</td>
<td>0.961a</td>
</tr>
<tr>
<td>Required surgical intervention</td>
<td>9 (6.9)</td>
<td>79 (11.1)</td>
<td>0.113</td>
</tr>
<tr>
<td>Glasgow Outcomes Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At discharge</td>
<td>3.9±2.1</td>
<td>4.3±2.4</td>
<td>0.967</td>
</tr>
<tr>
<td>At 6 mo</td>
<td>5.4±2.4</td>
<td>5.4±2.7</td>
<td>0.221</td>
</tr>
<tr>
<td>Disability Rating Scale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At discharge</td>
<td>8.8±9.7</td>
<td>8.3±10.3</td>
<td>0.324</td>
</tr>
<tr>
<td>At 6 mo</td>
<td>5.8±9.9</td>
<td>7.0±11.2</td>
<td>0.151</td>
</tr>
</tbody>
</table>

Values are presented as number (%) or mean ± standard deviation. Morbidity and mortality outcomes were similar between groups, with no differences in death or measures of disability between groups. Ketamine exposure was associated with more seizure activity.

Table 1. Demographics and clinical characteristics (n = 841)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Ketamine exposure</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exposed (n=131)</td>
<td>Unexposed (n=710)</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>37.3±16.9</td>
<td>42.0±18.6</td>
</tr>
<tr>
<td>Male sex</td>
<td>101 (77.1)</td>
<td>526 (74.1)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>27.0±5.8</td>
<td>26.3±5.6</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian or Pacific Islander</td>
<td>1 (0.8)</td>
<td>17 (2.4)</td>
</tr>
<tr>
<td>Black</td>
<td>11 (8.4)</td>
<td>93 (13.1)</td>
</tr>
<tr>
<td>Native American</td>
<td>0</td>
<td>2 (0.3)</td>
</tr>
<tr>
<td>White</td>
<td>68 (51.9)</td>
<td>324 (45.6)</td>
</tr>
<tr>
<td>Unknown</td>
<td>51 (38.9)</td>
<td>274 (38.6)</td>
</tr>
<tr>
<td>GCS score</td>
<td>7±3</td>
<td>8±4</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>20.7±13.6</td>
<td>18.8±13.1</td>
</tr>
<tr>
<td>Prior seizure history</td>
<td>5 (3.8)</td>
<td>36 (5.1)</td>
</tr>
<tr>
<td>Intubated on scene</td>
<td>116 (88.5)</td>
<td>314 (44.2)</td>
</tr>
<tr>
<td>ICH presence</td>
<td>86 (65.6)</td>
<td>416 (58.6)</td>
</tr>
<tr>
<td>TXA allocation group</td>
<td></td>
<td>0.798</td>
</tr>
<tr>
<td>Placebo</td>
<td>45 (34.4)</td>
<td>227 (32.0)</td>
</tr>
<tr>
<td>1 g</td>
<td>38 (29.0)</td>
<td>225 (31.7)</td>
</tr>
<tr>
<td>2 g</td>
<td>48 (36.6)</td>
<td>258 (36.3)</td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard deviation or number (%). Baseline characteristics and group allocations were similar between groups, however ketamine-exposed subjects were younger, with a worse initial GCS and were more likely to be intubated.

Table 2. Morbidity and mortality results (n = 841)

Physiologic response
Elevated intracranial pressure was significantly less frequent in the ketamine-exposed group (instances of ICP elevation, 56.3% vs. 82.3%; P = 0.048). Instances of hypoxia, and extremes of heart rate, SBP, and temperature were similar between groups (Table 3).

TBI biomarker trajectories
Ketamine exposure was associated with significantly smaller changes in concentration for GFAP at 12-, 24-, and 48-hours following admission and for MAP2 at 12- and 24-hours following admission. UCHL1 changes from baseline were not significantly different between groups at any time point (Fig. 2). There were no differences in biomarker concentrations when compared

Peters et al. Ketamine-associated outcomes after TBI

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Table 3. Physiologic response results (n = 841)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ketamine exposure</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exposed (n=131)</td>
<td>Unexposed (n=710)</td>
</tr>
<tr>
<td>ICP &gt;20 mmHg (n=140)</td>
<td>9/16 (56.3)</td>
<td>102/124 (82.3)</td>
</tr>
<tr>
<td>Hypoxia PaO₂ &lt;80 mmHg</td>
<td>48 (36.6)</td>
<td>246 (34.6)</td>
</tr>
<tr>
<td>Hypothermia (temperature ≤ 35 °C)</td>
<td>23 (17.6)</td>
<td>44 (6.2)</td>
</tr>
<tr>
<td>Hyperthermia (temperature ≥ 38 °C)</td>
<td>0</td>
<td>7 (1.0)</td>
</tr>
<tr>
<td>Heart rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bradycardic (&lt;60 bpm)</td>
<td>18 (13.7)</td>
<td>93 (13.1)</td>
</tr>
<tr>
<td>Tachycardic (&gt;100 bpm)</td>
<td>64 (48.9)</td>
<td>347 (48.9)</td>
</tr>
<tr>
<td>Systolic blood pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypotensive (&lt;90 mmHg)</td>
<td>19 (14.5)</td>
<td>74 (10.4)</td>
</tr>
<tr>
<td>Hypertensive (&gt;180 mmHg)</td>
<td>20 (15.3)</td>
<td>135 (19.0)</td>
</tr>
</tbody>
</table>

Values are presented as number (%). Physiologic measures compared between groups demonstrated that ketamine exposure was associated with fewer recorded measurements of elevated ICP; there were no other statistically significant differences between the groups. ICP, intracranial pressure; bpm, beats per minute.

*P < 0.05

ICH subgroup analysis

Of 841 subjects with ketamine exposure data, 502 subjects (59.7%) had a radiographically confirmed ICH, 86 of 131 (65.6%) in the ketamine-exposed group and 416 of 710 (58.6%) in the ketamine-unexposed group (Fig. 1). Demographic characteristics and TXA study group distribution were similar to the entire cohort, including a significant age difference (ketamine exposed, 38.1 ± 17.5 years vs. ketamine unexposed, 42.0 ± 18.8 years; P = 0.030) and a significantly higher percentage of intubated subjects in the ketamine-exposed group (90.7% vs. 53.8%, P < 0.001). GCS was not significantly different in the ICH subgroup (ketamine exposed, 6 ± 3 vs. ketamine unexposed, 7 ± 3; P = 0.086); all other demographic variables were similar to the
Mortality in the ICH subgroup was higher than in the entire cohort but there was again no difference between ketamine exposure groups (ketamine exposed, 18.6% vs. ketamine unexposed, 23.3%; P = 0.177). There were no differences in GOSE or DRS measurements between groups, and no difference in surgical intervention (Table S2). Using a simplified model, ketamine exposure continued to be associated with increased seizure activity (3.5% vs. 1.0%, P = 0.009); cardiac events were also associated with ketamine exposure (2.3% vs. 0.2%, P = 0.025).

Physiologic responses were similar to the entire cohort as well, but no statically significant difference in ICP was observed in this subgroup analysis (ketamine exposed, 56.3% vs. ketamine unexposed, 82.0% with an instance of elevated ICP; P = 0.055) (Table S3).

Biomarker trajectories in the ICH subgroup were similar to the entire cohort, including a smaller increase from baseline for the biomarkers GFAP and MAP2 at similar time points, and no differences in UCHL1 between groups (Fig. S1). At the 48-hour time point, GFAP concentration was lower in the ketamine-exposed group (2,261 ± 4,727 pg/mL vs. 4,497 ± 10,508 pg/mL, P = 0.003) (Table S4).

**DISCUSSION**

In this retrospective analysis of a large, multinational, multicenter trial, ketamine was administered to 15.5% of all subjects sustaining TBI. It is notable that a significant number of subjects with TBI received ketamine in this large clinical trial involving 12 centers and almost 40 emergency medical services agencies, despite ketamine’s traditional avoidance in TBI. In our analysis, ketamine-exposed subjects had a more severe head injury profile based on initial GCS and intubation status yet had no differences in survival or disability. An important qualification of these data is that the ketamine-unexposed group was on average 5 years older than the ketamine-exposed subjects, and older age is associated with worse outcomes after TBI [12]. However, no prior studies have examined ketamine’s association with morbidity and mortality after TBI, and these findings, especially taken in context of the higher injury severity, are reassuring given the frequency of use of ketamine in patients with TBI.

There remain important safety considerations in the use of ketamine in patients with TBI given our findings associating its use with cardiovascular events and seizure activity. Seizure activity was significantly associated with ketamine administration in both the entire cohort as well as in the ICH subgroup, and ketamine administration was significantly associated with cardiac events in the ICH subgroup. However, these were rare events, and at this time it remains unclear whether the association between seizure activity and ketamine administration is due to the worse injury profile of the ketamine-exposed group or can be attributed to the administration of ketamine itself. Notably, ketamine has been shown to be associated with cardiovascular collapse in other patient populations [13]. Any administration of ketamine should continue to consider its cardiovascular and neurological side effects.

In this study, we found that ketamine administration was associated with a decrease in the frequency of elevated ICP, which is in contrast to the traditionally accepted association of ketamine and increased ICP [3]. Early studies examining ketamine’s effects on ICP had notable limitations that may explain their findings: study subjects were healthy volunteers without TBI, and respiratory rate was not controlled, which is notable as ketamine does reduce respiratory rate, which has the potential to impact ICP.

Table 4. TBI biomarker measurements

<table>
<thead>
<tr>
<th>TBI biomarker</th>
<th>0</th>
<th>6</th>
<th>12</th>
<th>24</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFAP (pg/mL)</td>
<td>Ketamine exposed</td>
<td>2,297.80 ± 6,056.11</td>
<td>2,333.59 ± 3,124.52</td>
<td>2,389.92 ± 2,354.44</td>
<td>2,435.75 ± 3,878.17</td>
</tr>
<tr>
<td></td>
<td>Ketamine unexposed</td>
<td>2,765.08 ± 8,949.93</td>
<td>4,115.59 ± 11,629.04</td>
<td>4,770.27 ± 13,819.83</td>
<td>3,766.88 ± 8,940.49</td>
</tr>
<tr>
<td>UCHL1 (pg/mL)</td>
<td>Ketamine exposed</td>
<td>7,296.43 ± 9,013.75</td>
<td>2,161.63 ± 3,536.04</td>
<td>1,331.08 ± 2,504.39</td>
<td>746.50 ± 1,707.05</td>
</tr>
<tr>
<td></td>
<td>Ketamine unexposed</td>
<td>8,046.90 ± 14,472.96</td>
<td>2,969.04 ± 10,425.80</td>
<td>1,877.22 ± 10,783.73</td>
<td>668.47 ± 1,247.98</td>
</tr>
<tr>
<td>MAP2 (pg/mL)</td>
<td>Ketamine exposed</td>
<td>311.22 ± 1,043.94</td>
<td>286.03 ± 713.10</td>
<td>352.07 ± 765.72</td>
<td>368.39 ± 778.61</td>
</tr>
<tr>
<td></td>
<td>Ketamine unexposed</td>
<td>282.28 ± 893.85</td>
<td>424.01 ± 1,107.0</td>
<td>411.83 ± 894.85</td>
<td>406.0 ± 835.29</td>
</tr>
</tbody>
</table>

Values are presented as mean ± standard deviation.
TBI, traumatic brain injury; GFAP, glial fibrillary acidic protein; UCHL1, ubiquitin C-terminal hydrolase L1; MAP2, microtubule-associated protein 2.

https://doi.org/10.20408/jti.2023.0034
Another important consideration is that we only analyzed instances of extremes in ICP and not duration or severity of the ICP response. Our findings associating ketamine administration with reduced instances of elevated ICP are consistent with the few clinical studies that have explored ketamine’s effects directly in subjects with TBI, which have shown that ketamine either had no effect on ICP [14,15] or reduced ICP.

Finally, the longitudinal circulating biomarkers of brain injury examined in the original TXA for TBI trial presented a unique opportunity to evaluate the effect that ketamine had on the trajectory of these biomarkers. By examining the changes in the concentrations at multiple time points, we observed a potential suppressive effect from ketamine administration in that ketamine exposure was associated with a reduced rise in both GFAP and MAP2 concentrations at all time points, and a significantly reduced GFAP concentration at 48-hours postinjury in the ICH subgroup. Based on our previous observations that these biomarker concentrations are positively associated with injury severity [8], this suppressive effect associated with ketamine exposure warrants further investigation. Furthermore, these data support the potential utility of using longitudinal TBI biomarker trajectories to monitor pharmacologic effect and therapeutic responses associated with ketamine administration [8].

Limitations
The primary limitation of this study is the retrospective collection of these prospectively collected data which therefore limits our findings to associations between ketamine exposure and outcomes rather than establishing a causal relationship. Furthermore, ICP was measured in fewer than 20% of subjects which limits our power to draw conclusions. Finally, complete details regarding the dose and timing of ketamine administration were not available and physiologic responses were limited to instances of extremes.

Conclusions
This retrospective analysis of a multinational, multicenter TXA for TBI trial, ketamine administration was not associated with increased mortality or disability and was associated with fewer instances of elevated ICP, despite being administered to more severely injured subjects. Further prospective studies related to the association between ketamine administration and clinical outcomes and physiologic measures especially longitudinally collected protein biomarkers are warranted.

ARTICLE INFORMATION

Author contributions
Conceptualization: AJP, MS; Data curation: AJP, SAK, SK; Formal analysis: AJP, SK; Funding acquisition: AJP, SR, MS; Investigation: AJP, SR, MS; Methodology: AJP, SK; Project administration: AJP; Visualization: AJP, SK; Writing–original draft: AJP, SAK; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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

Funding
The primary study (Prehospital Tranexamic Acid Use for Traumatic Brain Injury trial) was supported by a grant from the National Heart, Lung, and Blood Institute (No. NHLBI 5R01HL126585-02). The traumatic brain injury biomarker collection portion of the primary study was supported by a grant from the Defense Medical Research and Development Program (No. W81XWH-12-CCCJPC-TACR).

Data availability
Data analyzed in this study are available from the corresponding author upon reasonable request.

Supplementary materials
Table S1. ICH subgroup demographics and clinical characteristics (n = 502)
Table S2. ICH subgroup morbidity and mortality outcomes (n = 502)
Table S3. ICH subgroup vital signs responses (n = 502)
Table S4. ICH subgroup TBI biomarker
Fig. S1. Association of ketamine administration on biomarker trajectories following traumatic brain injury (TBI) in the intracranial hemorrhage (ICH) subgroup.

Supplementary materials are available from https://doi.org/10.20408/jti.2023.0034.

REFERENCES


A decade of treating traumatic sternal fractures in a single-center experience in Korea: a retrospective cohort study

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**Purpose:** Clinical reports on treatment outcomes of sternal fractures are lacking. This study details the clinical features, treatment approaches, and outcomes related to traumatic sternal fractures over a 10-year period at a single institution.

**Methods:** A retrospective cohort study was conducted of patients admitted to a regional trauma center between January 2012 and December 2021. Among 7,918 patients with chest injuries, 266 were diagnosed with traumatic sternal fractures. Patient data were collected, including demographics, injury mechanisms, severity, associated injuries, sternal fracture characteristics, hospital stay duration, mortality, respiratory complications, and surgical details. Surgical indications encompassed emergency cases involving intrathoracic injuries, unstable fractures, severe dislocations, flail chest, malunion, and persistent high-grade pain.

**Results:** Of 266 patients with traumatic sternal fractures, 260 were included; 98 underwent surgical treatment for sternal fractures, while 162 were managed conservatively. Surgical indications ranged from intrathoracic organ or blood vessel injuries necessitating thoracotomy to unstable fractures with severe dislocations. Factors influencing surgical treatment included flail motion and rib fracture. The median length of intensive care unit stay was 5.4 days (interquartile range [IQR], 1.5–18.0 days) for the nonsurgery group and 8.6 days (IQR, 3.3–23.6 days) for the surgery group. The median length of hospital stay was 20.9 days (IQR, 9.3–48.3 days) for the nonsurgery group and 27.5 days (IQR, 17.0 to 58.0 days) for the surgery group. The between-group differences were not statistically significant. Surgical interventions were successful, with stable bone union and minimal complications. Flail motion in the presence of rib fracture was a crucial consideration for surgical intervention.

**Conclusions:** Surgical treatment recommendations for sternal fractures vary based on flail chest presence, displacement degree, and rib fracture. Surgery is recommended for patients with offset-type sternal fractures with rib and segmental sternal fractures. Surgical intervention led to stable bone union and minimal complications.

**Keywords:** Sternum; Bone fractures; Wounds and injuries; Surgery
INTRODUCTION

Background
Sternal fractures resulting from trauma are relatively rare, representing 3% to 8% of all blunt trauma cases [1–4]. The most common mechanism of injury is direct blunt force to the anterior chest, typically from traffic accidents, with falls being the next most common cause [1,4–6]. The body of the sternum is the most common site of these fractures, while fractures of the manubrium or xiphoid process are comparatively rare [2,4,7]. The mortality or morbidity associated with sternal fractures is determined not by the fracture itself, but by the severity of the accompanying injury, with mortality rates varying between 4% and 45% [2,4,8].

Most cases are managed with conservative treatment. However, conditions such as chronic nonunion, severe pain that impacts breathing, displacement, overlapping fractures that cannot be rectified by closed reduction, and sternal instability are indications for surgical treatment [3]. The most common surgical treatment is open reduction and internal fixation (ORIF) using a plate. This method is recognized as the most effective for stabilizing the anterior chest wall, preventing impaired bone healing, and avoiding other complications [4,5,9].

Objectives
Limited data have been published on the long-term experience of a single center regarding the treatment and outcomes of sternal fractures. Consequently, the objective of this study was to present the clinical aspects, treatment, and outcomes of traumatic sternal fractures over 10 years at a single center.

METHODS

Ethics statement
This study was approved by the Institutional Review Board of Pusan National University Hospital (No. H-2304-021-126). The requirement for informed consent was waived due to the retrospective nature of the study. This study was conducted in compliance with the principles of the Declaration of Helsinki.

Study design and participants
This retrospective cohort study involved patients admitted to a regional trauma center between January 2012 and December 2021. Using the hospital’s inpatient inquiry system, we identified 7,918 patients with chest injuries who had been admitted to the Regional Trauma Center of Pusan National University Hospital (Busan, Korea). Among these patients, we reviewed the medical records of 266 who were diagnosed with traumatic sternal fractures. The criteria for inclusion in the study were as follows: (1) a sternal fracture had to be registered as a diagnosis and be searchable in the medical records; and (2) the location of the sternal fracture had to be confirmable through computed tomography (CT) or radiography. We excluded patients who had sustained a sternal fracture due to cardiopulmonary cerebral resuscitation and those for whom sternal fractures could not be confirmed because the imaging data were not recorded (Fig. 1).

The data collected included patient demographics, injury mechanism, injury severity, intrathoracic and extrathoracic injuries, sternal fracture characteristics, duration of hospital and intensive care unit (ICU) stays, in-hospital mortality rates, respiratory complications, and surgical features of the sternal fracture.

Diagnosis of sternal fractures and surgical indications
The diagnosis was established using chest CT, either non–contrast-enhanced or contrast-enhanced, or sternal lateral radiography. Based on the degree of displacement, the condition was categorized as either nondisplaced, offset, or displaced (Fig. 2).

Surgical indications included the following: (1) instances in which emergency surgery was conducted via thoracotomy due to injuries to intrathoracic organs or blood vessels, and where the patient’s condition allowed for the concurrent correction of the sternal fracture; (2) unstable fractures that were accompanied by severe dislocations or exhibited an offset of 50% or more; (3) instances of flail chest associated with respiratory failure; (4) observed malunion (nonunion or abnormal union) of the fractures; and (5) reports of pain with a numeral rating scale of 6 or higher that persisted for more than 72 hours despite adequate pain control.

The surgical procedure was conducted based on ORIF, utilizing plates inserted via a median vertical incision between the sternal notch and the tip of the xiphoid process. In certain instances, wire fixation was also implemented. Following surgery,
lateral radiography of the sternum was conducted. If sternal lateral radiography was not available, chest CT was performed instead.

Intrathoracic and extrathoracic injuries
The associated intrathoracic injuries included the following: (1) damage to the heart, aorta, or other arteries; (2) lung contusion; (3) hemothorax and/or pneumothorax; (4) rib fracture; and (5) retrosternal hematoma. Injuries classified as extrathoracic were those identified with an Abbreviated Injury Scale (AIS) score of 3 or higher, encompassing injuries to the head and neck, face, abdomen, and extremities.

Statistical analysis
When appropriate, summary statistics were presented as medians with interquartile ranges (IQRs) or as means with standard deviations. Categorical variables were expressed as numbers and percentages. To compare the frequencies of categorical variables between groups, the chi-square and Fisher exact tests were employed. The Mann-Whitney U-test and Wilcoxon rank-sum test were utilized to compare the mean values of continuous variables. A P-value of less than 0.05 was considered to indicate statistical significance. Data analysis was conducted using IBM SPSS ver. 22.0 (IBM Corp).

RESULTS
Of the 266 patients diagnosed with sternal fractures, we excluded two patients who had sustained these fractures following cardiopulmonary resuscitation due to illness, as well as four patients for whom imaging data were not available. The most common mechanism of injury was motor vehicle accidents, followed by falls and crushing injuries. The Injury Severity Score was categorized as mild (<9), moderate (9–15), severe (16–25), or profound (>25). The largest number of patients fell into the severe injury category, but the difference was not statistically significant (Table 1).

Of the 260 patients included in this study, 98 underwent surgical procedures for sternal fractures, while the remaining 162 received conservative treatment. Flail motion was observed in 96 patients, with 93 of these patients also presenting with rib fractures. Among the three patients without rib fractures, two exhibited flail motion with a fracture gap that had increased compared to the initial phase, and one patient had a segmental fracture of the sternal body. Regarding intrathoracic injuries, damage to the heart, aorta, or other arteries was confirmed in 20 patients from the surgery group and 14 from the nonsurgery group.

The median duration of ICU stay across all patients was 6.6 days (IQR, 2.0–21.3 days). For the surgery group, the median

Fig. 2. Degree of displacement in sternal fractures. The degree of the fracture was classified as follows. (A) If the fracture encompassed 0% to 9% of the sternal width, it was defined as nondisplaced (indicated by the arrow, which points to the fracture line). (B) If the fracture encompassed 100% or more of the sternal width, it was defined as displaced (indicated by the arrow, pointing to the fracture line).
Table 1. Patient characteristics and outcomes

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (n=260)</th>
<th>Surgery group (n=98)</th>
<th>Nonsurgery group (n=162)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>53.8±17.4</td>
<td>53.7±16.7</td>
<td>53.9±17.9</td>
<td>0.938</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td>0.264</td>
</tr>
<tr>
<td>Male</td>
<td>182 (70.0)</td>
<td>73 (74.5)</td>
<td>109 (67.3)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>78 (30.0)</td>
<td>25 (25.5)</td>
<td>53 (32.7)</td>
<td></td>
</tr>
<tr>
<td>Injury mechanism</td>
<td></td>
<td></td>
<td></td>
<td>0.918</td>
</tr>
<tr>
<td>Motor vehicle accident</td>
<td>164 (63.1)</td>
<td>63 (64.3)</td>
<td>101 (62.3)</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>67 (25.8)</td>
<td>24 (24.5)</td>
<td>43 (26.5)</td>
<td></td>
</tr>
<tr>
<td>Crushing injury</td>
<td>24 (9.2)</td>
<td>10 (10.2)</td>
<td>14 (8.6)</td>
<td></td>
</tr>
<tr>
<td>Penetrating injury</td>
<td>2 (0.8)</td>
<td>0</td>
<td>2 (1.2)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>3 (1.2)</td>
<td>1 (1.0)</td>
<td>2 (1.2)</td>
<td></td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>21.5±11.9</td>
<td>21.5±13.0</td>
<td>21.4±11.2</td>
<td>0.977</td>
</tr>
<tr>
<td>Mild (&lt;9)</td>
<td>33 (12.7)</td>
<td>14 (14.3)</td>
<td>19 (11.7)</td>
<td>0.828</td>
</tr>
<tr>
<td>Moderate (9–15)</td>
<td>49 (18.8)</td>
<td>18 (18.4)</td>
<td>31 (19.1)</td>
<td></td>
</tr>
<tr>
<td>Severe (16–25)</td>
<td>98 (37.7)</td>
<td>34 (34.7)</td>
<td>64 (39.5)</td>
<td></td>
</tr>
<tr>
<td>Profound (&gt;25)</td>
<td>80 (30.8)</td>
<td>32 (32.7)</td>
<td>48 (29.6)</td>
<td></td>
</tr>
<tr>
<td>Flail chest</td>
<td>96 (36.9)</td>
<td>63 (64.3)</td>
<td>33 (20.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>With rib fracture</td>
<td>93 (35.8)</td>
<td>60 (61.2)</td>
<td>33 (18.5)</td>
<td></td>
</tr>
<tr>
<td>Without rib fracture</td>
<td>3 (1.2)</td>
<td>3 (3.1)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Chest (AIS ≥3)</td>
<td>188 (72.3)</td>
<td>75 (76.5)</td>
<td>113 (69.8)</td>
<td>0.256</td>
</tr>
<tr>
<td>Intrathoracic injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart, aorta, or other artery</td>
<td>34 (13.1)</td>
<td>20 (20.4)</td>
<td>14 (8.6)</td>
<td>0.008</td>
</tr>
<tr>
<td>Lung contusion</td>
<td>126 (48.5)</td>
<td>46 (46.9)</td>
<td>80 (49.4)</td>
<td>0.798</td>
</tr>
<tr>
<td>Hemothorax and/or pneumothorax</td>
<td>137 (52.7)</td>
<td>66 (67.3)</td>
<td>71 (43.8)</td>
<td>0.001</td>
</tr>
<tr>
<td>Retrosternal hematoma</td>
<td>113 (43.5)</td>
<td>51 (52.0)</td>
<td>62 (38.3)</td>
<td>0.039</td>
</tr>
<tr>
<td>Extrathoracic injury (AIS ≥3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head and neck</td>
<td>77 (29.6)</td>
<td>22 (22.4)</td>
<td>55 (34.0)</td>
<td>0.051</td>
</tr>
<tr>
<td>Face</td>
<td>1 (0.4)</td>
<td>0</td>
<td>1 (0.6)</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Abdomen</td>
<td>70 (26.9)</td>
<td>25 (25.5)</td>
<td>45 (27.8)</td>
<td>0.773</td>
</tr>
<tr>
<td>Extremity</td>
<td>49 (18.8)</td>
<td>19 (19.4)</td>
<td>30 (18.5)</td>
<td>0.871</td>
</tr>
<tr>
<td>Outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICU stay (day)</td>
<td>6.6 (2.0–21.3)</td>
<td>8.6 (3.3–23.6)</td>
<td>5.4 (1.6–18.0)</td>
<td>0.065</td>
</tr>
<tr>
<td>Hospital stay (day)</td>
<td>23.0 (12.0–48.2)</td>
<td>27.5 (17.0–58.0)</td>
<td>20.0 (9.3–43.8)</td>
<td>0.001</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td>13 (5.0)</td>
<td>2 (2.0)</td>
<td>11 (6.8)</td>
<td>0.140</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>71 (27.3)</td>
<td>32 (32.7)</td>
<td>39 (24.1)</td>
<td>0.152</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation, number (%), or median (interquartile range).
AIS, Abbreviated Injury Scale; ICU, intensive care unit.

stay was 8.6 days (IQR, 3.3–23.6 days), while for the nonsurgery group, it was 5.4 days (IQR, 1.6–18.0 days). However, this difference was not statistically significant. Furthermore, the median length of hospital stay was 27.5 days (IQR, 17.0–58.0 days) for the surgery group and 20.0 days (IQR, 9.3–43.8 days) for the nonsurgery group. This difference was statistically significant. No significant difference was observed between the groups with regard to in-hospital mortality and respiratory complications, such as pneumonia. In a multivariate analysis examining the incidence of pneumonia following surgery for sternal fracture without rib fracture, none of the patients who underwent surgery developed pneumonia (Table 2). However, pneumonia did occur in seven of the 60 patients (11.7%) who did not undergo surgery (P = 0.192). In addition, no significant difference was found in the occurrence of pneumonia between the surgery and nonsurgery groups with an AIS score of less than 3 for head and neck injuries; this condition arose in nine (40.9%) and 20 patients (36.4%), respectively (P = 0.911).

Fractures were the most frequently observed injury, although sternomanubrial joint dislocation was noted in three instances, and a combination of dislocation and fracture was seen in three other cases. The sternal body was the most common site of sternal fracture, followed by the manubrium. Regarding the extent of displacement in sternal fractures, the offset type was the most frequently observed, occurring in 111 patients. Among these 111 patients with offset-type fractures, 19 exhibited an offset of 50%
or more. In the group of patients who underwent surgery, the offset type was most frequently seen, followed by the displaced type. In contrast, among the patients who did not undergo surgery, the nondisplaced type was most common, observed in 91 patients, while the offset type was seen in 62 patients (Table 3).

A total of 90 patients underwent ORIF, with three patients receiving wire fixation and three patients receiving a combination of wire and plate fixation. One patient treated with ORIF continued to experience chest wall instability, leading to the insertion and subsequent removal of a Nuss bar. One patient underwent resection of the xiphoid process. None of the patients who underwent surgery exhibited sternal instability or incomplete bone union during outpatient follow-up. Twenty patients reported experiencing prolonged pain, and two patients received treatment for wound complications. Fixation removal was carried out in 18 patients, with chest tightness being the most common reason for removal, reported by nine patients. This was followed by screw loosening in five patients and infection in one patient. The average duration from the initial operation to removal was 460 days. No patients encountered issues with bone union. The average duration from admission to surgery was 6 days, and the average duration from hospitalization to discharge postsurgery was 43 days (Table 4).

### DISCUSSION

Sternal fractures can typically be managed through conservative treatment without surgery. However, surgical intervention is indicated when unstable fractures are coupled with severe dislocations, or in cases of flail chest accompanied by respiratory failure. In such instances, if surgical treatment is not undertaken, an increased risk exists of respiratory distress and a prolonged period of ventilator application. This heightens the likelihood of respiratory complications, such as pneumonia, particularly as the duration of the ICU stay is extended. Therefore, it is crucial to appropriately identify patients who would benefit from either surgical or conservative treatments and administer the corresponding treatment accordingly [4].

Sternal fixation surgery has seen a recent exponential increase in performance, yet the indications for its application remain un-
established [10]. Our study revealed no significant difference in the mean Injury Severity Score between surgical and nonsurgical groups. However, the surgery group displayed a higher incidence of intrathoracic injuries, including heart, aorta, or other arterial injuries, and flail chest. This suggests that surgical sternal fixation may be indicated when heart or thoracic vessel injuries and multiple rib fractures necessitate surgery. Displacement can be classified into nondisplaced, offset, and displaced categories [11]. At our center, indications for surgery included either an offset of more than 50% or displacement. Of the 111 patients with offset displacement, 19 had an offset of 50% or more. Among these, six patients with flail motion underwent ORIF, all of whom had rib fractures. The remaining 13 patients did not exhibit flail motion, and only four of them had rib fractures. Of the six patients who underwent surgery without flail motion, one experienced a xiphoid resection due to abnormal union, and five had surgery due to persistent pain and chest discomfort. Of the 92 patients with an offset of less than 50%, 33 had a flail chest, of whom 32 had rib fractures and one had a segmental fracture of the sternal body. Therefore, in cases of offset displacement, the presence of a rib fracture contributed more to the occurrence of flail motion than the degree of displacement. This is further supported by the fact that of 96 patients exhibiting flail motion, 93 had rib fractures. In cases of flail motion without rib fractures, the displacement was not severe, but a segmental fracture of the sternum was observed. Thus, when deciding on surgical treatment, it is more appropriate to consider not only the degree of displacement but also the presence of flail motion as an indication for surgery.

In cases of anterior flail chest due to a sternal fracture accompanied by bilateral multiple rib fractures, particularly when fixation of the costal cartilage or sternocostal junction is necessary, conventional ORIF may not be easily executed. Under such circumstances, fixation using a Nuss bar can be employed [12]. In the present study, within the ORIF group, the flail motion persisted in one instance even after ORIF was performed. For this patient, fixation was carried out on the right fourth sternocostal junction and costal cartilage using sternum ORIF. A Nuss bar was inserted 1 week following the ORIF procedure and was removed 1 year after its insertion.

During conservative treatment, it is crucial to manage pain and maintain pulmonary hygiene to prevent respiratory complications, such as atelectasis and pneumonia [4]. Pain management can be achieved through various methods, such as patient-controlled epidural analgesia. This is particularly beneficial for patients who struggle to manage pain with oral, intravenous, or intramuscular analgesia; those with bilateral or numerous fractures; or those at an elevated risk of respiratory complications due to advanced age [13]. In our facility, we typically use a combination of acetaminophen and tramadol as the primary oral analgesia. Depending on the severity of the pain, we may add oral pregabalin to the regimen, and we resort to patient-controlled epidural analgesia when pain becomes unmanageable with oral analgesia. Additionally, we routinely implement respiratory rehabilitation in collaboration with the Department of Rehabilitation Medicine. Even in the absence of significant intrathoracic organ or blood vessel injury on a chest CT scan, the potential remains for cardiac contusion. Therefore, laboratory tests such as evaluation of cardiac markers, electrocardiography, and echocardiography may be necessary to assess cardiac function [14]. For such patients at our facility, we monitor cardiac markers and electrocardiography serially over a 72-hour period, and we also perform echocardiography.

Limitations
This study had certain limitations. First, it was a small-scale study conducted at a single center. Second, the study did not solely focus on patients with sternal fractures, but rather included all trauma patients who had sustained such fractures. As a result, it was challenging to pinpoint complications specifically attributable to sternal fractures, given that the length of ICU stay, the total duration of hospital stay, and the incidence rate of respiratory complica-

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**Table 4. Surgical characteristics and fixation removal**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Surgery group (n=98)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Materials of fixation</strong></td>
<td></td>
</tr>
<tr>
<td>Plate</td>
<td>90 (91.8)</td>
</tr>
<tr>
<td>Wire</td>
<td>3 (3.1)</td>
</tr>
<tr>
<td>Plate and wire</td>
<td>3 (3.1)</td>
</tr>
<tr>
<td>Plate and Nuss bar</td>
<td>1 (1.0)</td>
</tr>
<tr>
<td>Xiphoid process resection</td>
<td>1 (1.0)</td>
</tr>
<tr>
<td><strong>Postoperative complication</strong></td>
<td></td>
</tr>
<tr>
<td>Sternal instability</td>
<td>0</td>
</tr>
<tr>
<td>Prolonged pain</td>
<td>20 (20.4)</td>
</tr>
<tr>
<td>Wound problem</td>
<td>2 (2.0)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>32 (32.7)</td>
</tr>
<tr>
<td>Cause of fixation removal (n=18)</td>
<td></td>
</tr>
<tr>
<td>Screw loosening</td>
<td>5 (27.8)</td>
</tr>
<tr>
<td>Chest tightness</td>
<td>9 (50.0)</td>
</tr>
<tr>
<td>Infection</td>
<td>1 (5.6)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (16.7)</td>
</tr>
<tr>
<td><strong>Duration from admission to surgery (day)</strong></td>
<td>6.0±13.7</td>
</tr>
<tr>
<td><strong>Duration from surgery to discharge (day)</strong></td>
<td>43.3±84.6</td>
</tr>
<tr>
<td><strong>Duration from first surgery to removal surgery (day)</strong></td>
<td>459.9±526.7</td>
</tr>
</tbody>
</table>

Values are presented as number (%) or mean±standard deviation.
tions could be influenced by concurrent injuries unrelated to the sternal fracture. Finally, in the context of trauma, patients are commonly lost to outpatient follow-up due to transfer to another hospital or nonattendance after recovery. Consequently, it is difficult to ascertain long-term outcomes in these patients.

Conclusions
Surgery may be recommended for patients exhibiting flail chest in conjunction with the offset type of sternal fracture and accompanying rib fractures, or in patients with segmental sternal fracture. Furthermore, given that trauma patients often sustain multiple injuries, identifying significant differences in mortality and morbidity specifically attributable to sternal fracture surgery can be challenging. Therefore, a study involving a more standardized and homogeneous group is required.

ARTICLE INFORMATION

Author contributions
Conceptualization: Seon Hee K, GHK, JHK; Data curation: JHK, SBL, CIP; Formal analysis: CIP, DYR, NHL; Funding: Seon Hee K; Methodology: HHK, DYR, Sun Hyun K; Project administration: Seon Hee K, NHL, SBL; Visualization: SBL, GHK, JHK, DYR; Writing–original draft: NHL, Seon Hee K, Sun Hyun K; Writing–review & editing: NHL, HHK, CIP. All authors read and approved the final manuscript.

Conflicts of interest
Seon Hee Kim and Ho Hyun Kim are Editorial Board members of the Journal of Trauma and Injury, but were not involved in the peer reviewer selection, evaluation, or decision process of this article. The authors have no other conflicts of interest to declare.

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Data availability
Data analyzed in this study are available from the corresponding author upon reasonable request.

REFERENCES

Proximally based sural artery flap for the reconstruction of soft tissue defects around the knee and proximal third of the leg in India: a clinical study

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Purpose: The reconstruction of defects around the knee and the proximal third of the leg necessitates thin, pliable skin with a stable and sensate soft tissue cover. This study analyzed the use of a proximally based sural artery flap for the coverage of such defects.

Methods: This prospective clinical interventional study involved 10 patients who had soft tissue defects over the knee and the proximal third of the leg. These patients underwent reconstruction with a proximally based sural artery flap. The study analyzed various factors including age, sex, etiology, location and presentation of the defect, defect dimensions, flap particulars, postoperative complications, and follow-up.

Results: There were 10 cases, all of which involved men aged 20 to 65 years. The most common cause of injury was trauma resulting from road traffic accidents. The majority of defects were found in the proximal third of the leg, particularly on the anterolateral aspect. Defect dimensions varied from 6×3 to 15×13 cm², and extensive defects as large as 16 cm×14 cm could be covered using this flap. The size of the flaps ranged from 7×4 to 16×14 cm², and the pedicle length was 10 to 15 cm. In all cases, donor site closure was achieved with split skin grafting. This flap consistently provided a thin, pliable, stable, and durable soft tissue cover over the defect with no functional deficit and minimal donor site morbidity. Complications, including distal flap necrosis and donor site graft loss, were observed in two cases.

Conclusions: The proximally based sural fasciocutaneous flap serves as the primary method for reconstructing medium to large soft tissue defects around the knee and the proximal third of the leg. This technique offers thin, reliable, sensate, and stable soft tissue coverage, and can cover larger defects with minimal complications.

Keywords: Sural artery flap; Soft tissue defects; Sensate flap; Knee and proximal third defects
INTRODUCTION

Background
Injuries that result in soft tissue skin defects around the knee are common, often caused by road traffic accidents. They can also occur secondary to burns, surgical infections, and post–tumor resection. The reconstruction of these defects is challenging due to the need for thin, pliable skin that can restore knee functions [1]. Defects in and around the knee present a significant challenge to reconstructive surgeons due to their location over a mobile joint. This often necessitates stable, pliable tissue with sensation. The skin in this area has less redundancy and a poor arterial supply below the proximal third of the lower leg. Additionally, superficial venous return in this region is frequently ineffective. As a result, soft tissue defects that occur in this region are difficult to cover. To meet these demands, a proximally based sural artery flap appears to be one of the best choices. It is a thin, sensate flap with a good aesthetic appearance and minimal donor site morbidity [2]. This makes it a favorable option compared to other alternatives. However, there are few published reports on this flap.

Objectives
The purpose of this study was to evaluate the outcomes of the proximally based sural artery flap when used in the reconstruction of defects around the knee and the proximal third of the leg.

METHODS

Ethics statement
This study was approved by the Institutional Review Board of Osmania General Hospital (No. 20613001002D). Written informed consents for publication of the research details and clinical images were obtained from the patients.

Study design and patients
This is a prospective clinical interventional study that was conducted in the Department of Plastic Surgery at Osmania General Hospital (Hyderabad, India), a tertiary care center. The study involved 10 patients who presented with soft tissue defects around the knee or the proximal third of the leg and underwent reconstruction with a proximally based sural artery flap. All the patients were referred from the orthopedic department after the initial stabilization of fractures and any other injuries. The demographic data collected from the patients included age, sex, the mode and etiology of the injury, medicolegal status, any associated fractures, presentation of the defect, addictions, associated comorbid conditions, and complications.

All patients underwent a routine surgical profile, including a radiograph of the affected limb. This was done to rule out any associated fractures, and if any were found, appropriate management was undertaken. Additionally, a Doppler study of the affected lower limb was conducted to assess the vascular status of the limb.

After obtaining informed consents about the prognosis of the condition and the planned procedure, patients were included in the study. These patients then underwent preoperative planning for the flap. This involves marking the dimensions of the defect and planning the flap in reverse using a lint cloth, marking pen, and measuring tape.

Surgical technique
The following surgical technique was employed [2,3]. Either a standard lateral or prone position was adopted after administering spinal or general anesthesia. Under tourniquet control, meticulous debridement of the recipient site was carried out, and the exact dimensions of the defect were measured. The axis of the flap was drawn along a line that extended from the midpoint of the popliteal fossa to a point midway between the lateral malleolus and the Achilles tendon. Reverse planning was conducted using a lint piece to verify the reach of the flap. The pivot point of the flap was positioned approximately 2 cm from the midpoint of the popliteal fossa along the previously described axis. Preoperative Doppler for assessing flow in the sural artery was not conducted in any of the cases included in this study. Along the distal margin of the flap, the skin and fascia were incised. The sural nerve, associated vascular plexus, and the short saphenous vein were identified and cleanly divided. Dissection was carried out from distal to proximal. The deep fascia was included in the flap at the distal, medial, and lateral sides and was secured with the skin to prevent shearing.

In the proximal part of the flap, we made only a skin incision. The flap was designed to center the neurovascular bundle. In the upper section, we carefully dissected the sural nerve and the median superficial sural artery between the two heads of the gastrocnemius until we reached the predetermined pivot point (Fig. 1). We included approximately 3 cm of the surrounding soft tissue to safeguard the sural artery pedicle. We then constructed a suitable subcutaneous tunnel to allow the flap and pedicle to reach the recipient site. In some instances, we had to incise the tunnel due to potential pedicle compression. We deflated the tourniquet to verify the flap’s viability. The flap was then inset at the recipient site, and a corrugated rubber drain was placed un-
der the flap, which was removed between the 3rd and 5th day.
The donor area was covered with split skin graft in all cases. A plaster of Paris slab was applied across the knee joint to immobilize it in all patients. Patients were positioned either prone or laterally, with the operated limb elevated.

RESULTS

The patients in this study ranged in age from 20 to 65 years, with an average age of 36.9 years. All 10 patients in our study group were male. The most common cause of the defect was trauma resulting from road traffic accidents, accounting for nine cases. One case was due to an injury from a fall from a height. The most frequently observed site of the defect was the proximal third of the leg, seen in seven cases, followed by defects around the knee in three cases. Regarding the location of the defect, soft tissue defects in our study were most commonly found on the anterolateral aspect of the proximal third of the leg, with five cases. The defects analyzed in the study had an average size of 98.3 cm². The largest defect noted in the study measured 15 × 13 cm² (Fig. 2). The area of the flap harvested in this study group ranged from 7 × 4 to 16 cm × 14 cm (Fig. 3). The pedicle length of the flap ranged from 10 to 15 cm, with an average of 11.7 cm. All patients underwent split skin grafting for closure of the donor site. Two patients experienced complications of distal necrosis, which was managed by flap debridement and reinsertion. These same two patients also experienced donor site graft loss, which was managed with supplementary grafting. Details of the cases are shown in Table 1.

Representative cases

Case 1
A 32-year-old male patient experienced a road traffic accident (RTA)—specifically, a tractor tire ran over his leg while he was working in the field—and sustained an injury to his right leg (Fig. 4). He presented with a soft tissue defect on the anterolateral aspect of the proximal third of his leg, with an exposed implant. The dimensions of the defect were 15 × 10 cm², and the flap size was 16 × 11 cm², with a pedicle length of 11 cm. The postoperative period was uneventful, and the flap settled well.

Case 2
A 22-year-old male patient with a history of an RTA (a collision between a car and a bike) sustained an injury to his right leg (Fig. 5). He presented with a soft tissue defect on the anterolateral aspect of his knee, which exposed the distal femur. The dimensions of the defect were 12 × 6 cm², and the flap size was 13 × 7 cm², with a pedicle length of 15 cm. The postoperative period was uneventful, and the flap settled well.
Table 1. Details of the cases included in the study

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Etiology</th>
<th>Location of the defect</th>
<th>Presentation of the defect</th>
<th>Defect size (cm)</th>
<th>Flap size (cm)</th>
<th>Pedicle length (cm)</th>
<th>Complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32</td>
<td>Male</td>
<td>RTA</td>
<td>Anterolateral aspect of the proximal third of the leg</td>
<td>Exposed proximal tibia</td>
<td>15×10</td>
<td>16×11</td>
<td>11</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>Male</td>
<td>RTA</td>
<td>Anterolateral aspect of the proximal third of the leg</td>
<td>Exposed implant</td>
<td>8×6</td>
<td>11×6</td>
<td>11</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>Male</td>
<td>RTA</td>
<td>Anterolateral aspect of the proximal third of the leg</td>
<td>Exposed fracture site anteriorly, implant laterally</td>
<td>14×7</td>
<td>15×8</td>
<td>10</td>
<td>Distal flap necrosis, donor site graft loss</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>Male</td>
<td>RTA</td>
<td>Anterolateral and medial aspect of the proximal third of the leg</td>
<td>Exposed fracture site</td>
<td>15×13</td>
<td>16×14</td>
<td>12</td>
<td>Distal necrosis, donor site graft loss</td>
</tr>
<tr>
<td>5</td>
<td>65</td>
<td>Male</td>
<td>RTA</td>
<td>Anteromedial aspect of the proximal third of the leg</td>
<td>Exposed tibial bone near fracture site</td>
<td>12×11</td>
<td>14×12</td>
<td>11</td>
<td>None</td>
</tr>
<tr>
<td>6</td>
<td>51</td>
<td>Male</td>
<td>Fall from height</td>
<td>Anteromedial aspect of the proximal third of the leg</td>
<td>Exposed tibial bone</td>
<td>9×8</td>
<td>10×9</td>
<td>12</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>32</td>
<td>Male</td>
<td>RTA</td>
<td>Anterior aspect of the proximal third of the leg</td>
<td>Exposed implant</td>
<td>6×3</td>
<td>7×4</td>
<td>12</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>22</td>
<td>Male</td>
<td>RTA</td>
<td>Anterolateral aspect of the knee</td>
<td>Exposed distal femur</td>
<td>12×6</td>
<td>13×7</td>
<td>15</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>60</td>
<td>Male</td>
<td>RTA</td>
<td>Anterior aspect of the knee</td>
<td>Exposed distal femur</td>
<td>14×12</td>
<td>16×13</td>
<td>10</td>
<td>None</td>
</tr>
<tr>
<td>10</td>
<td>22</td>
<td>Male</td>
<td>RTA</td>
<td>Anterolateral aspect of the knee</td>
<td>Exposed lateral femoral condyle</td>
<td>6×5</td>
<td>7×5</td>
<td>13</td>
<td>None</td>
</tr>
</tbody>
</table>

RTA, road traffic accident.

Fig. 4. Images of case 1. (A) Preoperative image. (B) Flap design illustration. (C) Intraoperative image. (D) Postoperative image (follow-up after 1 year).
Case 3
A 20-year-old male patient was in an RTA (a collision between a car and a truck) and sustained an injury to his left leg (Fig. 6). He presented with a soft tissue defect on the antero-lateral aspect of the proximal third of his leg, where an implant was exposed. The dimensions of the defect were $8 \times 6 \text{ cm}^2$. The flap size was $11 \times 7 \text{ cm}^2$, with a pedicle length of 11 cm. The postoperative period was uneventful, and the flap settled well.

DISCUSSION
Improving the optimal methods for recipient site reconstruction and minimizing donor site morbidity are ongoing areas of exploration in reconstructive surgery. Reconstructing soft tissue defects around the knee is often a challenge for plastic surgeons due to the specific requirements necessary for knee joint reconstruction. The chosen method for reconstruction should be straightforward, reproducible, and reliable, with minimal morbidity at the donor site. The donor tissue should possess thin, pliable, stretchable, and sensate skin. Additionally, the undersurface should be nonadhesive to ensure that the knee's flexion and extension functions are not compromised [1]. Various flaps have been proposed for covering these defects around the knee, including local flaps (muscle, fasciocutaneous, perforator), cross-leg flaps, or free flaps [3]. The gastrocnemius flap is the most commonly used muscle for covering defects in this area. This muscle flap is easy to execute and highly reliable. However, its lack of innervation and the potential for unsatisfactory cosmetic results (such as bulkiness and contour deformity) are notable drawbacks to the use of muscle flaps [4].

The outcomes of local fasciocutaneous flaps are not consistently satisfactory. This is primarily because they are typically random pattern flaps with compromised vascularity at the tip. Consequently, distal necrosis often occurs at the site where these flaps are most needed. This subsequent healing process can compromise both the function and appearance of the knee joint [5].

More recently, local perforator flaps have been increasingly utilized due to their notable advantages, including low donor morbidity and superior aesthetic outcomes. Perforator flaps, such as the medial sural artery perforator flap, anterior tibialis artery perforator flap, reversed anterolateral thigh perforator flap, and the pedicled vastus medialis perforator, are favored for reconstructing skin defects around the knee. These flaps provide thin, pliable skin that fulfills most of the reconstruction requirements in the knee area. The cosmetic results following the application of these flaps are excellent, and the morbidity at the donor site is also minimal. However, these flaps do have some drawbacks, including a lack of sensation, the need for a Doppler to locate a suitably sized perforator near the defect, and a long and somewhat tedious dissection process [6,7].

The inferomedial thigh flap, which is based on perforators originating from the descending genicular artery, can provide flaps large enough to cover the entire knee. However, this procedure necessitates a preoperative evaluation of the perforator ves-
sels, as this flap can occasionally experience venous congestion, sometimes requiring an additional venous microanastomosis with a local vein. Such vascular incidents are less common with the proximally based sural island flap. In our series, all 10 flaps survived completely, with no vascular incidents, demonstrating the reliability of its blood supply. All grafted donor sites healed satisfactorily.

The proximally based sural island flap has proven capable of providing ample tissue for coverage. We have successfully raised flap dimensions as large as $16 \times 14 \text{ cm}^2$ to cover extensive defects. In the past, such large defects would have necessitated either a free flap or a cross-leg flap [1]. Microvascular reconstruction of defects in the knee joint area presents another viable option [8]. While this is a single-stage procedure, it does have its drawbacks. These include the need for specialized equipment, such as a microscope, and a surgeon with specific expertise. Additionally, identifying suitable recipient vessels at the site can also pose a challenge.

The proximally based sural fasciocutaneous flap, utilized in our study, offers certain benefits. Its tissue is thin and pliable, and the flap’s undersurface facilitates easy gliding of the knee joint. This flap is highly reliable and can be readily extended into the mid-third of the leg. It also has a long pedicle with a good arc of rotation, which allows for easy extension to the distal thigh [9].

The flap offers several advantages, including its ease and speed of elevation, and the fact that it does not necessitate microsurgical skills or meticulous dissection of the pedicle. Furthermore, this flap is thin and sensate, contributing to an aesthetically pleasing appearance at the site. It promotes fracture healing in defects where the fracture site is exposed by providing a stable and durable soft tissue cover. In instances where an implant is exposed, it safeguards the implant from infection. The flap also provides a smooth gliding surface, facilitating free movement of the knee joint in cases of knee defects [2,3,9].

Like any other flap, this one also has certain disadvantages, such as its appearance if a skin graft has been used at the donor site. This cosmetic disadvantage is not present if the donor site is primarily closed, specifically in cases where the flap width is less than 3 cm. However, in our study, the donor site was closed using split-thickness skin grafting in all cases. Since the donor site is located on the posterior calf region, which is typically concealed, most patients did not report this as a major complaint during the postoperative period, once the graft had completely settled. As the sural nerve is harvested along with the flap, there is a loss of sensation on the lateral side of the foot. This tends to diminish over time due to sensory overlap from surrounding regions, as observed in a well-established, distally based sural artery flap [2].

Cheon et al. [2] also employed the same technique, using the flap for reconstruction around the knee joint in 10 cases, with a follow-up period of 1 to 2.5 years. The outcomes were similar to those in our study, as the flap was thin, sensate, and did not impede the function of the knee joint. In their study, the maximum flap size raised was only $6 \times 10 \text{ cm}^2$, whereas in our study, we were able to raise a flap with a maximum area of $15 \times 13 \text{ cm}^2$. Cheon et al. [2] identified the loss of sensation on the lateral side of the foot as a significant drawback, but in our study, patients did...
not cite this as a major issue during the postoperative period. Aside from the complications of marginal flap necrosis and donor site graft loss, which were observed in two cases, there were no other complaints from the patients, even after a long-term follow-up of over 1 year.

Limitations
The limitation of the study was its sample size. Although the sample size for this study was small, it still demonstrated the versatility and usefulness of this flap. Further research with larger cohorts is warranted to validate our findings and provide a more comprehensive assessment of its clinical applicability.

Conclusions
The proximally based sural fasciocutaneous flap is a workhorse flap used for the reconstruction of soft tissue defects around the knee and the proximal third of the leg. It has proven to be reliable, efficient, and more versatile than other reconstructive options such as local flaps (muscle, fasciocutaneous, perforator), cross-leg flaps, or free flaps. This flap is relatively easy to learn and harvest, making it an ideal alternative for covering soft tissue defects, as described in the study. It yields acceptable functional and aesthetic outcomes with minimal donor site morbidity. The flap offers the advantages of providing thin, reliable, sensate, and stable soft tissue coverage with a good gliding surface, and it can cover larger defects with minimal complications. With its ease of dissection, consistent vascular pedicle, antegrade blood supply, adequate venous drainage, and thin skin, it is superior to surrounding peer flaps and yields satisfactory outcomes.

ARTICLE INFORMATION

Author contributions
Conceptualization: all authors; Data curation: PL, S Srinivas, DM, SP, S Sankar, SRC; Formal analysis: PL, S Srinivas, DM, SP; Methodology: PL, S Srinivas, DM, AS; Project administration: PL, S Srinivas, DM, SP, S Sankar, SCR; Visualization: PL, DM; Writing–original draft: all authors; Writing–review & editing: all authors; All authors read and approved the final manuscript.

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

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Data availability
Data analyzed in this study are available from the corresponding author upon reasonable request.

REFERENCES

One year of treating patients with open fractures of the lower extremity in a new military trauma center in Korea: a case series

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Purpose: The Armed Forces Trauma Center of Korea was established in April 2022. This study was conducted to report our 1-year experience of treating soldiers with open fractures of the lower extremity.

Methods: In this case series, we reviewed the medical records of 51 Korean soldiers with open fractures of the lower extremity between April 2022 and March 2023 at a trauma center. We analyzed patients with Gustilo-Anderson type II and III fractures and reported the duration of transportation, injury mechanisms, injured sites, and associated injuries. We also presented laboratory findings, surgery types, intensive care unit stays, hospital stays, rehabilitation results, and reasons for psychiatric consultation. Additionally, we described patients’ mode of transport.

Results: This study enrolled nine male patients who were between 21 and 26 years old. Six patients had type II and three had type III fractures. Transport from the accident scene to the emergency room ranged from 75 to 455 minutes, and from the emergency room to the operating room ranged from 35 to 200 minutes. Injury mechanisms included gunshot wounds, landmine explosions, grenade explosions, and entrapment by ship mooring ropes. One case had serious associated injuries (inhalation burn, open facial bone fractures, and hemopneumothorax). No cases with serious blood loss or coagulopathies were found, but most cases had a significant elevation of creatinine kinase. Two patients underwent vascular reconstruction, whereas four patients received flap surgery. After rehabilitation, six patients could walk, one patient could move their joints actively, and two patients performed active assistive movement. Eight patients were referred to the psychiatry department due to suicidal attempts and posttraumatic stress disorder.

Conclusions: This study provides insights into how to improve treatment for patients with military trauma, as well as medical services such as the transport system, by revising treatment protocols and systematizing treatment.

Keywords: Military personnel; Degloving injuries; Leg injuries; Post-traumatic stress disorders
INTRODUCTION

Background
Korea has been in a state of ceasefire for 70 years since the end of the Korean War in 1953. The Korean military maintains 500,000 soldiers, accounting for about 1% of the Korean population in the present day [1]. Accidents such as landmine explosions, gunshots, and falls during training can occur in the military. Lower extremity injuries are especially common in the military due to soldiers’ training and exercise to maintain their physical condition. Patients with lower extremity injuries are usually hospitalized for a long time because their activity level is limited [2]. In addition, severe lower extremity injuries occasionally occur. Those with multiple severe injuries often show unstable vital signs and undergo repeated operations with considerable complications and psychological problems [3].

Objectives
The Armed Forces Trauma Center (AFTC; Seongnam, Korea) was established in April 2022. This study was conducted to report our 1-year experience of treating patients (soldiers) with open fractures of the lower extremity. In addition, the clinical processes of treating these patients were described in detail.

METHODS

Ethics statement
This study was approved by the Institutional Review Board of Armed Forces Capital Hospital (No. AFCH 2023-04-001). The requirement for informed consent was waived due to the retrospective nature of the study.

Study design

Data collection
In this observational study (case series), we reviewed the medical records of 51 Korean soldiers with open fractures of the lower extremity between April 2022 and March 2023 at a single trauma center.

Criteria and variables
After categorizing the severity using the Gustilo-Anderson classification, we analyzed patients with type II and III fractures (Fig. 1) [4]. The process of transporting patients was described as time elapsed from the accident scene to the emergency room (ER) and from the ER to the operating room (OR). We analyzed the patients’ injury mechanisms, injured sites, types of surgery performed, associated injuries, and clinical processes. The injury mechanisms included gunshot wounds, landmine explosions, grenade explosions, being crushed under a vehicle wheel, being trapped by mooring ropes, and falls. We classified the injured sites as pelvis, thigh (femur), knee, calf (tibiofibular), ankle, and foot. The surgeries performed were bony fixation, vascular reconstruction, and performing flap. We also reported the associated injuries of these patients and calculated the Injury Severity Score (ISS), Revised Trauma Score (RTS), and Trauma and Injury Severity Score (TRISS) for each case. We presented the initial laboratory findings upon arrival at the ER and clinical processes such as intensive care unit (ICU) stays, hospital stays, rehabilitation results, and reasons for referral to the psychiatry department for consultation.

Processes for responding to military trauma patients

Transportation system for trauma patients in the Korean military
Almost all military servicepersons who require transportation to a hospital are immediately reported to the Medical Emergency Operation Center (MEOC) under the Korean Armed Forces Medical Command (Fig. 2). The MEOC offers on-site counseling and treatment, determines the appropriate hospital (military or civilian) for patients, and prepares a transport strategy using military or civilian vehicles or helicopters. Among them, patients with traumatic injuries requiring surgical or intensive management are usually transported to the AFTC after discussion with the MEOC.

Fig. 3. shows the field triage protocol for trauma patients. Patients with minor injuries are transported to military hospitals under corps. Ultra-emergency patients who have an unstable airway, severe shock, and traumatic arrest (Fig. 4) are transported to the nearest military hospital for initial resuscitation. The helicopters depart at the same time, and then patients are re-transported.
Military Trauma Center

The Medical Emergency Operation Center under the Korean Armed Forces Medical Command.

Minor injury
- Military hospital under corps

Accident scene

Ultra-emergency
- The nearest military hospital
- Departs military helicopter at the same time

Need further evaluation and treatment

Military Trauma Center

After initial assessment and treatment

- Unstable airway
  - GCS score $\leq 9$
  - AVPU: unresponsive
- Severe shock
  - SBP $< 90$ mmHg
  - Capillary refill time $> 2$ sec
- Traumatic arrest

Fig. 2. The Medical Emergency Operation Center under the Korean Armed Forces Medical Command.

Fig. 3. Field triage protocol in the Korean military.

Fig. 4. Field triage protocol: ultra-emergency. The Medical Emergency Operation Center evaluates patients' severity and decides where to direct them. GCS, Glasgow Coma Scale; AVPU, alert, voice, pain, unresponsive; SBP, systolic blood pressure.

<table>
<thead>
<tr>
<th>Transport to Armed Forces Trauma Center (Seongnam, Korea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major</td>
</tr>
<tr>
<td>Penetrating injury: head, neck, torso, proximal part of elbow, or knee</td>
</tr>
<tr>
<td>Suspected fracture or depressed fracture of skull</td>
</tr>
<tr>
<td>Suspected spinal injury with motor or sensory disturbance</td>
</tr>
<tr>
<td>Two or more fractures of humerus or femur</td>
</tr>
<tr>
<td>Crushed, degloved, mangled, pulseless extremity</td>
</tr>
<tr>
<td>Amputation of proximal part of wrist or ankle</td>
</tr>
<tr>
<td>SBP $&lt; 90$ mmHg</td>
</tr>
<tr>
<td>Heart rate $&gt; SBP$</td>
</tr>
<tr>
<td>GCS score $&lt; 6$</td>
</tr>
<tr>
<td>Respiratory rate $&lt; 10$ or $29$ breaths/min</td>
</tr>
</tbody>
</table>

Fig. 5. Field triage protocol: major injury. The Medical Emergency Operation Center (MEOC) evaluates patients' severity and decides where to direct them. SBP, systolic blood pressure; GCS, Glasgow Coma Scale.

AFTC workforce and building structure
A total of 11 trauma surgeons work in the AFTC. Four are military officers, six are civilians who were dispatched from a cooperative hospital, and one is a civilian surgeon employed by the military. This center is part of the biggest military hospital in Korea, with 666 beds and 130 doctors (excluding residents). Physicians affiliated with this military hospital support the AFTC, including surgeons (thoracic, orthopedic, plastic, vascular, hepatobiliary, and neurosurgeons), interventionists, anesthesiologists, cardiologists, pulmonologists, neurologists, physiatrists, psychiatrists, and so on.

The AFTC is a three-story building with a helipad on the roof, which is designated as the shortest distance by foot (Fig. 6A). The ground floor includes a trauma ER with two resuscitation rooms (Fig. 6B), a computed tomography (CT) room, a magnetic resonance room, and an intervention room. The first floor includes offices and educational rooms. The second floor includes a trauma OR (Fig. 6C), a general ward for trauma patients with 60 beds, and a trauma ICU (TICU) with 20 beds (Fig. 6D).

AFTC treatment protocols
One or more trauma surgeons are on duty all the times in the AFTC. Trauma surgeons respond to patients' arrival at the trauma ER, apply critical care in the TICU, participate in surgery, and operate the trauma general ward. When the MEOC contacts the AFTC trauma team leader (a trauma surgeon) for patient transportation, the team leader decides whether to accept the patient, and then whether to activate the trauma team following standard criteria (Fig. 7). The trauma team consists of trauma surgeons (including the trauma team leader), trauma ER nurses, emergency medical technicians, radiology technicians, and security guards. The trauma team leader can also call for additional staff affiliated with the supporting military hospital, such as surgeons from other departments, anesthesiologists, and interventionists.
When trauma patients arrive at the AFTC, trauma surgeons assess and resuscitate them if needed, together with trained nurses assigned to the trauma ER. They then discuss the treatment plan with supporting staff members. In the trauma ER, protocols are in place for CT scans, transfusion, laboratory studies, and performing necessary procedures.

**RESULTS**

Table 1 shows the transportation processes of patients from the accident site to the AFTC ER, along with their demographics. This study included nine male patients aged between 21 and 26 years old. Five patients were transported directly to the AFTC (cases 1, 2, 4, 5, 7), and four patients (cases 3, 6, 8, 9) were transferred to the center through another hospital. Military trauma patients can be transported in four ways: military helicopter, military ambulance, public helicopter, public ambulance. In this study, four patients were transported by military helicopter, four patients by military ambulance, and one patient by public helicopter. The time it took to transport patients from the accident scene to the AFTC ER ranged from 75 minutes (case 4) to 455 minutes (case 9), and from the ER to the OR ranged from 35 minutes (case 4) to 200 minutes (case 6). Cases that went through another hospital (cases 4, 6, 8, 9) took more time to transport. Among them, military-specific injuries included gunshot wounds (cases 1, 3), landmine explosions (cases 2, 5) (Fig. 8A–C), a grenade explosion (case 4), and entrapment by a warship's mooring ropes (case 7) (Fig. 8D–F). The foot was the most common site of injury, and only one patient (case 4) had serious associated injuries (namely, an inhalation burn, open facial bone fractures, and hemopneumothorax with multiple rib fractures). Systolic blood pressure, ISS, Revised Trauma Score, and TRISS were not unusually low except in one case (case 4).

Table 2 displays the initial laboratory findings upon arrival at the ER. No cases with serious blood loss (hemoglobin, < 7.0 g/dL) or coagulopathies were found. Most cases showed a significant elevation of creatinine kinase (316–2,876 IU/L), except for cases 3 and 5, which were within normal range.

Table 3 shows the operative methods used. The patients in cases 4 and 7 underwent vascular reconstruction, and the patients in cases 2, 4, 5, and 7 received external fixation during their initial surgery. The patients in cases 4, 5, 7, and 8 underwent flap surgery.

Table 4 shows hospitalization-related variables. Case 4, a patient with multiple injuries, remained in the ICU for 169 days due to requiring long-term ventilator care and management of serious infections. Patients who required rehabilitation for an extended period were hospitalized for more than 16 weeks (cases 1, 2, 4, 5, 7, 8, 9). The results of rehabilitation were as follows: the patients in cases 1, 2, 3, 6, 8, and 9 were able to walk; the patient in case 5 was able to perform active joint movements; and the patients in cases 4 and 7 were able to perform active assistive joint movements. Eight patients in this study required referral to the psychiatry department. Four of these patients had suicidal ideation; those patients had injuries caused by suicide attempts (cases 3, 4, 8, and 9). Their suicidal ideation were addressed following the accidents. All eight patients had posttraumatic stress disorder (PTSD).
<table>
<thead>
<tr>
<th>Case no.</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Transferred from another hospital</th>
<th>Mode of transport</th>
<th>Elapsed time (min)</th>
<th>Injury mechanism</th>
<th>Injured site</th>
<th>Severity</th>
<th>Associated injury</th>
<th>SBP (mmHg)</th>
<th>ISS</th>
<th>RTS</th>
<th>TRISS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>22</td>
<td>Male</td>
<td>No</td>
<td>Military ambulance</td>
<td>305</td>
<td>Gunshot</td>
<td>Foot</td>
<td>II</td>
<td>None</td>
<td>124</td>
<td>4</td>
<td>7.550</td>
<td>98.40</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>Male</td>
<td>No</td>
<td>Military helicopter</td>
<td>115</td>
<td>Landmine explosion</td>
<td>Ankle, foot</td>
<td>II</td>
<td>Multiple lacerations</td>
<td>144</td>
<td>5</td>
<td>7.841</td>
<td>99.58</td>
</tr>
<tr>
<td>3</td>
<td>26</td>
<td>Male</td>
<td>Military hospital</td>
<td>Military helicopter</td>
<td>120</td>
<td>Gunshot</td>
<td>Foot</td>
<td>II</td>
<td>None</td>
<td>162</td>
<td>4</td>
<td>7.841</td>
<td>99.28</td>
</tr>
<tr>
<td>4</td>
<td>24</td>
<td>Male</td>
<td>No</td>
<td>Military helicopter</td>
<td>75</td>
<td>Grenade explosion</td>
<td>Foot, bilateral</td>
<td>IIc</td>
<td>Inhalation burn, open facial bone fractures, hemopneumothorax with multiple rib fractures</td>
<td>96</td>
<td>50</td>
<td>7.841</td>
<td>84.74</td>
</tr>
<tr>
<td>5</td>
<td>23</td>
<td>Male</td>
<td>No</td>
<td>Military helicopter</td>
<td>85</td>
<td>Landmine explosion</td>
<td>Ankle, foot</td>
<td>IIIb</td>
<td>None</td>
<td>114</td>
<td>4</td>
<td>7.841</td>
<td>99.61</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>Male</td>
<td>Civilian hospital</td>
<td>Military ambulance</td>
<td>405</td>
<td>Crushed under vehicle wheel</td>
<td>Foot</td>
<td>II</td>
<td>None</td>
<td>143</td>
<td>4</td>
<td>7.841</td>
<td>99.61</td>
</tr>
<tr>
<td>7</td>
<td>25</td>
<td>Male</td>
<td>No</td>
<td>Public helicopter</td>
<td>135</td>
<td>Trapped by mooring ropes</td>
<td>Calf (tibio-fibular)</td>
<td>IIc</td>
<td>Rib fracture, multiple lacerations</td>
<td>83</td>
<td>11</td>
<td>7.108</td>
<td>98.76</td>
</tr>
<tr>
<td>8</td>
<td>23</td>
<td>Male</td>
<td>Civilian hospital</td>
<td>Military ambulance</td>
<td>390</td>
<td>Fall</td>
<td>Thigh (femur), ankle, foot</td>
<td>II</td>
<td>Multiple lacerations</td>
<td>115</td>
<td>10</td>
<td>7.841</td>
<td>99.12</td>
</tr>
<tr>
<td>9</td>
<td>21</td>
<td>Male</td>
<td>Civilian hospital</td>
<td>Military ambulance</td>
<td>455</td>
<td>Fall</td>
<td>Foot</td>
<td>II</td>
<td>Lumbar spine compression fracture</td>
<td>120</td>
<td>13</td>
<td>7.841</td>
<td>99.19</td>
</tr>
</tbody>
</table>

AFTC, Armed Forces Trauma Center; ER, emergency room; OR, operation room; SBP, systolic blood pressure; ISS, Injury Severity Score; RTS, Revised Trauma Score; TRISS, Trauma and Injury Severity Score.

Gustilo-Anderson classification.
Table 2. Initial laboratory findings in the emergency room

<table>
<thead>
<tr>
<th>Case no.</th>
<th>WBC (10^3/μL)</th>
<th>Hemoglobin (g/dL)</th>
<th>Platelet (10^3/μL)</th>
<th>Prothrombin time (INR)</th>
<th>Lactate (mmol/L)</th>
<th>Creatinine kinase (IU/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17.59</td>
<td>13.2</td>
<td>261</td>
<td>1.01</td>
<td>1.5</td>
<td>348</td>
</tr>
<tr>
<td>2</td>
<td>10.17</td>
<td>12.5</td>
<td>228</td>
<td>1.15</td>
<td>1.8</td>
<td>316</td>
</tr>
<tr>
<td>3</td>
<td>6.73</td>
<td>13.5</td>
<td>361</td>
<td>1.00</td>
<td>1.4</td>
<td>99</td>
</tr>
<tr>
<td>4</td>
<td>42.99</td>
<td>11.3</td>
<td>295</td>
<td>1.17</td>
<td>9.0</td>
<td>2,836</td>
</tr>
<tr>
<td>5</td>
<td>13.29</td>
<td>12.3</td>
<td>167</td>
<td>1.08</td>
<td>4.8</td>
<td>93</td>
</tr>
<tr>
<td>6</td>
<td>11.19</td>
<td>15.3</td>
<td>268</td>
<td>1.03</td>
<td>1.1</td>
<td>690</td>
</tr>
<tr>
<td>7</td>
<td>9.55</td>
<td>9.6</td>
<td>60</td>
<td>1.32</td>
<td>3.9</td>
<td>572</td>
</tr>
<tr>
<td>8</td>
<td>23.33</td>
<td>13.3</td>
<td>247</td>
<td>1.11</td>
<td>3.2</td>
<td>1,039</td>
</tr>
<tr>
<td>9</td>
<td>18.11</td>
<td>11.9</td>
<td>215</td>
<td>1.15</td>
<td>1.7</td>
<td>759</td>
</tr>
</tbody>
</table>

WBC, white blood cell; INR, international normalized ratio.

DISCUSSION

Transportation processes
When a patient with traumatic injuries (or other serious illness) occurs, the military tries to choose the fastest transportation method. Helicopters are very useful for the military because military camps are scattered throughout the country. However, helicopter operations are limited by inclement weather, including rainy, snowy, severely windy, and foggy conditions. Additionally, military helicopters are not able to operate near the ceasefire line, since it could cause military tension. When it is difficult for the MEOC to operate a helicopter and when they suspect that a patient's injury is serious, they arrange transportation to a nearby military or civilian hospital. After evaluation and (if needed) resuscitation, MEOC discusses the situation with AFTC medical staff and decides whether to transfer the patient to the AFTC.
Table 3. Operative methods

<table>
<thead>
<tr>
<th>Case</th>
<th>Open fractured site</th>
<th>Cause of injury</th>
<th>Vascular reconstruction</th>
<th>External fixation during initial surgery</th>
<th>Internal fixation</th>
<th>Flap</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Right foot</td>
<td>Gunshot wound</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>Left ankle and foot</td>
<td>Landmine explosion</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Left foot</td>
<td>Gunshot wound</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Both feet</td>
<td>Grenade explosion</td>
<td>Yes (PTA, right)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Right ankle and foot</td>
<td>Landmine explosion</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Left foot</td>
<td>Crushed under vehicle wheel</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>Right calf (tibiofibular)</td>
<td>Trapped by warship’s mooring ropes</td>
<td>Yes (ATA)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Left thigh (femur), ankle, and foot</td>
<td>Fall</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes (foot)</td>
</tr>
<tr>
<td>9</td>
<td>Right foot</td>
<td>Fall</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

PTA, posterior tibial artery; ATA, anterior tibial artery.

Table 4. Hospitalization-related variables

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Length of stay (day)</th>
<th>Results of rehabilitation</th>
<th>Reason for psychiatric consultation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intensive care unit</td>
<td>Hospital&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>216</td>
<td>Able to walk</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>243</td>
<td>Able to walk</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>46</td>
<td>Able to walk</td>
</tr>
<tr>
<td>4</td>
<td>169</td>
<td>335</td>
<td>Active assistive joint movement</td>
</tr>
<tr>
<td>5</td>
<td>29</td>
<td>&gt;271&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Active joint movement</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>70</td>
<td>Able to walk</td>
</tr>
<tr>
<td>7</td>
<td>13</td>
<td>&gt;181&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Active assistive joint movement</td>
</tr>
<tr>
<td>8</td>
<td>13</td>
<td>&gt;132&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Able to walk</td>
</tr>
<tr>
<td>9</td>
<td>11</td>
<td>130</td>
<td>Able to walk</td>
</tr>
</tbody>
</table>

PTSD, posttraumatic stress disorder.

<sup>a</sup>Hospital stays were recorded until August 20, 2023. <sup>b</sup>Still hospitalized.

Characteristics of military trauma

Several cases in this study included military-specific injuries unusual in civilian society, such as gunshot wounds, landmine explosions, grenade explosions, and entrapment by a warship’s mooring ropes. Additionally, there were cases of military-specific injuries caused by pinching a foot between a cannon and a cannonball, crashing a parachute, and falling from a military helicopter. These cases occurred during the study period but were excluded since they involved closed fractures of the lower extremity. Crashing injuries caused by heavy military equipment, such as moving tanks, cannons, helicopters, and warships, should be taken seriously. In addition, the medical staff of a military trauma center should understand the characteristics of various weapons. For example, even blank cartridge shot can cause severe injury due to the gunpowder blast and projectile gas [5, 6]. Grenade explosions can cause whole-body injury by countless fragments with burns, including to the airway [7].

No case of serious blood loss (hemoglobin, < 7.0 g/dL) and coagulopathy was observed in this study because military medical officers were able to control bleeding well at the accident scenes. Additionally, the AFTC ICU, which is separated into single-occupancy rooms, could help patients maintain a comfortable state and enable monitoring of possible self-injury and abnormal behaviors. Patients with suicidal attempts or a concerning level of PTSD who require repeated surgery are admitted to the ICU until ready for a closed psychiatric ward or until their psychiatric problems become less concerning.

Treatment strategies for open fractures in lower extremities

Trauma patients should be considered in two aspects: (1) the severity of the injured site; and (2) possible life-threatening associated injuries. Aspects of the military context contribute to fractures in many patients. This is natural because soldiers undergo high-intensity training, exercise regularly, and often participate in...
hazardous tasks such as landmine removal. Most patients experience minor injuries, but some cases are very serious, such as limb injuries with degloving, severe associated injuries, or both [8,9]. Many cases involve injuries from which patients find it difficult to achieve a full recovery. The treatment of these patients requires a strategy consisting of several steps.

The first step is to decide whether to salvage or sacrifice the injured leg. Trying to salvage the injured limb may require repeated operations, cause serious complications (such as infection, thrombosis, and chronic pain), impose a huge financial burden, and delay rehabilitation. For many patients with severe leg injuries, amputation might be a better option [10,11]. Patients admitted to the AFTC have their medical expenses covered by the military, and most soldiers, such as military officers and sergeants who suffered disabilities from accidents on duty, can keep their jobs postinjury and are paid during the treatment period. Therefore, we tried our best to salvage the leg in each case, since we could focus on saving the leg without worrying about time or cost [12]. In this study, no cases involved amputation of a lower limb.

The second step is to manage concurrent injuries that could have adverse effects. Life-threatening injuries such as those affecting the brain, heart, lungs, liver, and large vessels are treated with priority.

The third step is to perform surgery. OR decisions were made according to the injury mechanism, injured site, general condition, and the surgeon’s experience, including their skill level [13,14]. During operations, surgeons must solve problems such as vascular reconstruction, muscle repairing, and overlapping skin defects. The most crucial point for surgeons is planning. Surgeons should plan what may be feasible, up to a certain limit of reconstruction, if the injury is too serious to permit a full recovery. In particular, landmine explosions can cause serious intimal injuries that make it difficult to reconstruct vascular structures and create flaps for covering defective tissue. We tried to salvage limbs as much as possible, since most patients in this study were young, otherwise healthy soldiers.

The fourth step is to perform rehabilitation, which may take a long time [15,16]. The timing for initiating rehabilitation depends on many factors such as how the fracture heals, the fixation method, and how related ligaments heal. The rehabilitation process typically begins with restrictive weight bearing, followed by a range of motion evaluation, continuous passive motion, and finally muscle strengthening exercises [17]. Appropriate pain control is needed across the rehabilitation period. Moreover, addressing psychological problems is the most difficult part of recovery [18–20]. Many patients have PTSD, and a psychiatrist’s active involvement is required if the cause of injury is self-harm or a suicidal attempt. In conclusion, management of lower extremity injuries requires complex processes. This study has shown our experiences and management policy for lower extremity injuries in a new military trauma center, which could be useful for other trauma centers that manage lower extremity injuries.

Strengths and limitations
The strengths of this study include its analysis of data based on a specialized transporting system and treatment strategies for military trauma patients. We were able to observe the entire period of treatment from initial ER management to rehabilitation. However, this study has several limitations. First, the volume of the data was small because the AFTC was established only 1 year ago. Second, it is difficult to evaluate the relevance of intensive care, since there was only one case (case 4) with life-threatening associated injuries.

Conclusions
This study showed the experiences of treatment in patients with lower extremity injuries in the military. We hope that the study may help improve treatment in patients with military trauma, as well as improve military medical services such as the transport system, in order to revise treatment protocols and systematize treatment during hospitalization.

ARTICLE INFORMATION

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

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

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Data availability
Data analyzed in this study are available from the corresponding author upon reasonable request.
REFERENCES

Traumatic degloving injuries: a prospective study to assess injury patterns, management, and outcomes at a single center in northern India

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Purpose: This study investigated the epidemiology, management, outcomes, and postoperative disabilities of degloving soft tissue injuries (DSTIs) treated at a tertiary care center in northern India.

Methods: A prospective study of patients with DSTIs was conducted over 15 months. The type of degloving injury, the mechanism of injury, and any associated injuries were analyzed using the World Health Organization Disability Assessment Schedule (WHODAS) 2.0 along with the management, outcomes, and disabilities at a 3-month follow-up.

Results: Among 75 patients with DSTIs, the average age was 27.5 years, 80.0% were male, and 76.0% had been injured in traffic accidents. The majority (93.3%) were open degloving injuries. Lower limbs were affected most often (62.7%), followed by upper limbs (32.0%). Fractures were the most commonly associated injuries (72.0%). Most patients required more than two procedures, including secondary debridement (41.3%), split skin grafting (80.0%), flap coverage (12.0%), or vacuum-assisted closure (24.0%), while five patients underwent conservative management for closed degloving injuries. Postoperative complications included surgical site infections (14.7%) and skin necrosis (10.7%). Two patients died due to septic shock and multiple organ dysfunction syndrome. The mean length of hospital stay was 11.5±8.1 days, with injuries affecting the lower limbs and perineum requiring longer hospital stays. The mean WHODAS 2.0 disability score at 3 months was 19. Most patients had mild disabilities. Time away from work depended largely upon the site and severity of the injury. Approximately 75% of patients resumed their previous job or study, 14% changed their job, and 8% stopped working completely due to residual disability.

Conclusions: DSTIs are common injuries in trauma and management is challenging. Although open DSTIs are clinically evident at secondary survey, closed degloving injuries may be missed in the primary survey, necessitating a high index of suspicion, thorough clinical examination, and protocol-based management. Primary preventive strategies (e.g., road safety protocols, preplacement training, and proper protective equipment in industries) are also needed to reduce the incidence of these injuries.

Keywords: Degloving soft tissue injury; Avulsion; Wounds and injuries; Debridement; Disability
INTRODUCTION

Background

Degloving soft tissue injuries (DSTIs) are characterized by the detachment or avulsion of skin and subcutaneous tissue from the underlying fascia and muscles. These injuries can involve any part of the body, but the lower limbs and trunk are more commonly affected, with a variable amount of injury to soft tissues [1–3]. Degloving injuries can be open or closed and complete or partial. Open partial degloving injuries have a detached skin flap that still covers the underlying structure while, in complete degloving, the underlying structures are exposed. Closed degloving injuries are characterized by detachment of subcutaneous tissue from underlying fascia resulting in a hematoma with an overlying intact skin [1–3]. Degloving injuries are common in northern India. Various cultural and aesthetic factors can contribute to an increased incidence of these injuries such as the religious practices of the Sikh population who wear the pagri (turban), which increases the risk of head injuries and avulsion injuries to the head and face, and the kada (wrist bracelet) which predisposes to degloving injuries involving the hands and wrists. In addition, the practice of wearing multiple rings on one’s fingers predisposes to finger avulsion injuries. DSTIs in industrial workplaces are primarily caused by conveyor belts and occasionally by roller machines. Recognizing such injuries is essential since delayed diagnosis of closed degloving can lead to subsequent secondary infection [4]. DSTIs are associated with high-velocity injuries and have a high risk of contamination that can develop into a secondary infection or even necrotizing soft tissue infection if not managed promptly [5]. Clinical diagnostic indicators and well-established guidelines for the management of DSTIs are lacking; thus, prompt recognition is the first crucial step for a favorable outcome. Treatment can vary from conservative management to multidisciplinary surgical intervention, which may include excision of devitalized tissue followed by primary skin closure, skin graft, flap cover, and/or skeletal fixation to restore meaningful function [1]. Differentiating viable tissue from nonviable tissue can be difficult during the initial presentation since tissues with threatened blood supply become ischemic, and necrosis develops over time [5]. Outcomes vary based on the mechanism of injury, impact type, affected site, type of degloving (open or closed, complete or partial), associated injuries, and in certain polytrauma patients, the necessary prioritization of life and limb. Most available literature focuses on the treatment of DSTIs and does not look into injury patterns, outcomes and disabilities after the management of such injuries, and preventive strategies, if any.

Objectives

In this study, we prospectively studied DSTIs with respect to mechanism, clinical presentation, management, complications, and outcomes based on disability assessments at 3-month follow-ups.

METHODS

Ethics statement

The study protocol was reviewed and approved by the Institutional Review Board of Postgraduate Institute of Medical Education and Research (PGIMER) (No. INT/IEC/2022/000145). Written informed consent was obtained from all patients. The study was conducted in compliance with the principles of the Declaration of Helsinki.

Study design

This prospective observational study was conducted at the academic, tertiary care center of PGIMER (Chandigarh, India) over a period of 15 months. DSTIs were defined as the avulsion of soft tissue (skin and subcutaneous tissue) from the underlying fascia and muscles. In open degloving injuries, torn skin might still be attached as a flap, while closed degloving injuries had detachment of subcutaneous tissue from the underlying fascia with intact overlying skin creating a cavity filled with hematoma (Morrel-Lavallée lesion). In this study, closed degloving injuries were diagnosed by clinical assessment with or without the use of ultrasonography (USG), computed tomography (CT), or magnetic resonance imaging (MRI). The 75 patients with DSTIs, whose ages ranged from 5 to 60 years, were studied prospectively. Patients who presented to the hospital ≥ 72 hours after injury or who received primary treatment elsewhere were excluded. On presentation, all patients underwent thorough assessment and resuscitation according to Advanced Trauma Life Support guidelines. We recorded demographic data; circumstances of the injury including date, time, and mode of injury (traffic accident, industrial accident, domestic accident, fall from height, sports injury); site of the injury; and associated injuries. Baseline evaluation of the patient included a medical history documenting any co-morbidities, a complete physical examination of the part affected, relevant laboratory tests (blood sugar level, coagulation profile, renal function test, hemogram [hemoglobin, platelets, and total leucocyte count]), and relevant imaging studies (x-ray of the affected part and MRI or CT angiography) if clinically indicated. Most open DSTIs were debrided within 24 hours, followed by reassessment after 48 to 72 hours. The type and number of surgical
procedures required were recorded. Postoperative complications and the total length of hospital stay were recorded. Patients were followed up after discharge at 2 weekly intervals for the first month, thereafter at monthly intervals until 3 months. The final outcome and disability were assessed at the 3-month follow-up according to the World Health Organization Disability Assessment Schedule (WHODAS) 2.0 [6].

Statistical analysis
Data analysis was done using IBM SPSS ver. 22.0 (IBM Corp) and Microsoft Excel 2010 (Microsoft Corp). Quantitative variables, including blood sugar levels, hemograms, coagulation profiles, renal function tests, and liver function tests were represented as mean ± standard deviation or median (interquartile range), as applicable. The normality of continuous data was checked by applying the Kolmogorov-Smirnov test. Qualitative variables such as occupation, sex, mode of injury, and site of injury were represented using the chi-square test. The follow-up of patients, including the baseline status at discharge, and the first, second, and third-month check-up was evaluated using a repeated measures analysis of variance test. For any skewed data, the nonparametric Mann-Whitney test was applied.

RESULTS

Preoperative assessment
Of the 75 patients, 60 (80.0%) were male and 15 (20.0%) were female, with ages ranging from 5 to 60 years and an average age of 27.5 years. Twenty-nine (38.7%) were students and 23 (30.7%) were manual workers, while the rest were farmers, drivers, painters, electricians, or plumbers. Traffic accidents were responsible for 57 injuries (76.0%), followed by 10 industrial accidents (13.3%), five domestic accidents (6.7%), two falls from a height (2.7%), and one impact from a falling heavy object (1.3%). Seventy patients (93.3%) had open degloving injuries while five (6.7%) had closed degloving injuries. Lower limbs were most commonly affected (n =47, 62%), followed by upper limbs (n = 24, 32.0%), head and neck (n = 12, 16.0%), perineum (n = 11, 14.7%), and torso (n = 4, 5.3%), while the rest (n = 3, 4.0%) involved the back. Fractures were most commonly associated with the DSTI injury (n = 54, 72.0%), followed by amputation of fingers or limbs and cut tendons (n = 12, 16.0%), traumatic brain injuries (n = 7, 9.3%), and solid or hollow viscus injuries (n = 6, 8.0%). All patients with closed degloving injuries had associated closed fractures; three (4.0%) had trochanteric fractures and two (2.7%) had pelvic fractures. Low-impact injuries (causing soft tissue lacerations) were seen in three cases (4.0%), medium-impact injuries (causing avulsion or fracture along with laceration) were seen in 35 (46.7%), and high-impact injuries (severe crush or amputation) were seen in 37 (49.3%). Characteristics of the patients are shown in Table 1.

Postoperative assessment and follow-up
The treatment received varied according to the type and extent of the degloving and associated injuries (Table 2). All patients were initially resuscitated and subsequently underwent primary debridement. The majority of patients required multiple surgical procedures: secondary debridement in 31 patients (41.3%), split skin grafting (SSG) in 60 patients (80.0%), flap coverage (local or regional) in nine patients (12.0%), revision of amputation in 12 patients (16.0%), tendon repair in four patients (5.3%), and vacu-

Table 1. Characteristics of patients with DSTI (n=75)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>27.5±14.7</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>60 (80.0)</td>
</tr>
<tr>
<td>Female</td>
<td>15 (20.0)</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
</tr>
<tr>
<td>Traffic accident</td>
<td>57 (76.0)</td>
</tr>
<tr>
<td>Industrial accident</td>
<td>10 (13.3)</td>
</tr>
<tr>
<td>Domestic accident</td>
<td>5 (6.7)</td>
</tr>
<tr>
<td>Fall from height</td>
<td>2 (2.7)</td>
</tr>
<tr>
<td>Hit by a falling heavy object</td>
<td>1 (1.3)</td>
</tr>
<tr>
<td>Type of DSTI</td>
<td></td>
</tr>
<tr>
<td>Open</td>
<td>70 (93.3)</td>
</tr>
<tr>
<td>Closed</td>
<td>5 (6.7)</td>
</tr>
<tr>
<td>Associated injury</td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>7 (9.3)</td>
</tr>
<tr>
<td>Fracture</td>
<td>54 (72.0)</td>
</tr>
<tr>
<td>Lower limb</td>
<td>33 (44.0)</td>
</tr>
<tr>
<td>Upper limb</td>
<td>16 (21.3)</td>
</tr>
<tr>
<td>Pelvis</td>
<td>5 (6.7)</td>
</tr>
<tr>
<td>Solid organ or hollow viscus</td>
<td>6 (8.0)</td>
</tr>
<tr>
<td>Amputation of fingers or limbs and cut tendon</td>
<td>12 (16.0)</td>
</tr>
<tr>
<td>None</td>
<td>15 (20.0)</td>
</tr>
<tr>
<td>Anatomic site of DSTI</td>
<td></td>
</tr>
<tr>
<td>Head and neck</td>
<td>12 (16.0)</td>
</tr>
<tr>
<td>Lower limb</td>
<td>47 (62.7)</td>
</tr>
<tr>
<td>Upper limb</td>
<td>24 (32.0)</td>
</tr>
<tr>
<td>Back</td>
<td>3 (4.0)</td>
</tr>
<tr>
<td>Perineum</td>
<td>11 (14.7)</td>
</tr>
<tr>
<td>Torso</td>
<td>4 (5.3)</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation or number (%). DSTI, degloving soft tissue injury.
um-assisted closure (VAC) in 18 patients (24.0%); whereas conserva-
tive management with repeated hematoma aspirations and
compression dressings were performed in five closed degloving
injuries (6.7%). Postoperative complications included surgical
site infections in 11 patients (14.7%), followed by skin necrosis
(n = 8, 10.7%), septic shock (n = 6, 8.0%), and a combination of
skin and flap necrosis (n = 5, 6.7%), and two deaths (2.7%) due to
septic shock and multiple organ dysfunction syndrome (MODS).
Twenty-four patients (32.0%) had no postoperative complica-
tions. The mean length of hospital stay was 11.5 ± 8.1 days, which
varied according to the site and extent of the DSTI injury and as-
associated injuries. DSTIs affecting the head and neck had an aver-
age stay of 10.5 days; lower limbs, 25 days; upper limbs, 5 days;
back, 5 days; perineum, 18 days; and injuries affecting the torso, 7
days (Fig. 1). The number of weeks off from work also varied ac-
cordng to the site and severity of the injuries, as well as postoper-
arive complications. Two patients (2.7%) were unable to work for
2 weeks, 15 patients (20.0%) for 2 to 4 weeks, 30 patients (40.0%)
f or 4 to 8 weeks, 16 patients (21.3%) for 8 to 12 weeks, and five
patients (6.7%) for 12 to 24 weeks. After their injury, 56 patients
(74.7%) resumed their previous job or study, 11 (14.7%) changed
their job, and the remaining six patients (8.0%) stopped working
completely due to the severity of their injuries. Residual disability
at the 3-month follow-up was calculated using the WHODAS 2.0
(0, no disability; 100, highest disability). With a mean score of
19.7 (range, 3.5–68.5), the majority of patients had mild disabili-
ty. By correlating the WHODAS 2.0 scores and the number of
weeks off from work (Fig. 2), we found that, among 53 patients
with mild disability (score, 0–20), 52 (98.1%) resumed their pre-
vious job or study, while only one (1.9%) changed their job. Among
16 patients with moderate disability (score, 21–40), eight
(50.0%) resumed their previous job or study, while the other
eight (50.0%) changed their jobs. Among four patients with se-
vere disability (scores 41–60), only one (25.0%) were able to re-
sume their previous work, while one (25.0%) changed their job,
and the other two (50.0%) stopped working completely. All two
patients with major disability (score, >60) stopped working
completely due to severity of their injuries.

**DISCUSSION**

This single-institution study enrolled 75 patients with DSTIs and
studied their demographic details, injury patterns, management,
outcomes, and disabilities at a 3-month follow-up. The available
literature is largely descriptive with only a few studies reporting
on injury patterns and management. No other study has focused

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of surgical procedures</td>
<td>2.5±1.0</td>
</tr>
<tr>
<td>Treatment received</td>
<td></td>
</tr>
<tr>
<td>Primary debridement</td>
<td>71 (94.7)</td>
</tr>
<tr>
<td>Secondary or revision debridement</td>
<td>31 (41.3)</td>
</tr>
<tr>
<td>Split skin graft</td>
<td>60 (80.0)</td>
</tr>
<tr>
<td>Flap cover (local or regional)</td>
<td>9 (12.0)</td>
</tr>
<tr>
<td>Revision of amputation</td>
<td>12 (16.0)</td>
</tr>
<tr>
<td>Tendon repair</td>
<td>4 (5.3)</td>
</tr>
<tr>
<td>Vacuum-assisted closure</td>
<td>18 (24.0)</td>
</tr>
<tr>
<td>Conservative management</td>
<td>5 (6.7)</td>
</tr>
<tr>
<td>Primary suturing</td>
<td>1 (1.3)</td>
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<tr>
<td>Length of hospital stay (day)</td>
<td>11.5±8.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
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<tbody>
<tr>
<td>Mean length of hospital stay according to anatomical site of the DSTI (day)</td>
<td></td>
</tr>
<tr>
<td>Head and neck</td>
<td>10.5</td>
</tr>
<tr>
<td>Lower limb</td>
<td>25.0</td>
</tr>
<tr>
<td>Upper limb</td>
<td>5.0</td>
</tr>
<tr>
<td>Back</td>
<td>5.0</td>
</tr>
<tr>
<td>Perineum</td>
<td>18.0</td>
</tr>
<tr>
<td>Torso</td>
<td>7.0</td>
</tr>
<tr>
<td>Postoperative complication</td>
<td></td>
</tr>
<tr>
<td>Surgical site infection</td>
<td>11 (14.7)</td>
</tr>
<tr>
<td>Skin necrosis</td>
<td>8 (10.7)</td>
</tr>
<tr>
<td>Skin and flap necrosis</td>
<td>5 (6.7)</td>
</tr>
<tr>
<td>Septic shock</td>
<td>6 (8.0)</td>
</tr>
<tr>
<td>Death</td>
<td>2 (2.7)</td>
</tr>
<tr>
<td>None</td>
<td>24 (32.0)</td>
</tr>
<tr>
<td>No. of weeks off work</td>
<td></td>
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<tr>
<td>2</td>
<td>2 (2.7)</td>
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<tr>
<td>&gt;2–4</td>
<td>15 (20.0)</td>
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<td>&gt;4–8</td>
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<td>&gt;8–12</td>
<td>16 (21.3)</td>
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<tr>
<td>&gt;12–24</td>
<td>5 (6.7)</td>
</tr>
<tr>
<td>&gt;24</td>
<td>7 (9.3)</td>
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<tr>
<td>Postinjury work status</td>
<td></td>
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<tr>
<td>Resumed previous job</td>
<td>56 (74.7)</td>
</tr>
<tr>
<td>Changed job</td>
<td>11 (14.7)</td>
</tr>
<tr>
<td>Stopped working</td>
<td>6 (8.0)</td>
</tr>
<tr>
<td>Disability&lt;sup&gt;a&lt;/sup&gt; at 3-mo follow-up</td>
<td>19.6±15.7</td>
</tr>
<tr>
<td>Mild</td>
<td>53 (70.7)</td>
</tr>
<tr>
<td>Moderate</td>
<td>16 (21.3)</td>
</tr>
<tr>
<td>Severe</td>
<td>4 (5.3)</td>
</tr>
<tr>
<td>Major</td>
<td>2 (2.7)</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation or number (%)
DSTI, degloving soft tissue injury.
<sup>a</sup>Measured using the World Health Organization Disability Assessment Schedule (WHODAS) 2.0 [6].
The mean length of hospital stay was 11.51±8.14 days and varied according to the site and extent of the injury as well as concomitant injuries. DSTIs affecting the head and neck had an average stay of 10.5 days (lower limbs, 25 days; upper limbs, 5 days; back, 5 days; perineum, 18 days; and torso, 7 days).

In our study, the mean age of the affected patients was 27.5 years and 80% were male. This corresponds to other studies that also found young men to be commonly affected [7–13]. The higher prevalence of men affected is due to a disproportionately higher proportion of men as drivers, industrial workers, and farmers. Traffic accidents were responsible for 75% of the total injuries with lower limbs mostly affected. These findings are consistent with other studies that showed a higher association between traffic accidents and DSTIs of the lower limbs [8–11]. Patients with DSTIs affecting the head and neck due to traffic accidents did not have a safety helmet at the time of injury. Preplacement training and the use of protective gear in industries play an important role in the prevention of workplace related injuries [12]. Only three patients (20%) with DSTIs due to industrial accidents had preplacement training. Thus, primary preventive strategies such as preplacement training, road safety protocols, and use of protective gear can theoretically eliminate or decrease the incidence of DSTIs.

DSTIs are serious injuries and often result from high-velocity trauma. The majority of patients in our study had open-type degloving and multiple associated injuries: fractures (72.0%), amputation of fingers or limbs and cut tendon injuries (16.0%), traumatic brain injuries (9.3%), and solid or hollow viscus injuries (8.0%). The presence of fractures, limb amputation, and traumatic brain or abdominal injuries was a surrogate marker for the severity of injury. Although Injury Severity Scores were not calculated in our study, the morbidity and mortality increased with an increase in such associated injuries. Previous studies did not mention associated injuries or the type of DSTI (with one exception [8]), which have a significant impact on treatment planning, outcome, and postoperative disability. Although the number of patients in our study with closed degloving injuries was limited, they were associated with trochanteric and pelvic fractures.

The incidence of DSTIs is unknown due to a lack of clinical diagnostic criteria, variable severity, and the need to prioritize treatments for a polytrauma patient where saving life and limb takes priority. Closed degloving injuries, however severe they may be, can be missed or dealt with after stabilization of the patient. De-
fining the severity of injury prior to treatment is important since the viability of an avulsed flap is critical. Viability assessment by clinical inspection and intravenous (IV) fluorescein have been described; however, the efficacy of IV fluorescein in DSTIs is unknown [13–15]. Thus, clinical examination is the most feasible method, however subjective it may be. Skin and soft tissues with bleeding edges and good capillary refill will most likely survive, while discolored tissue with fixed staining that is non-blanchable on digital pressure, and tissues with thrombosed subcutaneous veins require excision [13–15]. Moreover, the diagnosis of closed DSTIs is difficult since the early subtle changes of bruising or hematoma with an intact overlying skin can mask an underlying fluid collection, which if not recognized and managed promptly can lead to life-threatening necrotizing infections [16]. DSTIs can be diagnosed by clinical examination and/or imaging of the affected part if required [16]. Anechoic and hypoechoic lesions on ultrasound, with or without echogenic foci or even fluid, can indicate closed degloving injuries. However, MRI is the modality of choice for diagnosing closed degloving injuries [16,17].

The management approach for DSTIs following resuscitation and severity assessment can include the preservation of degloved but viable tissue with primary closure, a skin graft with or without VAC, or a flap cover and/or secondary debridement if required [10]. In our center, the majority of open DSTIs are debrided within the first 24 hours, followed by reassessment after 48 to 72 hours. Most can be managed with SSG except for major pelvic and thigh degloving injuries, which require staged tissue reconstruction procedures. In our study, the majority of patients required multiple surgical procedures, including secondary debridement (41.3%), SSG (80.0%), a local or regional flap (12.0%), or VAC (24.0%), whereas 6.7% received conservative management. In a study by Hakim et al. [8], 62.9% of patients were managed with primary debridement, and 19.1% received serial debridement with or without VAC application. Milcheski et al. [9] reported the use of tissue banking for hemodynamically unstable patients, followed by grafting after stabilization. Arnez et al. [10] reported excision of nonviable tissue and flap coverage in two-thirds of patients and skin grafts in 44% of patients. Yan et al. [11] reported incision of the degloved skin with defatting, multiple stab incisions, and securing skin to the recipient bed with sutures. Sakai et al. [18] reported using degloved skin as a full-thickness graft with the use of VAC to secure it. There is reported use of a bilayer dermal regeneration template in DSTIs as well. However, due to the paucity of research, case reports, and analysis of the cost of its use, randomized controlled trials are required to validate its use in the trauma setting [19]. VAC was used in approximately 25% of our patients and showed excellent results as it promotes accelerated granulation tissue and can also be applied over skin grafts [20–22]. In our study, five patients with closed degloving injuries were managed with percutaneous aspiration and compression dressings, which required multiple treatments. A lack of treatment guidelines for closed degloving injuries also makes treatment more challenging. Reported treatment options include observation, compression dressings, percutaneous aspiration, incision and drainage, and debridement [23]. A high incidence of hematoma reaccumulation has been reported after aspiration, and healing by secondary intention is sometimes required [17]. In addition, a higher incidence of concomitant pelvic fractures and traumatic brain injuries increases morbidity and mortality in closed degloving injuries. In our study, the most common postoperative complication was surgical site infection (14.7%), followed by skin necrosis (10.7%). Eight patients presented with septic shock, two of whom died due to refractory septic shock and MODS. One-third of patients in our study had no postoperative complications. A single previous study [8] described a wound infection rate of 3.9% and a skin necrosis rate of 1.1% in patients with DSTI. A higher incidence in our study might be due to differences in the severity and extent of the degloving injuries in the study population.

In this study, outcomes were evaluated by length of hospital stay and degree of disability. The mean length of hospital stay was 11.5 ± 8.1 days with a maximum of 30 days. Extensive DSTIs with associated injuries that required multidisciplinary and staged management required longer admission. The majority of patients who were managed with SSGs were discharged and managed at primary health centers with regular follow-up in our outpatient clinic. This was done to accommodate new patients, since we receive a large influx of trauma patients as a tertiary care center with limited bed availability. Only two published studies have reported a median length of hospital stay as 10 days [8] and 32.5 days [9]. Reasons for this vast discrepancy might include the characteristics of the study population, a study focused on specific anatomic areas or on extensive degloving injuries, and a retrospective study design.

This is the only study to assess postmanagement disability in terms of time off from work and WHODAS 2.0 scores. Overall, 40.0% of patients required 4 to 8 weeks off from work, 20.0% were off for 2 to 4 weeks, and 21.3% were off work for 8 to 12 weeks. A single study [11] mentioned time to ambulation, with >75% of patients without long bone fractures ambulating 4 to 6 weeks postoperatively, while injuries associated with fractures...
took much longer. Disability assessment has not been addressed in previous studies, which might be due to their retrospective nature. The WHODAS 2.0 is used to standardize disability levels and covers six domains of functioning: cognition, mobility, self-care, getting along (interacting with others), daily life activities, and participation in community activities. In our study, disability was calculated at 3 months after the injury, where 0 being no disability and 100 being full disability. The disability scores ranged from a minimum of 3.5 to a maximum of 68.5. The mean score was 19.6 and at 3 months most patients had mild disability. The WHODAS 2.0 scores were correlated with the number of weeks off from work to assess the feasibility and practical application of scoring. Overall, 98.1% of patients with mild disabilities resumed their previous job, while only one changed his job. Half of the patients with moderate disabilities changed their job, while the other half resumed their previous jobs. Half of the patients with severe disabilities stopped working completely, 25.0% changed their jobs, and 25.0% were able to resume their previous work. All patients (100%) with major disabilities stopped working completely.

Limitations
There were certain limitations in this study. The study population was limited to a single tertiary care center to which only the most complicated cases requiring multidisciplinary care were referred, and approximately 50 cases of DSTI that had received primary treatment elsewhere were excluded from our study. The Injury Severity Score was not recorded in our study. The time from admission to operative intervention was also not recorded, since polytrauma patients that require a multidisciplinary approach and multiple surgical specialty evaluations may have an increased time to treatment and therefore may have worse outcomes. The viability of the degloved tissue was not recorded in our study and was left to the discretion of the operating surgeon for planning. There was a limited number of patients with closed degloving injuries. There were wide variations in the mechanism of injury, associated injuries, clinical presentation, and treatment options. Therefore, further studies with larger cohorts are required to study closed degloving injuries, since there is a considerable difference between open and closed DSTIs.

Conclusions
Degloving injuries are common in a trauma setting and their management is challenging. Some of these injuries may be missed during the primary survey as the ongoing resuscitation of a trauma patient revolves around the most urgent life and limb-threatening injuries. Although CT or MRI can detect degloving injuries, these diagnostic modalities are used for other associated injuries rather than degloving in particular. Thus, DSTIs can be missed with imaging as well. These injuries are often associated with high-velocity trauma and have a high risk of contamination, which contributes to an increased risk of secondary infection and necrotizing soft tissue infection if not diagnosed promptly. Furthermore, differentiating viable from nonviable tissues in partial degloving injuries can be difficult during the initial presentation, as the discoloration and necrosis of detached skin take time to evolve. In our study, most patients were male, and the majority of injuries were due to high-velocity trauma in traffic accidents. Open degloving injuries mostly affected lower limbs and were commonly associated with fractures. Closed degloving injuries were diagnosed clinically and radiologically with MRI, followed by percutaneous aspiration and compression dressings. Injuries affecting lower limbs and the perineum had a longer mean length of hospital stay. Disability at 3 months, as calculated by the WHODAS 2.0, found that a majority had mild disability. Nearly 75% of patients resumed their previous job or study, 14% changed their job, and 8% stopped working completely due to the severity of their injuries. Timely surgical intervention can help reduce postoperative complications and promote early rehabilitation, thereby reducing residual disability. Thus, a high index of suspicion with a multidisciplinary approach, a thorough clinical examination, and timely assessment of the affected part are required for treatment. However, because of the gaps in site-specific and severity-specific treatment guidelines that take into account the variability in degloving injuries, evidence-based guidelines and treatment approaches are needed to improve outcomes. Primary prevention strategies such as proper protective equipment, road safety protocols, and preplacement industrial training can help prevent or decrease the burden of such injuries.

ARTICLE INFORMATION

Author contributions
Conceptualization: DJ, AP; Methodology: AP; Supervision: AP, RS; Validation: AP, RS; Visualization: RS; Writing–original draft: DJ; Writing–review & editing: all authors. All authors read and approved the final manuscript.

Conflicts of interest
The authors have no conflicts of interest to declare.
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Data availability
Data analyzed in this study are available from the corresponding author upon reasonable request.

REFERENCES

INTRODUCTION

Patients transported from fire sites may exhibit various injury patterns. Among them, major trauma and skin burns are easy to be detected initially and are familiar to physicians. Carbon monoxide (CO) poisoning and inhalation burns from smoke are relatively less familiar owing to fewer opportunities for treating these types of patients in general hospitals than those in burn centers being specialty hospitals that intensively treat patients with major burns.

However, most physicians may be unfamiliar that cyanide poisoning can occur at the fire site. Cyanide poisoning is highly significant owing to its high mortality and the existence of antidotes. Although the antidote must be immediately administered, it is stored in some dedicated toxicology centers.

Here, I present a case of a patient with cyanide poisoning who was transferred from a burning building and was treated with an antidote. Despite no major bleeding and mild CO poisoning, severe metabolic acidosis was initially shown. Subsequently, the symptoms improved following antidote administration. Airway obstruction and pneumonia occurred following hospitalization and were treated with endotracheal intubation, antibiotics, and steroids. Patients at fire sites can be transferred to regional emergency medical centers, regional trauma centers, burn centers,
toxicology centers, hyperbaric oxygen chamber centers, and local emergency department (ED). At the prehospital stage, determining the kind of injuries the patient suffered and which damage is the most dangerous is challenging; therefore, the patient can be transferred to any of those hospitals. Therefore, to avoid missing treatment opportunities, physicians must be aware of cyanide poisoning.

CASE REPORT

A 35-year-old man with no previous medical history was rescued from a burning building and transferred to our ED at Dankook University Hospital (Cheonan, Korea) by the emergency medical service. At the time of arrival, the paramedics reported that he was suspended from the fourth floor of the building (approximately 10 m) and fell to the ground; therefore, he was brought to the trauma center. Upon initial assessment, the following were his vital signs: blood pressure, 130/70 mmHg; heart rate, 135 beats/min (sinus tachycardia); respiratory rate, 30 beats/min; body temperature, 36 °C; and oxygen saturation, 99%. He was alert but mildly agitated. Second-degree burns of 25% of the total body surface area on both arms and legs and first-degree burns on his face were noted (Fig. 1). Inhalation burn was suspected owing to the soot around his mouth; however, his breathing sound was normal. No external bleeding was observed. Oxygen was supplied, and fentanyl was administered intravenously during the primary survey. Ultrasonography and whole-body computed tomography (CT) scans revealed no bleeding. Arterial blood gas analysis (ABGA) showed severe metabolic acidosis and a high lactate concentration with the following results: pH, 7.099; PaO₂, 241 mmHg; PaCO₂, 29.3 mmHg; HCO₃⁻, 12.6 mmol/L; base excess, −14.3 mmol/L; and lactate, 12.4 mmol/L. The carboxyhemoglobin (COHb) level was 14.1%, which was not too high to perform hyperbaric oxygen therapy. The results were similar to the initial findings at the serial follow-up ABGA approximately 20 minutes later (Table 1).

Approximately 30 minutes following the patient’s arrival, the paramedics who rescued the patient came to the hospital and provided corrected information. The patient was found in his bathroom and did not experience a fall; therefore, major trauma could be excluded. While considering the causes of severe metabolic acidosis, major bleeding and severe carbon monoxide poisoning were excluded; however, the patient was suspected of cyanide poisoning due to combustion. Therefore, the antidote (Cyanokit, Serb Pharmaceuticals) was administered. ABGA 30 minutes following antidote administration showed an improvement; moreover, follow-up ABGA showed an improvement pattern.

To confirm airway injury due to inhalation burn, following antidote administration, an otolaryngologist performed upper airway bronchoscopy; however, no specific injury findings were observed. However, owing to the possibility of pneumonia or airway obstruction, he was admitted to the intensive care unit (ICU) and prescribed steroids and antibiotics. The next day, he complained of sudden hoarseness of voice and difficulty in breathing.

Fig. 1. Second-degree skin burns of the arms and legs. Twenty-five percent of the total body surface area is noted. (A) Right arm. (B) Right leg.
and stridor was heard on auscultation; therefore, emergency tracheal intubation was performed. Immediately following intubation, upper airway bronchoscopy was performed again; however, no signs of airway injury were revealed. Additionally, fever (above 39 °C) and pneumonia developed (Fig. 2). On the 4th hospitalization day (HD), a pulmonologist performed bronchoscopy, and inhalation injury grade 2 (moderate injury) was discovered (Fig. 3). Pneumonia worsened until the 9th HD; however, it showed improvement from the 10th HD. The patient and his guardians opted for the other treatments to be performed at the hospital nearby his hometown; therefore, he was transferred. Afterward, it was confirmed that he was discharged from that hospital 2 weeks later without complications.

Ethics statement
Informed consent was not obtained from the patient because I could not get in touch with him following his discharge from our hospital. However, the Institutional Review Board of Dankook University Hospital approved the study with a waiver of informed consent (No. DKUH 2023-08-029-001).

DISCUSSION

Major trauma, skin burn, inhalation burn, CO poisoning due to fire smoke, and cyanide poisoning are typical injuries caused by combustion. If the accident is an explosion at an industrial company, exposure to toxic materials depending on the type of compound used is possible. Recently, several burn centers are specializing in treating patients with major burns. Conversely, most other hospitals have become very used to providing only initial resuscitation and subsequently transferring patients to burn centers. Consequently, it is possible that various injuries cannot be considered. Although major trauma and skin burns can be easily identified through gross findings and whole-body CT, CO poisoning can be identified relatively simply by checking the COHb level. However, inhalation burn is not readily identified, and it is easy to overlook cyanide poisoning. This case provides us with the following three lessons.

Cyanide poisoning
Cyanide compounds are commonly known as chungsangari in Korea. Cyanide has very high mortality and is quickly absorbed in the body that it has been used as a suicide pill (or spy pill) in the past. In the United States, the gas form of cyanide was used until the 2000s as a means of execution. Even if patients survive, it is known to cause neurological sequelae by leaving serious hypoxic brain damage [1,2]. Cyanide can be produced during combustion, plating, and mining and is also detected in plum pulps, cigarettes, bamboo shoots, cassava, and medicines, including laetrile and nitroprusside [3–6]. The most common situation of cyanide poisoning is during a domestic fire [7]. Tests on survivors of an airplane explosion at the Manchester Airport in 1985 confirmed a significant CO level in approximately 20% of survivors, whereas a significant cyanide level was detected in 90% [8]. Consequently, cyanide poisoning, which is highly dangerous, is known to occur frequently; however, physicians often do not recognize it because it is difficult to confirm it through direct blood tests, and toxidromes are nonspecific. A high suspicion index is required in diagnosis, and only high anion gap metabolic acidosis and high lactate concentration are the available ancillary laboratory tests [9]. Another significant reason of cyanide poisoning is the existence of antidotes. In Korea, the following two types of antidotes are available: Cyanokit and cyanide antidote kit. Cyanokit contains hydroxocobalamin, a precursor to vitamin B12,

<table>
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<th>Pre-antidote</th>
<th>Post-antidote</th>
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<td></td>
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NA, not applicable.

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Fig. 2. Chest x-ray images of the patient. (A) Initial chest x-ray. No pathological lesion is observed. (B) Chest x-ray on the 9th hospitalization day. Pneumonia is observed in both lungs. (C) Chest x-ray on the 10th hospitalization day. Improved status of pneumonia.

Fig. 3. Bronchoscopic findings. Moderate edema and congestion as well as carbon soot deposition are noted. (A) Carina. (B) Left main bronchus.

and is the treatment of choice for cyanide poisoning (Fig. 4) [10,11]. This antidote should be immediately administered owing to rapid cyanide absorption. The problem is that the Cyanokit is classified as an orphan drug; therefore, it is deployed only in 10 dedicated toxicology centers in Korea, and the holding amount is insufficient (an average of three packs per toxicology center), and it is very expensive [12]. The price per pack is ₩2.3 million (US $1,800). Fortunately, no cost is borne by the patient; however, it may have to be moved to a long-distance hospital depending on the location of the fire, and it cannot be supplied to everyone in the event of a large number of patients. Particularly, when hydroxocobalamin was used in the prehospital setting, 41.7% of survival was reported in patients with cardiac arrest [13], which is a significantly higher result than 3% to 10% of survival of cardiac arrest from other causes [14]. Therefore, physicians should be more aware of cyanide poisoning from fire situations. A previous study [11] reported that most burn centers did not administer the proper antidote, and antidotes were unavailable at burn centers in Korea. Is it appropriate to transfer a patient to a burn center following initial resuscitation? In this case, when the patient first visited our ED, it was considered that the cause of metabolic acidosis was bleeding or CO poisoning and not cyanide poisoning. I was convinced of cyanide poisoning only after observing ABGA improvement following Cyanokit administration.

Typical progression of inhalation burns
The second significant point is the typical progression of inhalation burns, as shown in this case. In the ED, the patient's breathing sound was normal, and chest x-ray did not reveal any pathologic findings; however, airway obstruction developed in the ICU the following day, and emergency intubation was required. Moreover, pneumonia developed on the 3rd HD. Recently, inhalation burns are also becoming unfamiliar for most physicians; therefore, it is possible that the patient may be mistaken for being stable only with initial findings in the ED [15,16]. Physicians should be well aware of the possibility of airway obstruction and bacterial pneumonia after several days following the injury. Preemptive endotracheal intubation may often be required [10,17].

The limitation of upper airway examination on inhalation burns
Third, of note, bronchoscopy, which can observe only the upper airway in patients with inhalation burns, has limitations. This patient underwent upper airway bronchoscopy twice, and no pathologic findings were revealed. However, grade 2 injury (moderate injury) was noted at the lower airway tract. Grades 2 to 4 have higher mortality than grades 0 to 1 injuries [18]. In the case of an inhalation burn, lower airway evaluation is required.
Very high temperature air usually damages the structures above the carina, and chemical injury is usually likely to occur in the lower part [19,20]. Furthermore, airway injury appears after several days rather than immediately following combustion, and overall better outcomes are reported in groups that underwent bronchoscopy; therefore, it is necessary to consider during the hospitalization [21–23].

**Conclusions**

In Korea, there are several types of specialty hospitals, including regional emergency medical centers, regional trauma centers (level I trauma centers), toxicology centers, burn centers, and hyperbaric chamber centers. When transferring the patient, which among the centers is the most appropriate to visit? This is not easy to answer as determining which damage is the most serious at the prehospital stage is very difficult, and these centers separately exist in Korea. It is necessary to improve the healthcare system. However, along with the improvement of the system, it is essential to raise physicians’ awareness of these types of injuries. Cyanokit, an orphan drug, can be sent to another hospital by the parcel service following physicians’ request even if it is not a dedicated toxicology center (Fig. 5). The problem is that most physicians are unaware of this process, and certain antidotes should be immediately administered but the time delay is considerable; therefore, it may not be practical or effective. Moreover, if primary physicians are unaware, they may decide on a simple transfer to a burn center without antidotes following initial stabilization although additional treatment may be required. A fire situation can frequently be classified as a disaster, and there may be different rescuers and transferrers in a disaster situation. Therefore, caution is needed as this may lead to initial incorrect information, as in the present case. Patients from fire sites can present at least five types of injuries, and they can be transferred to any ED depending on their severity and location. Therefore, trauma surgeons, emergency physicians, ED doctors, and burn center workers must be familiar with these injuries.
ARTICLE INFORMATION

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

Funding
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Data availability
Data sharing is not applicable as no new data were created or analyzed in this study.

REFERENCES


**INTRODUCTION**

Epidural hematoma (EDH) following head trauma is observed in only approximately 2% of all head injuries [1], yet it carries a high risk of mortality. The clinical presentations of EDH can vary widely in the acute stage. When EDH is diagnosed, an emergency craniotomy may be indicated, depending on the clinical and radiological findings. In cases of supratentorial and infratentorial EDH (SIEDH), which affects both the upper and lower tentorial cavities, even more urgent surgical evacuation may be required. The literature on SIEDH is sparse, consisting only of a few small series. Prompt diagnosis and the application of appropriate surgical techniques are crucial for the rapid and safe management of SIEDH. Herein, we present three cases of SIEDH treated at our institution, employing a range of surgical approaches.

**Keywords:** Hematoma; Epidural; Cranial; Craniotomy; Case reports

**CASE REPORT**

**Case 1**

A 24-year-old man was admitted to the emergency department presenting with cranial trauma following an episode of syncope and a subsequent fall backwards. He was drowsy upon arrival, with a Glasgow Coma Scale (GCS) score of 14, and reported experiencing a headache as well as nausea accompanied by vomiting. Physical examination revealed a contusion on the left occipital region of the scalp. A brain computed tomography (CT) scan showed an acute EDH in the left occipital area extending to the posterior fossa, with detachment of the left transverse sinus (Fig. 1A–C). The patient's headache and nausea were attributed to increased intracranial pressure resulting from the subdural hematoma.
The patient underwent surgery under general anesthesia, positioned laterally. We marked the incision and prepared the surgical site to perform a combined supratentorial craniotomy and suboccipital craniotomy, leaving a bone bridge over the transverse sinus to preserve the sinus (Fig. 2). A hockey stick–shaped scalp incision was made on the occiput, with the vertical limb positioned along the midline, and the upper extent was tailored based on the extent of the supratentorial EDH. A linear fracture was noted on the left parietal bone. The initial craniotomy was performed above the left transverse sinus to expose and evacuate the supratentorial hematoma. The posterior branch of the middle meningeal artery was identified as the source of the bleeding (Fig. 3A, B). Following the removal of the supratentorial EDH with the transverse sinus left intact, we gained access to the infratentorial EDH via the same supratentorial craniotomy (Fig. 4). In the posterior fossa, no active bleeding foci were found, allowing for the comfortable removal of the infratentorial EDH without necessitating a suboccipital craniotomy. The surgical site contained no residual EDH and did not require a dural tenting suture (Fig. 1D).

The patient was discharged 7 days after surgery without exhibiting any neurological deficits or symptoms. No instances of rebleeding occurred after discharge.

**Case 2**

A 50-year-old man sustained a headfirst backward fall from a height of 1.5 m. Upon admission, he presented with a stuporous mental state and a GCS score of 9. A brain CT scan revealed an acute SIEDH with separation of the transverse sinus from the skull (Fig. 5A–C). Sagittal and coronal CT images showed a relatively large volume of SIEDH, likely exerting pressure on the cerebellum and brainstem. This pressure would have contributed to increased intracranial pressure and a reduced level of consciousness.

The patient underwent surgery in the prone position. Given that the transverse sinus had already detached from the skull due to the substantial hematoma, the risk of iatrogenic sinus injury was minimal, even with a combined supratentorial and infratentorial craniotomy. We believed that this approach would not only reduce the duration of the craniotomy but also expedite the identification of the hemorrhage source and facilitate cessation of the bleeding. Consequently, we opted for a single supratentorial and infratentorial craniotomy traversing the sinus. Following a midline incision in the occipital scalp, we executed an occipital bone

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**Fig. 1.** Computed tomography (CT) scans of case 1. (A) Preoperative axial bone-setting CT reveals a linear fracture on the left parietal bone. (B) Preoperative axial CT scan displays the supratentorial portion of the left supratentorial and infratentorial extradural hematoma. (C) Preoperative axial CT scan shows the infratentorial portion of the left supratentorial and infratentorial extradural hematoma. (D) Postoperative axial CT scan reveals no residual epidural hematoma without the need for a dural tenting suture.

**Fig. 2.** Incision and surgical marking indicates the hockey stick–shaped incision. The craniotomy, conducted above and below the transverse sinus (TS), left a thin strip of bone on the sinus.
hematoma in the left temporal convexity, with no evidence of EDH (Fig. 6A). However, within an hour, the patient's mental status deteriorated to a deep drowsy state, with her GCS score decreasing to 12. A subsequent brain CT scan disclosed an acute left sided SIEDH (Fig. 6B, C). Presumably, following the lucid interval associated with EDH, the volume of the SIEDH increased rapidly, leading to a swift decline in the patient's level of consciousness.

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the hematoma (Fig. 3E, F). The craniotomy was performed on the left side, corresponding to the area where the hematoma was most pronounced. A left occipital linear fracture was identified that had not been detected on the CT scan, and the left transverse sinus was pinpointed as the source of the bleeding. Following complete removal of the SIEDH, adequate hemostasis was achieved. The patient's neurological deficits had completely resolved by the day following surgery.

**Ethics statement**

Written informed consents for publication of the research details and clinical images were obtained from the patients.

**DISCUSSION**

The simultaneous presence of EDH in both the upper and lower tentorial compartments is an uncommon occurrence and lacks characteristic clinical symptoms compared to infratentorial EDH. Clinical manifestations of supratentorial EDH may include headache, nausea, vomiting, hemiparesis, and unconsciousness. Conversely, infratentorial EDH can present as neck pain, cranial nerve palsy, and cerebellar dysfunction [5]. However, the lack of clinical signs does not preclude the diagnosis [6].

Infratentorial EDH is typically associated with fracture of the occipital bone [2,4,5,7]. Such fractures may be detected during surgery even if they were not identified on preoperative x-rays or CT scans. Nasi et al. [3] described the sources of bleeding in SIEDH as follows: venous bleeding from bone fractures with diploic bleeding accounts for 50%, injury to the transverse/ sigmoid sinus for 22%, oozing from meningeal venous vessels for 8%, and detachment of the transverse sinus without wall injury for 6%, with the remaining cases being of unknown cause. Due to the venous origin of the bleeding, the clinical manifestations of SIEDH may evolve gradually. However, once the hematoma reaches a critical size, rapid deterioration due to acute brain stem compression can occur, which may be life-threatening.

Surgery is the primary treatment for SIEDH. The surgical approach for the removal of SIEDH has been extensively documented in the literature. Several authors have recommended a combined supratentorial and suboccipital craniotomy, preserving a bone bridge over the transverse sinus to provide an anchor for dural tenting sutures [3–5]. An alternative method involves accessing the posterior fossa EDH via a supratentorial craniotomy, using suction to navigate between the sinus and the cranium, as demonstrated in our first case [2]. From our experience, this latter technique is safe and can be executed more rapidly in instances where the transverse sinus is intact. Furthermore, we observed that even in the absence of dural tenting sutures, no residual EDH was left at the surgical site, nor was there any subsequent rebleeding. In situations like our second and third cases, where the SIEDH is predominantly located in the supratentorial space or the bilateral transverse sinuses are substantially separated from the skull due to the size of the SIEDH, the hematoma can be removed easily, safely, and swiftly through a single, extensive supratentorial and infratentorial craniotomy (Fig. 3). Ultimately, the challenge in SIEDH surgery lies in balancing the need to avoid iatrogenic injury to the transverse sinus, creating space for dural tentorium sutures to prevent residual EDH, and reducing intracranial pressure by promptly removing the hematoma. Drawing from our experience with a series of cases, we propose the following surgical guidelines for SIEDH:

(1) If the volume of SIEDH is relatively small and the patient has not developed increased intracranial pressure (ICP), it is appropriate to perform a combined supratentorial and
suboccipital craniotomy while preserving a bony bridge over the transverse sinus.

(2) If the SIEDH is massive and necessitates rapid decompression due to IICP, performing a single large supratentorial and infratentorial craniotomy is advantageous.

(3) When performing a single large supratentorial and infratentorial craniotomy, the extent of the craniotomy should not exceed the area of the transverse sinus separated by the hematoma, in order to prevent iatrogenic injury to the sinus.

(4) When conducting a single large supratentorial and infratentorial craniotomy, it is considered safe to position the central part of the craniotomy at the site where the hematoma is thickest.

In cases involving a large SIEDH, surgeons must exercise extreme caution to avoid damaging the sinus. Proactively organizing blood transfusions during the surgical preparation phase can be immensely beneficial in the event of an emergency. While some researchers advocate for conservative management of small, noncompressive hematomas, it is crucial to ensure meticulous clinical and radiological monitoring [4].

The reported overall mortality rate for SIEDH is approximately 4%, with 92% of patients experiencing a favorable prognosis following surgical intervention [3]. Timely diagnosis and the application of appropriate surgical methods are crucial for the swift and secure management of SIEDH [8]. Additionally, it is important to recognize that larger SIEDH cases are often correlated with substantial blood loss.

ARTICLE INFORMATION

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

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

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Data availability
Data sharing is not applicable as no new data were created or analyzed in this study.

REFERENCES

Expediting venous drainage in large anterolateral thigh flaps for scalp electrical burns in India: two case reports on the use of primary vein grafts for second vein anastomosis

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INTRODUCTION

High-voltage electrical burns of the scalp can result in large areas of skin loss and the exposure of skull bones. The nature of the thermal insult implies the possibility of full-thickness skull bone loss with a risk of dural infection and future calvarioplasty. The probability of multiple burn sites and other injuries consequent to a high-voltage electrical injury may preclude the ideal of primary debridement and definitive flap coverage, as treating these other problems may be potentially lifesaving.

Free flaps are a single-stage solution for adequate wound coverage. Historically, muscle flaps (especially the latissimus dorsi) were preferred, but the availability of the anterolateral thigh (ALT) flap has allowed the replacement of lost skin with skin, which would also be advantageous for second-stage calvarial reconstruction where indicated.

We present two such clinical situations where the elective use of an interposition vein graft from the second accompanying vein of the ALT flap to a second recipient vein in the neck enabled complete flap survival.

CASE REPORT

Case 1
A 25-year-old man sustained a high-voltage electrical burn at work 6 months earlier, with approximately 25% mixed thermal burns involving the back, gluteal region, face, neck, and scalp. He lost vision in both eyes. He underwent primary management with debridement and airway support with a tracheostomy, followed by split-skin grafting of raw areas over the neck, right
hand, and forearm. He was referred with a large area of scalp skin loss with exposed dead calvaria. Both eyelids on the right side were destroyed. The left lower eyelid was present, and since there was some perception of light, a future keratoplasty was planned. On examination, a 19 × 16-cm area of scalp was bereft of skin, extending from the bregma to the root of the nose anteroposteriorly and from one temporal line to the other transversely (Fig. 1). The exposed frontal and temporal bones were desiccated.

Under general anesthesia, the margins of the wound were freshened (Fig. 2A), the dead frontal bone was removed without any dural breach (Fig. 2B), and the supraorbital bandeau was retained after burring the surface. A 22 × 18-cm ALT flap was planned from the right thigh to permit inset into unscarred skin (Fig. 2C). Because the lesser scar was on the right side, the right superficial temporal vessels were chosen as the recipient. The flap was a musculocutaneous type with one artery and two accompanying veins. Since there was only a single superficial temporal vein, the other flap vein was anastomosed to the external jugular vein in the neck by using a 17-cm great saphenous vein interposition graft electively (Fig. 2D). The flap was inset around all edges of the freshened skin defect, and the anterior edge of the flap on the left side was sutured to the lower lid remnant margin.

Subsequently, the patient underwent three sittings of flap thinning and adjustment. A further attempt was made to recreate a semblance of the left upper eyelid to permit future keratoplasty (Fig. 3).

At the 3-year follow-up, he was provided with a wig to conceal the alopecic flap as well as dark glasses. The keratoplasty was not

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Chawaria et al. ALT flaps in scalp electrical burns

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Fig. 1. High-voltage electrical burn of the scalp with exposed dead frontal bone (case 1). (A) Vertex view showing dead frontal bone. (B) Complete loss of both eyelids. (C) Right lateral view. (D) Left lateral view with scar over region of temporal vessels. The patient provided written informed consent for publication of the clinical images.

Fig. 2. Images of case 1. (A) The debrided wound. (B) The dead frontal bone. (C) The harvested flap. (D) The vein graft for the second vein of the anterolateral thigh flap.
successful, but he is presently able to move around with a walking aid for the blind and has been trained in Braille to permit him to seek a job (Fig. 4).

Case 2
A 33-year-old man sustained a high-voltage electrical burn to the scalp and upper limb 7 months earlier. He also sustained a spinal injury with his fall from the overhead transformer, which was treated conservatively and resulted in mild weakness of both lower limbs and an altered gait. He was referred with a 14 × 22-cm scalp skin defect and exposed dead calvaria (Fig. 5).

The resected full-thickness calvaria consisted of the superior frontal bone, both temporal bones, and both parietal bones (Fig. 6A, B). Although there was no dural breach, dural hitching sutures were used around the entire defect after debridement. The ALT flap was harvested from the right thigh, as exploration of the left thigh was negative for a suitable perforator (Fig. 6C), and anastomosis was done to the superficial temporal vessels. The second venous anastomosis was done to the ipsilateral common facial vein in the neck using a 12-cm cephalic vein interposition graft primarily (Fig. 6D). The flap was completely inset with a split-skin graft applied over the recipient pedicle to prevent compression. The incision in the neck was closed primarily.

We scheduled a follow-up of not more than 9 weeks for this patient, at which time the flap was found to be completely viable, and all donor and recipient wounds were healed (Fig. 7). The patient discontinued follow-up, likely because he was from a broken home with multiple socioeconomic issues.

In both cases there was no reexploration, no loss of vascularity in any part of the flap, and no infection. The second case had a 15-mL seroma under the flap, detected on the 9th day and drained under local anesthesia with no further consequence. In

Fig. 3. Appearance after second flap thinning in case 1. (A) Frontal view. (B) Vertex view. (C) Left lateral view. (D) Right lateral view. (E) Right oblique view. (F) Left oblique view. The patient provided written informed consent for publication of the clinical images.
both cases, a split-skin graft for the large donor defect was harvested from the opposite thigh to expedite uneventful healing.

**Ethics statement**

Written informed consents for publication of the research details and clinical images were obtained from the patients.

**DISCUSSION**

McLean and Buncke [1] and Chavoin et al. [2] described the earliest use of free flaps for scalp electrical burns using the superficial temporal vessels. The omentum was used in one case by McLean and Buncke [1], and Chavoin et al. [2] used groin flaps in two cases after preliminary debridement. The superficial temporal vessels were used as recipient vessels.

In 1994, Shen [3] presented six cases of electrical burns of the scalp, for which musculocutaneous latissimus dorsi flaps were used, and the author cited a preference for the neck vessels as they were away from the zone of thermal trauma. Though the article does not state explicitly whether two veins were anastomosed, it mentions the use of vein grafts to neck veins in two of six cases.

Lutz et al. [4] described 30 scalp reconstructions, four of which were for large electrical burns (120–420 cm$^2$). One of those four reconstructions failed because of venous congestion. The superficial temporal vessels were the vessels of choice, but the series had three cases where vein grafts had to be used, presumably for venous anastomosis.

Imanishi et al. [5] highlighted the lack of consistency in the nomenclature of veins in the temporal region. There is the superficial temporal vein as well as deep veins (the latter being of small caliber), which do communicate with each other.

The need to avoid using the superficial temporal vessel as the recipient vessel in five moderate scalp defects compelled Hashem and Al Qattan [6] to artificially lengthen the pedicles of the rectus abdominis and latissimus dorsi flaps to enable anastomosis with neck vessels and avoid the use of vein grafts.

Calikapan et al. [7] reported a series of seven consecutive cases with simultaneous duraplasty in four. They specified the use of the two concomitant temporal veins and the need for a vein graft to the neck veins in one case with postoperative venous congestion.

Forty-five free flaps, specifically referring to the use of the superficial temporal vessels as recipient vessels, were first reported by Hansen et al. [8], 19 of which were for scalp defects with an average defect size of 140 cm$^2$; none were ALT flaps. They saw

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**Fig. 4.** Appearance after rehabilitation at 30 months with the use of a camouflaging wig (case 1). (A) Frontal appearance. (B) Dark glasses. (C) Wig to enable social acceptance. (D) He is able to independently navigate using a stick. The patient provided written informed consent for publication of the clinical images.

**Fig. 5.** Exposed frontal and parietal bones and large skin defect (case 2).
that three of 43 flaps had a > 2:1 discrepancy in vein size and elected to use the retromandibular, external jugular, or contralateral facial vein; the latter two cases needed vein grafts. Interestingly, they made a distinction between the superficial temporal vein and the venae comitantes of the superficial temporal artery.

Use of the superficial temporal vein remains a matter of debate. Ausen and Pavlovic [9] stated that the course of the superficial temporal vein is not as predictable as the artery and often does not follow the artery except in the most proximal portion. Whereas the artery almost always bifurcates into two major branches, the vein presents more anatomical variability; it may remain as one vessel or divide into two or three major branches. Therefore, when the two venae comitantes are being Anastomosed, it is very likely that the proximal drainage is into the same vein.

Sudirman et al. [10] reported an interesting use of the retrograde and antegrade limbs of the superficial temporal vessels in a cohort of 60 patients with recurrent reconstructions following tumor excisions in the presence of frozen neck. The retrograde route was preferred over the antegrade when the flow or drainage was inadequate and relied on anastomosis across the midline of the scalp. They reported no statistical significance in loss of flap regardless of the direction of the anastomosis. All defects were in the middle or upper third of the face and ALT flaps were used in most cases.

Maricevich et al. [11], in a systematic review of more than 3,000 cases, reported an increased risk of free flap compromise and loss with the use of vein grafts (7.4% vs. 3.4%). Despite this statistic, they found that eight of 16 such failures were not directly related to the technical use of vein grafts but were caused by other factors such as dressing pressures and tracheostomy ties. Furthermore, they agreed that the use of such a vein graft is likely to be of benefit in large free flaps for scalp reconstructions where the superficial temporal pedicle was questionable.

In 2019, Daya and Pillay [12] used this concept to perform double venous anastomosis for the cut ends of the superficial
temporal vein in six cases of facial and temporal defects, with no complications.

Kumbla and Myers [13] described the empiric use of a preliminary arteriovenous loop with the superficial temporal vessels in two stages for a large post–neoplasia excision scalp defect needing a latissimus dorsi flap. They justify the use of vein grafts to overcome the issue of arterial spasm, especially in the setting of prior radiation to the area.

The availability of the distal end of the superficial temporal vein and putative drainage pathways across the midline may not be a given in the setting of large scalp defects. We believe that large flaps as described in our report need the anastomosis of a second vein to eliminate any chance of postoperative venous compromise. The anatomical compulsion of a single sizable superficial temporal vein forces the surgeon to opt for a second venous anastomosis using the veins in the neck, even at the cost of adding an interposition graft.

The debate over a single versus double venous anastomosis continues. It is pertinent that in a meta-analysis by Chapat et al. [14] of 16 articles and 3,684 flaps with an overall success rate of 96.15%, they reported a failure rate of 1.51% in the group with two anastomoses versus 5.03% in the group with single anastomoses. There were also more surgical revisions in the single venous anastomosis group (11.87%) than in the double anastomoses group (6.04%). They further stated that, since the ALT flap does not offer the luxury of a superficial and deep venous system like the radial forearm or the deep inferior epigastric artery flap, performing a second venous anastomosis for the ALT flap is mandatory.

In conclusion, the reconstruction of large scalp defects following electrical burns has improved with the advent of the ALT flap. Using the superficial temporal vessels permits optimal flap size and reach for defects that reach from ear to ear. Since the superficial temporal vessels do not consistently allow a second venous anastomosis, primary vein grafts from the second venae comitantes to neck veins ensure a favorable flap outcome.

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**Data availability**
Data sharing is not applicable as no new data were created or analyzed in this study.

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3618–23.
Radiological assessment and follow-up of a nonsurgically treated odontoid process fracture after a motor vehicle accident in Egypt: a case report

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INTRODUCTION

Motor vehicle accidents are a leading cause of death and severe organ injuries worldwide. Odontoid fractures, which typically occur in the C2 vertebra, are common injuries across various age groups, particularly among the elderly. This type of fracture often results from injuries such as falls that force the head into hyper-extension. The most common symptom is neck pain, though neurological deficits may also occur, depending on the degree of displacement and cord injury. Less frequently, other associated pathologies such as cardiac arrest may occur [1–7]. Computed tomography (CT) scans are the primary imaging modality for diagnosing spinal fractures. If a cord injury is suspected due to associated neurological deficits, an magnetic resonance imaging (MRI) is recommended [2–8]. A type II odontoid fracture may also be associated with a loss of joint stability, known as "atlanto-axial dislocation," between the atlas (C1) and axis (C2) [3–9].

CASE REPORT

On February 13, 2016, a newlywed 25-year-old woman was traveling with her husband on a highway with a maximum speed limit of 120 km/hr. However, their car was moving at a speed exceeding 170 km/hr when the left front wheel suddenly burst. The driver immediately applied the brakes, causing the large van to spin in the air at a high speed. This resulted in most of the 14 pas-
sengers being ejected through the car windows due to the centrifugal force. After the car came to a halt on the side of the road, only the driver, her husband, and one other passenger remained inside the vehicle. The rest of the passengers were scattered over a considerable distance on both sides of the road. The woman fell from a significant height, landing headfirst onto the hard surface of the road.

The patient was transported by ambulance to Qena General Hospital (Qena, Egypt), where initial first aid measures were administered. Subsequently, the patient was transferred to Sohag University Hospital (Sohag, Egypt). The patient presented with severe neck pain and a large, contused wound on the scalp, located at the sagittal midline of the head. Despite these injuries, the patient was fully conscious and exhibited normal vital signs. The abdomen was lax, and aside from a few minor abrasions on both upper limbs, no other injuries were detected. There was no evidence of a neurological deficit.

Imaging investigations were conducted. Abdominal ultrasonography was performed, revealing no collections or injuries to the abdominal organs. A nonenhancing multislice CT scan of the head and neck was also carried out, including sagittal, coronal, and three-dimensional reformatted images (Figs. 1–3). This scan revealed a complete fracture of the odontoid process at its base, the site of connection between the dens and the C2 vertebral body, with no displacement. No other injuries or fractures were detected. The CT scan of the brain was normal. Although MRI would be crucial for assessing this case, it was not performed due to the absence of neurological deficits.

An external neck collar was utilized for temporary fixation until a treatment plan could be determined. Some orthopedic surgeons favored internal fixation using a screw. Others recommended nonsurgical external fixation with a Minerva orthosis device, as depicted in Fig. 4. Ultimately, the decision was made to use this device. The patient was discharged with the device in place, which was prescribed for a minimum of 3 months’ use. The patient took medications to promote bone formation, although the specific type was not disclosed to us.

A few weeks after the accident, the patient discovered she was pregnant. This made repeated follow-up CT scans both limited and potentially harmful to the integrity of the pregnancy. Three months later, with the detailed consent of the patient and her husband, a follow-up CT scan was deemed necessary to evaluate the case. The scan would determine whether the external fixation was effective and if the healing process had occurred, or if alternative surgical treatment would be required. To minimize radiation exposure, the CT scan was performed with very limited cut sections and the patient's abdomen and pelvis were covered with multiple layers of protective lead aprons. The CT scan revealed that complete healing had occurred with very minimal tilting to the left (Figs. 5, 6). The patient began gentle physiotherapy until she fully recovered, eventually returning to her work as a civil engineer. A few months later, in December 2016, she gave birth to her first child, who was completely healthy. The child, now approximately 6 years old, began preschool last year.

Fig. 1. A computed tomography scan of the cervical spine in a coronal reformatted view. The image clearly shows a complete fracture at the base of the odontoid process (C2).
Fig. 3. A sagittal reformatted computed tomography scan of the cervical spine. (A, B) The images reveal the previously described complete, irregular fracture at the base of the odontoid process (C2).

Fig. 4. Minerva orthosis, an external support device used in patient treatment. The image demonstrates the correct method of application for this device during use.

Ethics statement
The patient and her husband provided written informed consent for publication of the research details and clinical images. No personal data or photos were used.

DISCUSSION
An odontoid process fracture, also known as a peg or dense fracture, typically results from high-force trauma to the head and neck, such as injuries sustained in swimming pool accidents or motor vehicle collisions. There are three types of this fracture (Fig. 7). Type II fractures (as observed in our case study) have the highest rate of nonunion due to their increased propensity for displacement. CT and MRI are the primary imaging modalities for diagnosing spinal fractures in general, and odontoid process fractures in particular. X-rays have a limited role in diagnosis due to the need for special positioning, which can exacerbate the injury through further dislocation and associated cord injury. Early diagnosis is crucial, as a delayed diagnosis often leads to poor outcomes. Patients with an odontoid process fracture are susceptible to either neurogenic or cardiopulmonary shock [1–6]. Various internal stabilization techniques have been described for odontoid fractures, including screw fixation and instrumented fusion. More recently, temporary atlantoaxial stabilization with an absorbable suture has been reported as an alternative surgical treatment. However, for the majority of cases, external stabilization using a Minerva orthosis remains the preferred treatment method. Our study strongly aligns with the experience of Razii et al. [2], suggesting that even patients with a fracture pattern showing significant angulation can be successfully managed conservatively.

Atlantoaxial dislocation accompanied by an odontoid fracture is a rare condition that carries a high risk of fatal complications. These complications are the primary reasons for surgical intervention [3]. According to Anderson and D’Alonzo classification, type II and III odontoid fractures are best treated with anterior fixation in selected patients. Odontoid screw fixation provides direct stabilization of the fracture. The choice of surgical treatment depends on various factors, including anatomical, clinical, and laboratory considerations. Some patients have specific diameters
that preclude the introduction of a second implant within the odontoid process, necessitating careful preoperative planning [4]. Taher et al. [5] reported successful management of a displaced odontoid synchondrosis fracture using temporary C1–2 instrumentation. This innovative approach to managing odontoid process fractures in children preserves cervical biomechanics and range of motion. However, it is still a surgical treatment and carries all the associated risks. Even with these risks, surgical treatment remains necessary if attempts at nonsurgical external fixation fail [5–9].

Our case report and literature conclude that type II fractures are the most dangerous and have the highest incidence of non-union. CT is the preferred method for diagnosis and follow-up, as it can assess whether complete bone union has occurred with nonsurgical external fixation. This approach completely avoids exposing the patient to the risks of surgery, even when the patient is pregnant, a condition that can impede fracture healing. Unless there is a compelling surgical indication, such as the need for decompression due to encroachment on the spinal cord, this case study suggests that it is preferable to give patients with odontoid process fractures the opportunity to heal through external fixa-
tion before resorting to surgical internal fixation. Follow-up CT scans can then be used to monitor the healing process.

ARTICLE INFORMATION

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

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Data availability
Data sharing is not applicable as no new data were created or analyzed in this study.

REFERENCES


INTRODUCTION

Blunt intrathoracic tracheal injuries are rare, even among blunt chest trauma patients. An early diagnosis based on a high index of suspicion allows for timely surgical management of potentially fatal airway trauma, thereby improving overall outcomes. Diagnosing these injuries can be difficult due to their nonspecific clinical features and the occasional difficulty in radiologic diagnosis. If a patient exhibits respiratory compromise with difficult ventilation and poor lung expansion, despite the insertion and management of an intercostal drain following high-energy blunt trauma, there should be a heightened suspicion of potential airway trauma. The aim of primary repair is to restore airway integrity and to minimize the loss of pulmonary parenchyma function. This case report discusses the rare clinical presentation of a patient with blunt trauma to the intrathoracic airway, the surgical management thereof, and his overall outcome. Although blunt traumatic injuries of the trachea are extremely rare and often fatal, early surgical intervention can potentially reduce the risk of mortality.

Keywords: Blunt intrathoracic tracheal trauma; Blunt chest trauma; Tracheal trauma; Case reports

A rare and unique experience of a blunt intrathoracic traumatic injury of the trachea and its management in South Africa: a case report

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Blunt intrathoracic tracheal injuries are rare, even among blunt chest trauma patients. Its diagnosis is often delayed due to nonspecific symptoms, and it can have potentially devastating consequences [1]. Karmy-Jones and Wood [2] estimated the incidence of tracheobronchial injuries among blunt trauma patients to be approximately 0.5% to 2% based on clinical and autopsy reports but emphasized that the true incidence is difficult to determine since most studies combined penetrating and blunt cases. In a review of 1,178 blunt trauma autopsy reports [3], the incidence of tracheobronchial rupture was 2.8% and 81% of these patients died before reaching the hospital. For those patients who reach the hospital, mortality is still high: in a retrospective study comprising 265 blunt trauma cases [4] 26% of the patients with ruptures of the trachea died despite hospital treatment, while another retrospective review article comprising over 200 blunt tracheobronchial injury cases [5] found a mortality rate of up to 30%.
High-energy trauma with abrupt compression, deceleration, or shearing forces can injure trachea, usually within 3 cm of the carina [1,4,6]. Signs and symptoms include dyspnea, hemoptysis, and subcutaneous emphysema, but the clinical findings are non-specific, and up to 10% of patients that have blunt intrathoracic tracheal trauma have no radiographic or physical evidence of the injury on their initial presentation [1]. The median time to diagnosis in blunt thoracic tracheal trauma has been reported to be 72 hours [4]. A high index of suspicion is crucial in order not to miss these injuries, as the mortality rate is reported to be up to 30%, but the functional outcome is generally good with early diagnosis and surgical repair [1,2,4,5,7]. Primary repair with suturing of the injury is the mainstay of surgical treatment, and intrathoracic tracheal injuries near the carina are approached via a right posterolateral thoracotomy [1,8,9].

As rare as this type of injury may be, the outcomes may be improved with early surgical intervention if there are indications noted on imaging, respiratory compromise with difficult ventilation, and poor lung expansion despite intercostal drain (ICD) insertion and management [1,6]. This case report discusses the rare clinical presentation of a patient with blunt trauma to the intrathoracic airway, the surgical management thereof, and his overall outcome.

CASE REPORT

Presentation
A 60-year-old man was found lying in a park, presumably assaulted with blunt objects to the torso and back. At the time of arrival, no known comorbidities were reported, but he was later diagnosed with smoker’s bullous lung disease. Paramedics found him and transported him to a primary health care facility, where he presented with a Glasgow Coma Scale (GCS) score of 7 out of 15. A pneumothorax was identified on a chest x-ray (CXR), and a right ICD was inserted. The patient was then transferred to a trauma emergency unit. Upon examination, he was found to have subcutaneous emphysema extending from the neck down to the scrotum and both arms. His vital signs were as follows: oxygen saturation of 96% on a fraction of inspired oxygen (FiO₂) of 0.5, blood pressure of 134/82 mmHg, and a pulse of 102 beats/min. An arterial blood gas analysis revealed a pH of 7.30, PCO₂ of 68, PO₂ of 92, lactate of 1.6, base excess of –1.1, bicarbonate of 24.1, hemoglobin of 13.3, and potassium of 4. Based on clinically reduced breath sounds detected on auscultation, a left ICD was subsequently inserted. Due to the patient’s low GCS score, he was intubated in the emergency department of the trauma unit without immediate complications.

Imaging
The CXR revealed a significant amount of subcutaneous emphysema, a massive right pneumothorax with an ICD in situ, and a small left pneumothorax, also with an ICD in situ (Fig. 1). The computed tomography (CT) pan-scan showed notable surgical emphysema, tracking inferiorly along the anterior and lateral abdomen and flank, and extending into the scrotum and anterior thighs. There was a tracheal injury at the level of T3 to T4, which was complicated by extensive surgical emphysema and pneumomediastinum (Figs. 2, 3). Multiple rib fractures were present, accompanied by associated lung contusions, and a collapse of the right middle and lower lobe of the lung.

Surgery
The decision to proceed with surgery was made after the CT scan, without conducting further investigations such as bronchoscopy. The patient gave consent for surgery. In the operating room, the patient was placed in the left lateral position. A right 4th intercostal space posterolateral thoracotomy was performed. A disruption and laceration of the right lateral tracheal cartilage was noted at the T3 to T4 level, spanning over two cartilage rings in an oblique line of 1.5 cm. The visceral pleura remained intact over the injury, with the right lung poorly expanding. The injury was repaired using absorbable braided 3-0 sutures. The lung was

Fig. 1. Preoperative chest x-ray of a patient with blunt tracheal trauma, showing massive subcutaneous emphysema, bilateral pneumothorax with bilateral intercostal drains, and the intubation tube in situ.
then reexpanded and inflated. It was noted that the patient had bullous lung disease. Upon completion of the surgery, an arterial blood gas test was performed on the table with a FiO\textsubscript{2} of 0.4. The results were as follows: pH of 7.37, PCO\textsubscript{2} of 44, PO\textsubscript{2} of 202, lactate of 0.9, base excess of –0.1, bicarbonate of 24.9, hemoglobin of 11.6, and potassium of 4.0. The patient was then transferred to the ward, as no intensive care unit beds were available. The patient was ventilated and did not require inotropic support.

**Postoperative**

The patient was ventilated in the ward for 10 days. The initially high ventilation pressures were reduced, and nosocomial respiratory sepsis was managed with empiric antibiotics, despite no growth in cultures. Nasogastric tube feeds were initiated, along with thromboprophylaxis and chest physiotherapy. On the 11th postoperative day, the patient was extubated, maintaining saturation on nasal prong oxygen at a rate of 2 mL/hr. The ICD was removed first on the left, then subsequently on the right, resulting in good lung expansion. Chest physiotherapy was conducted twice daily.

**Ethics statement**

This study was approved by the University of Witwatersrand Human Research Ethics Committee (No. M230288). Written informed consent for publication of the research details and clinical images were obtained from the patient.
DISCUSSION

As demonstrated by this case, early diagnosis is a prerequisite for the appropriate and successful treatment of tracheal rupture [6]. In keeping with previous reviews, primary repair of the trachea is adequate if the anatomy can be restored [9]. The respiratory complications of sepsis were treated accordingly when the indications arose, and this avoided further morbidity associated with such injuries [10,11]. The patient’s background of smoking and bullous lung disease predicted a longer or protracted recovery and the need for ventilatory support; however, the prognosis and outcome were still favorable and acceptable [2].

The majority of blunt intrathoracic tracheal injuries result from motor vehicle accidents or crush injuries [3–5]. Typically, the development of shearing forces at fixed points, such as the carina, during abrupt deceleration, or when the chest is compressed along its anteroposterior axis may explain why up to 80% of the injuries are found within 2 to 3 cm from the carina [2,4,7]. The tracheal cartilage may be disrupted, or sagittal tears may occur, with 8% presenting as complex injuries [1]. The related injuries seen with intrathoracic tracheal injuries after a high-energy impact are clavicular, sternal, and multiple rib fractures and lung contusions [1,5].

The signs and symptoms are mostly nonspecific, making the diagnosis challenging [1,6]. Tracheobronchial injuries in cases of blunt trauma are not immediately diagnosed in 25% to 68% of patients, and the median time to diagnosis of intrathoracic tracheal injury has been presented to be 72 hours [4]. Clinically subcutaneous emphysema is the most commonly occurring sign, and a large air leak and the inability of the lung to reexpand once an ICD is placed is indicative of these injuries, especially when there is a breach to the connective tissue around the trachea [1,12,13]. The diagnosis may be confirmed via imaging in the form of a plane CXR, neck and chest CT, or bronchoscopy [1,6]. The CXR may show pneumothorax, pneumomediastinum, subcutaneous emphysema and bony thoracic fractures. Radiolucent shadow along the anterior aspect of the spine, called “deep cervical emphysema,” should imply the possibility of tracheobronchial injury [1]. Findings suggestive of tracheal injury in CT are gas dispersion around the injury and bronchial lumen stenosis or displacement, but the radiologic diagnosis might still be challenging, raising the importance of clinical suspicion [6]. If the diagnosis remains unclear, bronchoscopy should be performed [1,2,6].

Intrathoracic tracheal injuries may be treated conservatively if the injury is less than 2 cm or less than one-third of the diameter of the trachea, there are no other injuries (e.g., to the esophagus), air leakage can be adequately controlled with the placement of ICD (i.e., there is expansion of the lung and no worsening subcutaneous emphysema), and there is no hemodynamic or respiratory compromise [1,6]. Additionally, the indications for surgery include the need to close a defect to improve ventilation and to avoid complications of spontaneously healed injuries that may result in stenosis or recurrent respiratory infections [14]. Tracheostomy is no longer routinely performed in airway trauma, especially if endotracheal intubation is achievable [4,15]. Intrathoracic tracheal injuries should be approached via a right thoracotomy in the 4th intercostal space [2,6,7]. Most injuries can be repaired by simple interrupted sutures or debridement and end-to-end anastomosis [1,2].

The overall mortality rate has been reported to be up to 30%, but when the diagnosis and surgery are done early after the injury, the long-term outcome is acceptable for 90% of patients [1,2,4–6]. Most instances of morbidity and complications are related to sepsis and long-term recovery [10,11]. Undiagnosed and untreated blunt intrathoracic tracheal injuries are usually followed by problems related to fibrosis and stenosis [1].

An early diagnosis, guided by a high index of suspicion, enables potentially fatal airway trauma to be managed surgically in a timely manner, thereby improving overall outcomes. The primary goal of repair is to restore the integrity of the airway and minimize the loss of pulmonary parenchyma function. Imaging modalities such as CXR, bronchoscopy, and CT scans can aid in identifying the extent of the injury, confirming the diagnosis, and facilitating surgical planning. Therefore, despite the extreme rarity and high mortality rate of blunt traumatic tracheal injuries, early management with surgical intervention may reduce the mortality rate.

ARTICLE INFORMATION

Author contributions
Conceptualization: all authors; Methodology: all authors; Investigation: all authors; Writing–original draft: all authors; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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**REFERENCES**

INTRODUCTION

This is the first case report highlighting the management of a trauma patient who sustained a significant impact and resultant trauma from a bean bag. Given the significant trauma from the ballistic, the patient required a thoracotomy for definitive management to prevent future infectious complications or erosion into surrounding structures. To our knowledge, this is the first case report describing this outcome for a drag-stabilized bean bag.

CASE REPORT

A 49-year-old man with no significant past medical history presented to our level I trauma center (Atrium Health Wake Forest Baptist, Winston-Salem, NC, USA) after sustaining injuries in an
altercation with local law enforcement in which he was shot with a "less lethal" bean bag and tased. Upon arrival, a primary survey revealed an intact airway, bilateral breath sounds, and a normotensive blood pressure. His Glasgow Coma Scale score was 13, and exposure revealed a penetrating left supraclavicular wound in addition to a taser dart lodged in his flank. A chest x-ray examination in the trauma bay showed a penetrating injury to the left upper chest, with the bean bag projectile retained in the left upper lobe and associated pulmonary contusion. No hemothorax or pneumothorax was noted. After a secondary survey was performed, showing no other traumatic injuries, completion imaging was obtained, revealing a foreign body in the left lung (Fig. 1) superiorly abutting the hilar vessels, left open clavicle fracture, a C5 tubercle fracture, possible grade 1 left vertebral injury and a left first rib fracture. Soft tissue gas was seen around the left subclavian and axillary arteries, although no definitive injury to the arteries was identified. The patient had strong palpable radial pulses and oxygen saturation of 94% on room air.

Due to concerns about the development of infectious complications and erosion into subjacent hilar vasculature, we decided to remove the foreign body. Given the patient's pulmonary and hemodynamic stability, the operation was performed the following morning when additional staff were available. Although there was no obvious vascular injury, we opted for a posterolateral thoracotomy for removal instead of thoracoscopy, in case there was significant bleeding or lung repair was needed. The patient was type- and cross-matched for blood products, and we proceeded to the operating room. He was positioned in the right lateral decubitus position. Thoracotomy was performed, revealing a bean bag ballistic lodged in the parenchyma of the left lung with the tail of the projectile still contained within the chest wall. The tail was initially mobilized and freed from the chest wall. Circumferential blunt dissection was carried out around the bean bag with gentle traction applied. While we considered stapled tractotomy down the length of the bean bag ballistic to assist in removal, this was ultimately unnecessary. After careful blunt circumferential dissection, the bean bag was removed in its entirety (Fig. 2). Fig. 3 demonstrates the bean bag ballistic after removal. The underlying lung had minimal bleeding and there was no visible vessel at the base of the wound. A topical hemostatic was applied to the ballistic cavity. A chest tube was then placed. The patient's chest was closed in standard fashion with interrupted Vicryl sutures. Postoperatively, the patient's chest tube was removed on day 5 and he was discharged on hospital day 7. At a 2-week outpatient follow-up visit, the patient was doing well and had no complications.

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

Although law enforcement officers utilize bean bag projectiles as a “less lethal” means of crowd control and protection, these ballistics pose significant risk and can result in serious injury, as demonstrated in this case report. Various “less lethal” projectiles are used by law enforcement, including rubber bullets, paintballs, and bean bag projectiles. The increased use of “less lethals” has been accompanied by a concomitant increase in reports of significant injury [1,2]. Some reported injury patterns include soft tissue contusions, ocular damage, blunt abdominal injury, cardiac contusion, pneumothorax, hemothorax, and extremity injuries [1,2]. The most common injury is soft tissue contusion, which is considered to be mild in nature [3].

This case report presents a rare intrathoracic injury from a bean bag ballistic and is the first to describe this outcome for a drag-stabilized bean bag. One other case report has described the surgical removal of a bean bag ballistic (the flexible baton, MK-12) from the thoracic cavity [1]. Notably, uncomplicated gunshot wounds have less than a 2% infection rate and do not require removal or debridement of the retained ballistic [4]. However, the fabric covering of this ballistic increased the infectious risk and raised concerns about the potential development of a lung abscess. Thus, a thoracotomy was performed to facilitate foreign body removal and to assess the possibly injured pulmonary vasculature.

Although life-threatening injuries are rare, the kinetic impact of these “less lethals” should not be underestimated. A recent article in the New England Journal of Medicine [2] advocated for alternative means of crowd control due to significant morbidity experienced by patients who were struck by bean bag projectiles, including skull fractures and several intracranial hemorrhages, during recent protests in Texas, USA. Surgeons treating patients with traumatic injuries should be familiar with these projectiles and their potential associated injury patterns, as they can result in significant morbidity and mortality.

ARTICLE INFORMATION

Author contributions
Conceptualization: all authors; Methodology: all authors; Writing—original draft: MB; Writing—review & editing: all authors. All authors read and approved the final manuscript.

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REFERENCES


INTRODUCTION

Axillary defects can result from trauma, burns, infections, or tumor excision. Local flaps are the primary method of choice for reconstruction, and the optimal donor areas are the contiguous chest wall or the arm [1,2]. The design of the flaps can be pedicled or propeller-type, and primary closure of the donor site is usually performed. The use of free tissue transfer is uncommon in the literature [3]. Using flaps enables optimal return of function and, in cases of neuromuscular unit loss, allows second-stage reconstruction. For moderate or large defects, the availability of local tissues may not be adequate, which sets the stage for using free skin flaps. Because the axilla is the junction between the limb and the shoulder, recipient pedicles can be accessed from either region. One case report described an axillary reconstruction using a composite free flap following tumor excision, where the subclavian vessels were used in an end-to-side anastomosis [4]. Scarring or previous injury to the vessels forces a search for recipient vessels farther away from the axillary defect [5].

This is a report of two axillary reconstructions using free thigh flaps, with special emphasis on the choice of the recipient vessel.

CASE REPORTS

Case 1
A 17-year-old male patient sustained electrical burns on approxi-
mately 15% of the body surface area while working on a trans-
former. The burns were on the right arm, axilla, right side of the
chest, and supraclavicular region. He initially underwent split-skin
grafting and right trapezius musculocutaneous flap coverage for
an exposed right scapula at another hospital. He presented 10
months later with a contracture of the right axilla. Clinically, the
patient had postburn scarring over the right side of the anterior
chest wall, the right infraclavicular region, and the posterior aspect
of the right arm, with a grade 3 axillary contracture (Fig. 1). The
patient had a right infraclavicular brachial plexus injury. He had
passive restriction of right shoulder abduction to only 30° with
Medical Research Council (MRC; scale of 0 to 5) grade 3 power.
Elbow flexion and extension, wrist extension, and finger extension
were absent. He had MRC grade 2 wrist and finger flexion.

Excisional release of the right axillary contracture was planned.
Neurolysis of the posterior cord and the median and ulnar nerves
was done. The thoracoacromial pedicle and cephalic vein were
prepared for anastomosis. The defect of the right axilla measured
12 × 14 cm and was resurfaced with an anterolateral thigh (ALT)
flap harvested from the right thigh, based on the musculocutane-
ous perforator from the descending branch of the lateral circum-
flex femoral artery. End-to-end microanastomosis was per-
formed with the pectoral branch of the thoracoacromial artery
and a single venous anastomosis of the flap vena comitans to the
cephalic vein (Fig. 2).

Postoperatively, the ALT free flap settled well, with no compli-
cations. The patient’s range of shoulder abduction improved to
90°. After 4 months of follow-up there was an improvement in el-
bow extension measuring grade 3 (Fig. 3). The restoration of el-
bow flexion and an augmentation of hand function with tendon
transfers was planned for a second stage.

Case 2
A 22-year-old male patient with a history of blunt trauma to the

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Fig. 1. Preoperative views of patient 1 showing (A) right axillary contracture due to scarring, (B) inadequate abduction, and (C) a previous trape-
zius myocutaneous flap and skin graft over the posteromedial arm. The results of a posterior cord and musculocutaneous nerve injury can also be
seen. The patient provided informed consent for the publication of the images.

Fig. 2. Surgical images of patient 1. (A) Release of scar to permit adequate shoulder abduction, exposure of the thoracoacromial vessels and neu-
rolysis of the cords of the brachial plexus. (B) Harvested anterolateral thigh anterolateral thigh flap. (C) Complete flap inset.
chest from the fall of a heavy object, sustained a degloving injury of the left axilla and a left proximal one-third humerus fracture with vascular injury (brachial artery thrombosis). There were multiple rib fractures and tension pneumothorax for which intercostal drainage had been done. Exploration and brachial artery thrombectomy, interposition vein graft bypass, exploratory thoracotomy, repair of lung laceration, and left humerus plating were done at another hospital.

The patient presented 15 days after the trauma with a 15 × 20-cm left axillary defect extending from the anterior axillary fold to the posterior axillary fold that was covered with granulations. Surgical incisions were present over the medial aspect of the arm (Fig. 4). Wound excision and free flap coverage were planned. A transverse cervical pedicle and the external jugular vein were exposed and prepared for anastomosis using an incision above and parallel to the clavicle. An 18 × 30-cm tensor fascia lata flap was harvested from the right thigh based on a perforator from the ascending branch of the lateral circumflex femoral artery. End-to-end microanastomoses were done with one arterial and two venous anastomoses (transverse cervical vein and external jugular vein). A split-skin graft was applied over the neck incision to prevent compression over the pedicle (Fig. 5). The postoperative flap healed uneventfully, and 3 months later the patient underwent flap thinning (Fig. 6).

Ethics statement
Written informed consents for the publication of research details

![Fig. 3](image-url) Images of patient 1 at 4-month follow-up. (A–C) Adequate shoulder abduction is shown. Further tendon transfers are planned to improve wrist extension.

![Fig. 4](image-url) Preoperative images of patient 2. (A, B) Preoperative defect with granulating wounds in the axilla, medial chest wall, and one-third circumference of the proximal arm.

![Fig. 5](image-url) Surgical images of patient 2. (A) Harvested tensor fascia lata flap. (B, C) Views of completed anastomosis to the transverse cervical vessels in the neck. (D) Completed flap anastomosis with split-skin graft over pedicle. (E) View from the axilla side of the flap inset.
and clinical images were obtained from both patients. The images do not reveal the identity of the patients.

DISCUSSION

The pedicled parascapular flap and the latissimus dorsi myocutaneous flap are most widely used for axillary reconstruction [6]. These, and the lateral thoracic perforator flap [1], are based on known, reliable perforators; replace like with like; and provide adequate tissue for coverage of even larger defects if needed by split-skin grafting the donor site.

Tissue expansion and the subsequent use of regional pedicled flaps provide large pliable flaps, with the added advantage of primary closure of the donor defect. Kulahci et al. [7] studied the use of preexpanded pedicled thoracodorsal artery perforator flaps for the reconstruction of postburn axillary contractures in six patients. Tissue expansion is well suited for conditions such as burn contracture in which there are no wounds to manage. In a meta-analysis of reconstructive procedures for the excision of hidradenitis suppurativa (by far the most common indication in the literature), the authors recommended the use of free flaps for defects larger than 200 cm² [8]. The use of free flaps is infrequent, given the wide choice of regional pedicled flaps available. However, in patients with extensive trauma or burns, where the regional flaps are not available or have already been used, free flaps are an obvious choice in axillary reconstruction.

In the first case of this report, the patient underwent a trapezius musculocutaneous flap for axillary coverage at another hospital for two probable reasons: nonavailability of flaps closer to the wound and not having considered the possibility of a free flap. The decision to use free flaps for axillary defects leads to the question of which recipient vessels to choose for anastomosis. The choice of recipient vessels depends on their proximity to the defect, the zone of injury, and the available pedicle length. An end-to-end anastomosis implies the use of a thoracodorsal pedicle, thoracoacromial pedicle, transverse cervical vessels, circumflex humeral vessels, lateral thoracic vessels, and the internal mammary vessels. Availability of any one of the above can avoid a difficult end-to-side anastomosis to the axillary artery in the depth of the wound.

Miyamoto et al. [9] reported the use of ALT free flaps for axillary reconstruction after sarcoma resection in six patients. Five of the six patients had multiple previous operations for tumor resection and reconstruction. Three of the six had previous ipsilateral latissimus dorsi myocutaneous flap coverage. Three were ALT flaps and, in three of the six patients, the vastus lateralis muscle was harvested along with the ALT flap to cover the extensive defect. Their choice of recipient vessels was the thoracodorsal artery in two cases, the thoracodorsal artery in two cases, the circumflex scapular artery in one patient, the subscapular artery in one patient, and the transverse cervical artery in one patient. The previous use of the latissimus dorsi flap would have precluded the use of its primary pedicle as a recipient.

Bali et al. [10] studied the feasibility of using the ALT free flap for reconstruction of burn contractures in various sites. Fifteen ALT free flaps were used at various anatomical sites, two of which were used for reconstruction of axillary contractures. The recipient vessels were a thoracodorsal artery and vein in one case and a thoracodorsal artery and serratus vein in the other case.

Chen et al. [3] retrospectively studied a series of 10 patients in whom ALT free flaps were used for reconstruction of postburn axillary contractures. The most used recipient vessels were the thoracodorsal artery and the concomitant vein. They reported satisfactory functional outcomes in all cases, with no donor site morbidity.

Fig. 6. Follow-up images of patient 2. (A, B) Adequate shoulder abduction is shown. (C) Complete flap healing. (D) Flap after first flap thinning. (E) The patient is awaiting a second session of flap liposuction. The patient provided informed consent for the publication of the images.
The first patient in our report had postburn contracture of the right axilla with infraclavicular plexus injury. Exploration of the brachial plexus and procedures for a plexus injury, such as neurolysis or nerve transfer, can be done only when stable skin coverage is in place. This led to the decision to use an ALT free flap to reconstruct the defect. Since the circumflex scapular region and thoracodorsal vessels were scarred, the thoracoacromial artery and cephalic vein were used as recipient vessels for microanastomosis. This was facilitated by cutting the pectoralis major (scarred and not functional) and the pectoralis minor.

Thoracoacromial vessels are usually used as alternative recipient vessels in head and neck microvascular tissue transfers where the usual recipient vessels are not available [11]. A cadaveric anatomical and sonographic study by Kompatscher et al. [12] described the ease of access to the thoracoacromial vessels and their pectoral branches for anastomosis. It is equally feasible to use the neck as a vessel source for a defect outside the neck, as described in the second case in this report.

The second patient had a large posttraumatic defect of the left axilla with trauma to the chest and left upper limb with brachial artery thrombosis. A tensor fascia lata musculocutaneous flap was harvested, as the perforator for the ALT flap could not be found on dissection. No attempt was made to expose the thoracoacromial vessel since it was in the zone of trauma. Scarring in the infraclavicular region precluded end-to-side anastomosis to the axillary or subclavian vessels. In addition, the patient had a previous vascular repair of the axillary-brachial artery. The choice of recipient vessels, in this case, was the transverse cervical pedicle and the external jugular vein, considering that the other more approachable vessels were in the zone of trauma and fibrosis.

Ogawa et al. [5] reported the use of three free flaps for necrotizing defects in the axilla and specified seeking recipient vessels far removed from the area of the defect. The thoracoacromial vessel was the first choice, and in that series, neck vessels such as the superior thyroid were the second choice. They endorsed using flaps with long pedicles to enable reach and adequate coverage of the defect.

In conclusion, When a free flap is used for axillary defect coverage, it is important to be aware of the selection of recipient vessels in the chest or the neck and select a donor flap with adequate pedicle length.

**ARTICLE INFORMATION**

**Author contributions**

Conceptualization: PR, SJ; Data curation: SR, PP; Formal analysis: ADB, PP; Interpretation: ADB, PP; Writing—original draft: ADB, PR, SR; Writing—review & editing: all authors. All authors read and approved the final manuscript.

**Conflicts of interest**

The authors have no conflicts of interest to declare.

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**Data availability**

Data sharing is not applicable as no new data were created or analyzed in this study.

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Successful nonoperative management of a simultaneous high-grade splenic injury and devascularized kidney in Australia: a case report

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INTRODUCTION

In hospitalized patients, abdominal solid organ injuries are associated with a mortality rate of approximately 5% [1]. Nonoperative management is the preferred approach for stable patients with isolated splenic injuries resulting from blunt trauma [2]. However, simultaneous multiple solid organ injuries are associated with the failure of nonoperative therapy and an increased risk of complications, including pneumonia, sepsis, and prolonged hospitalization [3,4]. Risk factors associated with the failure of nonoperative management include older age, the presence of vascular blush on computed tomography, and a large volume of hemo-peritoneum [4]. Additionally, signs of hemodynamic instability including hypotension on presentation, higher Injury Severity Scores (ISSs), and high transfusion requirements are factors associated with a higher mortality rate [3]. We describe below the successful nonoperative management of simultaneous high-grade splenic and kidney injuries following blunt trauma.

CASE REPORT

A man in his 30s presented to our level I trauma center (Westmead Hospital, Sydney, Australia) after being ejected from a motorbike at high speed whilst under the influence of methamphetamines. He was hemodynamically stable, but exhibited confusion and agitation, with a Glasgow Coma Scale of 14. The patient had severe blunt injuries to isolated solid abdominal viscera have been previously managed nonoperatively; however, management algorithms for simultaneous visceral injuries are less well defined. We report a polytrauma case of a 33-year-old man involved in a motorbike collision who presented with left-sided chest and abdominal pain. Initial imaging demonstrated multiple solid organ injuries with American Association for the Surgery of Trauma (AAST) grade V splenic injury and complete devascularization of the left kidney. The patient underwent urgent angioembolic coiling of the distal splenic artery with successful nonoperative management of simultaneous grade V solid organ injuries.

Keywords: Multiple trauma; Abdominal injuries; Splenic rupture; Angiography; Case reports
no relevant past medical history.

An extended focused assessment with sonography for trauma examination was positive for free fluid in the left subphrenic, hepatorenal, and pelvic spaces. Trauma pan computed tomography (CT) demonstrated a large volume of hemoperitoneum, grade V splenic injury, left adrenal hematoma, and a grade V left renal vascular pedicle injury with devascularized left kidney, but no perirenal hematoma (Fig. 1). Other injuries included anterior mediastinal hematoma, bony injuries including right scaphoid and lunate fractures, a left scapula supraclavicular fossa fracture, and an isolated posterior 11th rib fracture. The biochemical markers on presentation were notable for marked acidosis with a venous pH of 7.26 and lactate level of 3.7 mmol/L but a base excess of –1.6 mmol/L. Hemoglobin on presentation was normal (134 g/L), and the patient was identified to be heterozygous for factor V Leiden mutation Arg506Gln (associated with an increased risk of venous thromboembolism [5]).

The patient was managed with urgent interventional radiology 6 hours after presentation, with a diagnostic aortogram and splenic angiogram demonstrating traumatic dissection and abrupt occlusion of the left main renal artery approximately 2 cm from the renal ostium. No evidence of arteriovenous fistulae or active bleeding was noted. Despite the high-grade renal injury, the renal parenchyma remained intact, and percutaneous stenting was considered as a feasible management strategy. The interventional radiologist was unable to traverse the injury with a wire, and therefore the plan for stenting was abandoned. Significant fragmentation and devascularization of the spleen were identified. Thirteen coils were deployed with additional gelfoam embolization to distal splenic and associated branches beyond the pancreatica magna artery, as shown in Fig. 2. The patient’s scaphoid and lunate fractures were managed with open reduction and internal fixation, while the other bony injuries were nonoperatively managed. The patient was monitored with 6-hourly hemoglobin levels with a trough hemoglobin level of 83 g/L and serial examinations. Chemical venous thromboembolism prophylaxis was commenced 24 hours following angioembolization.

The patient remained hemodynamically stable throughout his admission; however, cyclical high fevers up to 39°C were observed with unremarkable septic screens. Intravenous empirical antibiotics were administered for 7 days after fever commencement. Interval abdominopelvic CT performed 4 and 8 days after presentation demonstrated splenic and left renal infarcts consistent with prior imaging, with no new hematoma formation, pseudoaneurysm, or associated intraabdominal abscesses. Atelecasis was identified on chest imaging. The patient was commenced on patient-controlled analgesia (PCA) and ketamine infusion initially. PCA was discontinued on day 6 posttrauma and de-escalated to only oral analgesia on day 7. He was discharged on day 13, with outpatient follow-up.

Ethics statement
Consent for publication of the research details and clinical images was obtained from the patient.

![Fig. 1. Portal venous phase computed tomography (CT) of the abdomen. On presentation, CT demonstrated large haemoperitoneum, grade V splenic injury, perisplenic haematoma, and a grade V left renal vascular pedicle injury with a devascularized nonenhancing left kidney. (A) Coronal view. (B) Axial view.](https://doi.org/10.20408/jti.2023.0017)
DISCUSSION

The management of solid injuries is predominantly nonoperative in hemodynamically stable patients, and angioembolization is a useful adjunct to solid organ preservation [6]. The success rates of nonoperative management have been reported to be approximately 86% in splenic trauma [4], 97% in hepatic trauma [7], and 92% in renal trauma [8]. The grading of splenic injuries according to the American Association for the Surgery of Trauma (AAST) Injury Scoring Scale ranges from grade I to V, with grade V referring to splenic and kidney injuries with vascular involvement and bleeding extension into the peritoneum or shattered or devitalized parenchyma. Although some evidence demonstrating a correlation between the failure of nonoperative management and the grade of injury [9], multiple other studies have indicated that nonoperative management is ideal independent of the lesion grade, more strongly for splenic injuries [10] than for renal injuries [9]. Some contemporary recommendations suggest operative management of grade V kidney injuries [6,11,12] depending on hemodynamic stability. In broad terms, however, the risk factors for failure of nonoperative management of solid viscus injuries, including refractory haemodynamic instability and worsening biochemical markers of perfusion (for example, lactate and base excess), reflect the physiologic status of the patient. In this case of a hemodynamically stable patient with no comorbidities, further attempts at renal revascularisation were not pursued. Prolonged ischaemic time is associated with exponential losses in kidney function [11]. An operative intervention was not pursued, as expectant management of sequelae (such as progression to chronic kidney disease or hypertension) during follow-up was considered to have a more favorable risk profile.

Patterns of concomitant solid organ injuries are less well studied and have fewer recommendations for nonoperative management. Important concepts include early recognition with CT imaging [2,13] and serial clinical examinations, with diffuse peritonitis, hemodynamic instability, or persistent biochemical signs of shock despite resuscitation being the only reliable markers of the failure of operative management. Older age, higher ISSs, head injury, the presence of femur fractures, and ongoing blood transfusion requirements are similarly factors that favor operative management and are predictors of failure of nonoperative management [3,4].

This case highlights the successful nonoperative management of concomitant splenic and renal injuries. Solid organ injury management should be dependent on clinical status, with radiology findings determining the role of angioembolization, even in the setting of multiple solid organ injuries.

ARTICLE INFORMATION

Author contributions
Conceptualization: PTTN; Data curation: PTTN; Investigation: PTTN; Methodology: PTTN; Project administration: PTTN; Supervision: HJ; Visualization: PTTN; Writing–original draft: PTTN; Writing–review & editing: all authors. All authors read and approved the final manuscript.
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Data availability
Data sharing is not applicable as no new data were created or analyzed in this study.

REFERENCES
Successful minimally invasive management using transcatheter arterial embolization in a hemodynamically stable elderly patient with mesenteric vascular injury in a hybrid emergency room system in Korea: a case report

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Mesenteric injury occurs rarely in cases associated with blunt abdominal trauma. Despite its low incidence, mesenteric injury can lead to fatal outcomes such as hypovolemic shock due to hemoperitoneum or sepsis due to intestinal ischemia, or perforation-related peritonitis. For mesenteric injuries, especially those involving massive bleeding, intestinal ischemia, and perforation, the standard treatment is surgery. However, in the case of operative management, it should be borne in mind that there is a possibility of complications and mortality during and after surgery. The usefulness of transcatheter arterial embolization (TAE) is well known in solid organs but is controversial for mesenteric injury. We present a 75-year-old man with mesenteric injury due to blunt abdominal trauma. Initial abdominal computed tomography showed no hemoperitoneum, but a mesenteric contusion and pseudoaneurysm with a diameter of 17 mm were observed near the origin of the superior mesenteric artery. Since there were no findings requiring emergency surgery such as free air or intestinal ischemia, it was decided to perform nonoperative management with TAE using microcoils in hybrid emergency room system. TAE was performed successfully, and there were no complications such as bleeding, bowel ischemia, or delayed bowel perforation. He was discharged on the 23rd day after admission with percutaneous catheter drainage for drainage of mesenteric hematoma. The authors believe that treatment with TAE for highly selected elderly patients with mesenteric injuries has the positive aspect of minimally invasive management, considering the burden of general anesthesia and the various avoidable intraoperative and postoperative complications.

Keywords: Mesenteric injury; Transcatheter arterial embolization; Nonoperative management; Hybrid emergency room system; Case reports
INTRODUCTION

Mesenteric injuries caused by blunt trauma occur infrequently, appearing in about 1% to 5% [1–3]. However, it can cause life-threatening hemorrhage, bowel ischemia, and perforation, and is of great clinical importance [4,5]. Surgery is the standard of treatment for mesenteric injuries, particularly those involving massive bleeding, bowel ischemia, and perforation, [6,7]. However, in the case of operative management, it should be borne in mind that there is a possibility of complications and mortality during and after surgery [8]. The usefulness of transcatheter arterial embolization (TAE) is well known in solid organ injuries such as liver, spleen, and kidney, but less attention has been paid to mesenteric injuries [9]. The authors are to report a case of successful nonoperative management with TAE for a 75-year-old male patient with mesenteric injury with pseudoaneurysm due to blunt trauma. According to the medical history, the patient underwent open abdominal surgery for gastric cancer, and is taking antiplatelet drugs after stent insertion due to myocardial infarction.

CASE REPORT

A 75-year-old man complained of abdominal pain as a result of a traffic accident while driving. The patient was diagnosed with mesenteric vascular injury on abdominal computed tomography (CT) performed at the previous hospital and was transferred to Wonkwang University Hospital Regional Trauma Center (Iksan, Korea) for surgical treatment. The patient was immediately admitted to hybrid emergency room system (HERS) and treated by a trauma team including an interventional radiologist. The patient’s Glasgow Coma Scale was 15 and initial vital signs were stable (blood pressure 148/84 mmHg and pulse 69 beats/min). The initial hemoglobin level was 11.5 g/dL, and 1 U of universal O+ packed red blood cells were transfused immediately after admission. His medical history revealed that he underwent open surgery for gastric cancer and was taking an antiplatelet drug (clopidogrel) after a coronary artery stent was inserted due to myocardial infarction. Abdominal CT performed at the previous hospital did not show a hemoperitoneum, and a mesenteric contusion and pseudoaneurysm with a diameter of 17 mm were found near the origin of the superior mesenteric artery (SMA) (Fig. 1). There were no findings requiring emergency surgery such as free air or intestinal ischemia. Without the need to move the patient to another room, CT was performed at HERS to check for injuries to other body regions, and then a treatment plan was decided. Injury to other body regions was not observed, but the size of the pseudoaneurysm increased to about 20 mm (Fig. 2). The patient was hemodynamically stable and there were no findings suggestive of bowel ischemia or perforation, so it was decided to perform TAE in HERS. Angiography revealed a pseudoaneurysm of about 20 mm in size, which occurred in the injured area of the SMA wall, about 100 mm from the SMA root, and embolization using detachable coils (Interlock, Boston Scientific; Concerto, Medtronic) was performed for a pseudoaneurysm. Also feeding artery was embolized by two Interlocks (Fig. 3).

Fig. 1. A computed tomography scan performed at a previous hospital shows a pseudoaneurysm that occurred proximal to the superior mesenteric artery (SMA). A saccular pseudoaneurysm of about 17 mm in size was seen near the SMA root (arrows), and a hematoma was observed near the mesentry. (A) Axial view. (B) Coronal view.
Abdominal CT on the 4th day of admission showed no active bleeding or pseudoaneurysm-related problems. An increase in hematoma was observed in the mesentery (Fig. 4), but the patient’s vital signs were stable and there was no decrease in hemoglobin. Also, no findings such as free air or intestinal ischemia were observed, and findings such as free air or bowel ischemia were not observed. The patient’s condition was closely monitored, including periodic abdominal physical examinations. The patient complained of abdominal discomfort despite the absence of fever and leukocytosis, so an abdominal CT was performed on the 13th day of admission. Local fluid collection inside the mesentery was observed on CT, and percutaneous catheter drainage (PCD) was performed (Fig. 5). The patient was discharged on the 23rd day after admission without any complications. Abdominal CT performed at an outpatient department at 3 weeks after PCD showed a significant decrease in fluid, and PCD was removed (Fig. 6).

Fig. 2. In the follow-up computed tomography scan, the size of the pseudoaneurysm increased to 20 mm (arrows). The amount of mesenteric hematoma was also increased. (A) Axial view. (B) Coronal view.

Fig. 3. Angiography of the superior mesenteric artery (SMA). (A) Angiography showed a pseudoaneurysm branching directly from the SMA (arrow). (B) Embolization using detachable coils (Interlock, Boston Scientific; Concerto, Medtronic) was performed for a pseudoaneurysm (arrow). Also, feeding artery was embolized by two Interlocks (arrowhead).
**DISCUSSION**

Mesenteric injury rarely occurs in blunt abdominal trauma from a traffic accident [1–3]. Despite its low incidence, mesenteric injury can lead to lethal outcomes related to hypovolemic shock due to hemoperitoneum, sepsis due to bowel ischemia, or peritonitis due to perforation [4,5,10]. Therefore, abdominal injury caused by high-energy trauma requires timely diagnosis and treatment. However, delayed diagnosis sometimes occurs because such patients are often accompanied by multiorgan injury or decreased or loss of consciousness due to traumatic brain injury or sedation. In particular, accurate diagnosis may be difficult for patients with unstable vital signs [4,11].

In this case, we considered the possibility of adhesion around the site of injury in the abdominal cavity because the patient had undergone open abdominal surgery for gastric cancer a year and a half ago. Since the damage is in the proximal part of the SMA, if the adhesions are severe, it is difficult to quickly access the bleed-

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**Ethics statement**

This study was approved by the Institutional Review Board of Wonkwang University Hospital (No. WKUH 2022-03-028). Written informed consent for publication of the research details and clinical images were obtained from the patient.

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*Fig. 4.* Computed tomography performed on the 4th day of admission. (A) The coil was well bundled inside the pseudoaneurysm (arrow). (B) A previously unseen localized hematoma (arrow) was newly observed. There was no evidence of active bleeding.

*Fig. 5.* Scans performed on the 13th day of hospitalization. (A) Computed tomography scan showed no significant change in hematoma volume. (B) Percutaneous catheter drainage was performed.
emia and perforation, nonoperative management with immediate TAE can be performed at HERS instead of moving to the operating room for OM. In HERS, CT scan, interpretation, and angiography can be performed immediately without the need to move the patient. Therefore, it is possible to control bleeding using TAE in highly selected patients, and even if there is a finding that requires surgery, it can act as a bridge through hemostasis during the preparation of the operating room [7,12]. It is difficult to define the indications for NOM or predict the success of NOM for mesenteric injury using CT findings alone, and there are very few case reports of NOM performed for mesenteric injury with active bleeding worldwide [9,13–15]. However, in patients who are hemodynamically stable and have bleeding from the mesenteric artery but no serious bowel injury, as in this case, TAE can be attempted cautiously. Also, even in this case, it is necessary to prepare for surgical treatment in preparation for the possibility of TAE failure. In addition, physical examination, hemodynamic monitoring, and follow-up imaging tests should be repeated after TAE to detect and resolve complications such as rebleeding, bowel ischemia, delayed bowel perforation, and fluid collection [3,9,12]. Above all, careful observation should be performed with the possibility of bowel ischemia always in mind. TAE for SMA may be safer than for inferior mesenteric artery because of the development of collateral vessels. However, TAE for SMA also has the potential to cause ischemia [10,13]. Therefore, close monitoring, physical examination and short-term follow-up CT is needed to confirm bowel ischemia. In our trauma center, the follow-up CT is taken the next day of TAE if bowel ischemia is suspected. If air bubbles are observed in the intestinal wall or free air is found on CT, it can be evidence of bowel infarction, so surgical treatment should be performed. Considering the burden of general anesthesia and various intraoperative and postoperative complications, NOM using TAE for mesenteric injury is positive in terms of minimally invasive management. If more cases are accumulated in the future, it is expected that indications for NOM using TAE for mesenteric injury will be established.

ARTICLE INFORMATION

Author contributions
Conceptualization: CYP; Methodology: CYP, SRA, JHL; Project administration: CYP; Visualization: CYP, SRA, SHS; Writing–original draft: all authors; Writing–review & editing: all authors. All authors read and approved the final manuscript.

Conflicts of interest
Chan Yong Park is an Editorial Board member of the Journal of

Fig. 6. Computed tomography scan performed 3 months after percutaneous drainage catheter removal showed that all previously observed hematomas had disappeared.
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REFERENCES

Bleeding control of an injury to the infrarenal inferior vena cava and right external iliac vein by ipsilateral internal iliac artery and superficial femoral vein ligation after blunt abdominal trauma in Korea: a case report

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INTRODUCTION

Inferior vena cava (IVC) injuries, while accounting for fewer than 0.5% of blunt abdominal trauma cases, are among the most difficult to manage. Despite advancements in prehospital care, transportation, operative techniques, and perioperative management, the mortality rate for IVC injuries has remained at 20% to 66% for several decades. Furthermore, 30% to 50% of patients with IVC injuries succumb during the prehospital phase. A 65-year-old male patient, who had been struck in the back by a 500-kg excavator shovel at a construction site, was transported to a regional trauma center. Injuries to the right side of the infrarenal IVC and the right external iliac vein (EIV) were suspected, along with fractures to the right iliac bone and sacrum. The injury to the right side of the infrarenal IVC wall was repaired, and the right internal iliac artery was ligated. However, persistent bleeding around the right EIV was observed, and we were unable to achieve proximal and distal control of the right EIV. Attempts at prolonged manual compression were unsuccessful. To decrease venous return, we ligated the right superficial femoral vein. This reduced the amount of bleeding, enabling us to secure the surgical field. We ultimately controlled the bleeding, and approximately 5 L of blood products were infused intraoperatively. A second-look operation was performed 2 days later, by which time most of the bleeding sites had ceased. Orthopedic surgeons then took over the operation, performing closed reduction and external fixation. Five days later, the patient underwent definitive fixation and was transferred for rehabilitation on postoperative day 22.

Keywords: Inferior vena cava injury; External iliac vein injury; Blunt abdominal trauma; Superficial femoral vein ligation; Case report

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high, ranging from 20% to 66%. Furthermore, 30% to 50% of patients with an IVC injury succumb during the prehospital phase [3].

The incidence rates for iliac vascular injuries and isolated iliac vein injuries resulting from abdominal blunt trauma stand at 2.3% and 0.1%, respectively. Literature indicates that the mortality rate for patients suffering from iliac vascular injury can range anywhere from 25% to 80% [4].

The traditional approach to treating traumatic injuries of the IVC involves surgical repair. Depending on the location of the injury and whether there is active bleeding or a hematoma, a variety of surgical repair techniques may be employed [5].

There are no clear society-based guidelines available that define the role of endovascular therapy in patients with IVC injuries [6]. There are, however, a handful of case reports demonstrating successful endovascular management of such injuries, contingent upon the patient’s condition [5].

We present a case in which successful surgical repair was achieved for an infrarenal IVC and right external iliac vein (EIV) injury. This was accomplished through the ligation of the ipsilateral internal iliac artery (IIA) and superficial femoral vein (SFV) followed by blunt abdominal trauma.

CASE REPORT

A 65-year-old male patient, who sustained a back injury from a 500-kg excavator shovel at a construction site, was transported to Uijeongbu St. Mary’s Hospital (Uijeongbu, Korea), a regional trauma center. His Glasgow Coma Score was 15, and he reported experiencing abdominal and pelvic pain.

The patient’s initial blood pressure was recorded at 65/40 mmHg, with a heart rate of 116 beats/min. His respiratory rate was measured at 20 breaths/min, and his body temperature was 36 °C. The initial hemoglobin level was 9.6 g/dL. A pelvic binder was applied during the prehospital stage.

The Focused Assessment with Sonography for Trauma yielded negative results. The chest x-ray was clear, while the pelvic x-ray revealed diastasis of the right sacroiliac (SI) joint, along with fractures of the right superior and inferior ramus. A computed tomography (CT) scan was taken as the operating room was being prepared. The scan suggested injuries to the right side of the infrarenal IVC and the right EIV. Additionally, they showed a fracture of the right iliac bone, the right sacrum ala, and the fourth sacrum. A substantial retroperitoneal hematoma and extravasation along the right EIV were also detected in the CT scan (Fig. 1). During the initial resuscitation, 1 L of crystalloid and 1 unit of packed red blood cells (pRBCs) were administered. Despite this, the patient’s blood pressure remained at 65/56 mmHg.

The patient was moved to the operating room, where we performed a crash laparotomy. We discovered a transected small bowel and promptly ligated the lumen to prevent further contamination. Although there was no evidence of intraperitoneal hemorrhage, we did find a retroperitoneal hematoma situated around the aortic bifurcation. The infrarenal IVC was exposed using the Cattell-Braasch maneuver. We repaired a 5-mm longitudinal injury on the right side of the infrarenal IVC wall using prolene. We then proceeded with further dissection of the iliac artery and vein. The right IIA was ligated. We observed multiple and diffuse bleeding around the right EIV. Despite suturing the suspected right EIV bleeding site with prolene, the bleeding persisted. Even after allowing ample time for manual compression, we were unable to achieve hemorrhagic control.

We opted to ligate the right SFV to diminish venous return. The right superficial femoral artery and vein were isolated, after which the SFV was ligated using silk. This procedure led to a decrease in bleeding, enabling us to secure the surgical field. We then managed to control the bleeding by packing gauze in the right lower quadrant, covering the right SI joint diastasis. A side-to-side anastomosis of the transected small bowel was performed using a linear stapler. Upon completion of the gauze packing, the patient’s blood pressure was recorded at 94/66 mmHg, body temperature at 35.5 °C, and lactate levels at 83 mg/dL. We proceeded with a temporary abdominal closure and closed the incision in the right inguinal area. The findings and procedures from the initial operation are summarized in Fig. 2, while the patient’s timeline is detailed in Fig. 3.

During the operation, approximately 5 L of blood products were infused using a rapid infusion system. These products included 9 units of pRBCs, 8 units of platelets, and 8 units of fresh frozen plasma (FFP). Prior to a second-look operation, an additional 3 units of pRBCs, 6 units of FFP, and 6 units of cryoprecipitate were infused.

On the morning of the second-look operation, the patient’s blood pressure registered at 109/67 mmHg, his body temperature was 36.8 °C, and his lactate level was 16 mg/dL. The second-look operation took place 2 days later. The majority of the bleeding sites had ceased. The injured right EIV was discovered to be ruptured, but the bleeding was successfully managed. Some of the bleeding sites were ligated with prolene (Fig. 4). The serosal injury to the ascending colon was repaired. The abdominal layers were closed in sequence. Following this, orthopedic surgeons assumed control of the operation and performed a closed reduc-
Fig. 1. Initial abdominopelvic computed tomography findings. Retroperitoneal hematoma (circles) and extravasations (arrows) with a suspected inferior vena cava (IVC) and right external iliac vein (EIV) injury are shown. (A) Retroperitoneal hematoma and extravasations around infrarenal IVC. (B) Retroperitoneal hematoma and extravasations around right EIV. (C) Retroperitoneal hematoma and extravasations around infrarenal IVC and right EIV, a coronal view.

Fig. 2. Summary of the first operation. The operation was implemented in numerical order. IVC, inferior vena cava.

Initial findings

1. IVC lateral wall injury
2. Right external iliac vein injury

Repair and ligation

1. IVC lateral wall repair
2. Right internal iliac artery ligation
3. Right external iliac vein repair
4. Right external iliac vein ligation
5. Right femoral vein ligation
6. Gauze packing

Five days later, the patient exhibited definite fixation and was subsequently transferred for rehabilitation on postoperative day 22. On postoperative day 14, the patient underwent a lower extremity CT angiogram, which revealed deep vein thrombosis (DVT) extending from the ruptured right EIV to the popliteal vein (Fig. 5). Despite this, the patient did not experience severe swelling, pain, pulmonary embolism, or compartment syndrome. Three months later, he was able to begin walking with the aid of a walker.

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

DISCUSSION

IVC is divided into subsegments, which are commonly referred to as infrarenal, suprarenal, retrohepatic, and suprahepatic [7]. Most IVC injuries necessitate surgical exploration to control bleeding and perform a definitive repair. A free rupture into the peritoneal cavity can be identified by any alteration in hemodynamics or by an inadequate hemodynamic response to rapid volume resuscitation [8–10]. If feasible, a running suture using 4-0 or 5-0 prolene can be employed to complete the primary repair. If
Fig. 3. Timeline of the patient's injury and management. FAST, Focused Assessment with Sonography for Trauma; RBC, red blood cell; OR, operating room; AP, anteroposterior; MTP, massive transfusion protocol; CT, computed tomography; ICU, intensive care unit.

Fig. 4. Operative findings of the second-look operation. (A) Anatomy of the bleeding site. (B) Right sacroiliac (SI) joint diastasis. IVC, inferior vena cava; IIA, internal iliac artery; EIA, external iliac artery; EIV, external iliac vein.
the repair proves challenging, a side-biting Satinsky clamp may be beneficial for venorrhaphy [7]. In cases where multiple techniques fail to control the hemorrhage, surgeons might contemplate ligating the IVC.

In the event of a vein injury, the surgical treatment options typically include either repair or ligation. There has been ongoing debate regarding the choice between repair and ligation in the case of an IVC injury. A meta-analysis published in 2021 [11] examined this issue, incorporating data from 14 studies and a total of 885 patients. The findings indicated that ligation was associated with a higher mortality rate compared to IVC repair. However, when it came to mortality rates, there was no statistically significant difference between infrarenal IVC ligation and repair.

Magee et al. [4] studied 6,262 patients with iliac vascular injuries, using data from the National Trauma Data Bank (2007–2012). The study focused on the outcomes of repair versus ligation of isolated iliac vein injuries. Their findings indicated that compared to iliac vein repair, ligation was associated with a higher mortality rate. However, there were no statistically significant differences between the two methods in terms of DVT, pulmonary embolism, fasciotomy, or amputation.

Bilateral IIA ligation is a surgical treatment option for managing massive retroperitoneal hemorrhage in unstable patients with pelvic fractures [12]. The patient in question was unstable, presenting with a massive retroperitoneal hemorrhage due to an infrarenal IVC and right EIV injury. It was determined that the sacrum fracture was on the right side, with the majority of his injuries being right-sided. Consequently, we surmised that ipsilateral IIA ligation would be sufficient to control the hemorrhage.

In this case, we tried to repair the infrarenal IVC injury rather than ligate it. Despite repair of the right EIV bleeding site and subsequent manual compression, distal bleeding continued. Therefore, we ligated the ipsilateral SFV to reduce inflow, which successfully controlled the hemorrhage. A CT angiogram on postoperative day 14 revealed a DVT below the ruptured right EIV. However, a CT angiogram 7 months postoperatively showed collateral venous flow around the ruptured right EIV. Despite the presence of a DVT distal to the ruptured right EIV, the patient’s condition and symptoms showed improvement.

In summary, we report a case of successful bleeding control of an infrarenal IVC and right EIV injury by ipsilateral IIA and SFV ligation after blunt abdominal trauma.
ARTICLE INFORMATION

Author contributions
Conceptualization: HC; Formal analysis: all authors; Methodology: HC; Project administration: HC; Visualization: HP, MK, DSL, THH, DHK; Writing–original draft: HP; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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Data sharing is not applicable as no new data were created or analyzed in this study.

REFERENCES

A traumatic abdominal wall hernia (TAWH) is a rare presentation, most commonly reported in the context of motor vehicle accidents and associated with blunt abdominal injuries and handlebar injuries in the pediatric population. A 13-year-old boy presented with multiple traumatic injuries and hemodynamic instability after a high-speed motor vehicle accident. His injuries consisted of massive traumatic abdominal wall hernia (grade 4) with bowel injury and perforation, blunt aortic injury, a Chance fracture, hemopneumothorax, and a humeral shaft fracture. Initial surgical management included partial resection of the terminal ileum, sigmoid colon, and descending colon. Laparostomy was managed with negative pressure wound therapy. The patient underwent skin-only primary closure of the abdominal wall and required multiple returns to theatre for debridement, dressing changes, and repair of other injuries. Various surgical management options for abdominal wall closure were considered. In total, he underwent 36 procedures. The multiple injuries had competing management aims, which required close collaboration between specialist clinicians to form an individualized management plan. The severity and complexity of this injury was of a scale not previously experienced by many clinicians and benefited from intrahospital and interhospital specialist collaboration. The ideal aim of primary surgical repair was not possible in this case of a giant abdominal wall defect.

Keywords: Traumatic abdominal wall hernia; Abdominal wall reconstruction; High-speed accidents; Pediatric trauma; Case reports
A 13-year-old boy was transferred to the emergency department of Sydney Children’s Hospital (Randwick, Australia) with traumatic injuries sustained as a car passenger in a high-speed MV A. He had initially been managed in a regional emergency department. On scene, the patient had a Glasgow Coma Scale score that fluctuated between 12 and 14, and he was hemodynamically unstable, requiring transfusions. Emergency management at the scene included intercostal catheter (left side) and endotracheal tube insertion, as well as ongoing blood transfusions for hemodynamic instability. On arrival to our facility, the patient had received 4 units of blood.

The physical examination revealed seatbelt bruising with abrasions and ecchymosis to the lower abdomen and pelvis. Focused assessment with sonography for trauma showed fluid in the right upper quadrant. A computed tomography (CT) scan revealed herniation of abdominal contents through a ruptured transverse abdominal rectus muscle, with sigmoid colonic rupture, left kidney injury, and a left side hemopneumothorax with associated lung contusion requiring intercostal catheter insertion. Computed tomography angiography (CTA) was suggestive of blunt aortic injury at the level of the visceral aorta with aortic hematoma, occlusion of the left renal artery with total devascularization of the left kidney, and intraluminal thrombus between the right renal artery and superior mesenteric artery with partial devascularization of the right kidney (Fig. 1). The CT scan also showed a vertebral flexion and distraction fracture at L4 involving the middle and posterior columns, an L3 transversus process fracture, and a markedly displaced right humeral shaft fracture.

Surgery involved resection of devitalized terminal ileum, distal descending and sigmoid colon, and hemostatic packing. Negative pressure wound therapy dressing was applied. The patient was admitted to the pediatric intensive care unit for hemodynamic instability, ongoing bleeding, and ventilation requirement. Continued blood loss from the abdominal drains (above 1l) required relaparotomy on postoperative day (POD) 1 with renewal of hemostatic packing. The patient was coagulopathic, and he had blood loss and was hemodynamically unstable, which required increased inotropic support postoperatively. Due to instability and concerns about sepsis from extensive necrotic abdominal wall tissue, he required a second relaparotomy the same day with radical debridement, which resulted in the loss of most of the anterior abdominal wall. Due to extensive debridement requirements, a third relaparotomy and debridement were performed on POD 2 with plastic, colorectal, and vascular surgery teams in attendance for inspection and planning ongoing management. The lack of abdominal wall precluded stoma formation, and two primary anastomoses were performed (ileocolic and descending colon sigmoid) on POD 4 during a planned relaparotomy, along with debridement of the abdominal wound and vacuum-assisted closure dressing change (Fig. 2). Surgical tracheostomy was performed on day 10 of admission. The unstable Chance fracture required ongoing spinal precautions. Laminectomy was delayed by more than 1 month, as the patient was unable to be placed prone due to the lack of an abdominal wall. The patient required approxi-
mately 20 further procedures for regular dressing changes and debridement.

After 3 and a half months, the abdominal wound was fully granulated. The plastic surgery team performed skin-only closure of the abdominal wall, with grafting of a 10 × 5-cm defect in the right inguinal area. The patient was discharged 5 months after initial presentation. An extensive multidisciplinary team, including nurses, physiotherapists, anesthesiologists for acute and chronic complex pain management, mental health professionals, and social work practitioners, was involved in the management of this patient.

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

DISCUSSION

MVAs are the commonest cause of TAWHs in adults [1]. In contrast, TAWHs in children are most commonly associated with handlebar injuries, with relatively few reported pediatric cases due to MVAs [1]. Most reported TAWHs are grade V [1]. In 60% of adult patients with TAWH and intra-abdominal injuries, these were most commonly bowel injuries (44%), followed by solid organ injuries (35%) [1]. In 40% of children with TAWH intra-abdominal injuries, bowel injuries comprised 70% [5]. Despite the lower number of intra-abdominal injuries in children the percentage of bowel injuries is higher than in the adult patient group (28% in children and 26.4% in adults).

As yet, there is no common consensus on diagnosis and management. Diagnostic imaging is correlated with intraoperative findings [1]. In most cases, TAWHs are located in the right lower quadrant of the abdomen (33%), followed by the left lower quadrant (27%) [1]. AWHs cannot be distinguished from preexisting abdominal hernias on CT. The hernia mostly contains the small bowel (69%) [1]. Most children with TAWHs (85%) require surgical management, and 80% undergo laparotomy [5].

Traumatic abdominal aortic injury (TAAI) is rare and generally associated with polytrauma [6]. TAAI occurs in < 1% of blunt abdominal traumas. Most TAAI cases have been reported in the context of MVAs and diagnosed by CT or CTA, or during exploration. The clinical findings of TAAI are limited to severe cases [6]. Most blunt abdominal aortic injuries have been reported at the level of the inferior mesenteric artery (33%), followed by the renal arteries (24%) [6,7]. Vertebral fractures have been reported in 27% of adults with TAWHs [2]. Traumatic lumbar spine fractures are generally associated with transverse process fractures [8]. Flexion and distraction spinal fractures usually involve T11 to L2 and result from head-on-car collisions [9].

In summary, we describe a complex pediatric case of TAWH complicated by abdominal aortic injury and vertebral fracture. Our total of 36 procedures for TAWHs in children and the complexity of surgical involvement constitute a rare scenario.

ARTICLE INFORMATION

Author contributions
Conceptualization: all authors; Writing–original draft: SDS; Writing–review & editing: all authors. All authors read and approved the final manuscript.

Conflicts of interest
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Data availability
Data sharing is not applicable as no new data were created or analyzed in this study.

REFERENCES

We introduce a convenient method of urethrography before catheterization for patients with pelvic trauma that can be used in a resuscitation area. A 10-mL syringe without a needle was used. X-ray contrast medium (Iohexol, 300 mg I/mL) was administered through the urethral orifice using a 10-mL syringe without needle and a simple pelvic anteroposterior film was taken (70 kilovolt [peak], 50 mAs). A 36-year-old soldier with a saddle injury from a gun barrel was taken to a trauma center. He had a pelvic fracture and complained of hematuria. Bedside urethrography above described was performed. The anterior urethra showed nonspecific findings, but dye leaked from the posterior urethra. Bedside Foley catheter insertion was attempted, but the catheter could not be advanced past the membranous urethra. Thereafter, suprapubic catheterization was performed. On the day of the injury, iliac artery embolization was carried out. The dislocated sacroiliac joint was also treated using open reduction and internal fixation. On hospital day 7, guidewire Foley insertion was performed. This bedside urethrography technique is simple and useful for pelvic fractures in which urethral injury is suspected.

**Keywords:** Urethra; Diagnostic imaging; Pelvic bones; Wounds and injuries; Case reports
needle (Fig. 1) and a simple pelvic anteroposterior (AP) film was taken (70 kilovolt [peak], 50 mAs).

**CASE REPORT**

A 36-year-old soldier with a saddle injury from a gun barrel was taken to the Armed Forces Trauma Center (Seongnam, Korea). He had a pelvic fracture and complained of hematuria.

Bedside urethrography was performed. X-ray contrast medium was administered through the urethral orifice using a 10-mL syringe without a needle, and a simple pelvic AP film was taken. The anterior urethra showed nonspecific findings, but dye leaked from the posterior urethra (Fig. 2). Bedside Foley catheter insertion was attempted, but the catheter could not be advanced past the membranous urethra. Thereafter, suprapubic catheterization was performed.

On the day of the injury, iliac artery embolization was carried out. The dislocated sacroiliac joint was also treated using open reduction and internal fixation. On hospital day 7, guidewire Foley insertion was performed.

**Ethics statement**

This study adhered to the principles outlined in the Declaration of Helsinki. Written informed consent for publication of the research details and clinical images was obtained from the patient.

**DISCUSSION**

Urethral injury is a common complication of pelvic trauma, occurring in as many as 24% of adults with pelvic fractures [2]. The most common site of these injuries by far is the posterior urethra. These injuries occur in 3% to 25% of patients with pelvic fractures [3].

The usage of a Foley catheter in ascending urethrography has several disadvantages: trauma to the urethra, inability to examine the anterior urethra, and slipping of the catheter out of the urethra during the examination, especially in cases of impassable urethral strictures [4]. Researchers have invented devices for retrograde urethrography; however, they were primarily suitable for prostatic calculi, calcification in the bladder, urethral calculi, or radio-opaque foreign bodies [4,5]. For male infants, a 5F or 8F end-hole polyethylene catheter was bound to the meatal orifice with a surgical tape during retrograde urethrography [6].

However, the above instruments and techniques were not convenient for the examination of pelvic injuries, especially in the resuscitation theater. As described in the present paper, x-ray contrast medium was administered through the urethral orifice using a 10-mL syringe without a needle, and a simple pelvis AP film was taken.

In our case, after the surgery, interventional radiologist recommended guidewire Foley insertion to prevent urethral stricture.
Urologist preferred spontaneous urethral healing. Thereafter, guidewire Foley was inserted on the 7th hospital day.

This bedside urethrography technique is simple and useful for pelvic fractures in which urethral injury is suspected.

ARTICLE INFORMATION

Author contributions
Conceptualization: HL; Funding acquisition: KH; Investigation: SYL, KH; Methodology: SYL; Project administration: HL, KH; Supervision: SYL; Visualization: KH; Writing—original draft: HL, KH; Writing—review & editing: all authors. All authors read and approved the final manuscript.

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Data availability
Data sharing is not applicable as no new data were created or analyzed in this study.

REFERENCES

INTRODUCTION

Penetrating gluteal stab injuries represent a major emergency that is infrequently encountered yet can present serious diagnostic and therapeutic challenges in emergency departments and trauma centers [1,2]. These injuries may be associated with life-threatening conditions, including visceral, vascular, neurological, inferior and/or superior gluteal artery, iliac artery, sciatic nerve, urethral, rectal, and spinal cord injuries. In cases with delayed treatment, pseudo-aneurysms may develop. A mortality risk of up to 25% is observed for serious injuries [3]. When devising a treatment strategy, it is essential to tailor interventional and surgical approaches to patients.

The objective of this study was to emphasize the importance of selecting the optimal surgical approach for achieving the best clinical outcomes in the treatment of such injuries. Accordingly, we share our experience with a young male patient who presented to the emergency department with uncontrollable bleeding following an isolated penetrating gluteal injury.

CASE REPORT

A 31-year-old man was admitted to the emergency department with massive blood loss and shock after a stab wound to the buttock. At admission, he was conscious but provided vague responses to questions and reported a loss of sensation in his penis. His vital signs included blood pressure of 60/40 mmHg, respiratory rate of 20 breaths/min with shallow respiration, oxygen saturation of 88%, heart rate of 135 beats/min, and body temperature of 36 °C. While in the supine position, the patient’s abdomen appeared normal, with no tenderness or palpable masses detected. The patient’s skin was cold and moist. When he was placed in the prone position and the pressure dressing was removed, a 3 × 5-cm stab wound was observed in the left gluteal region, with ac-
tive massive bleeding from this incision. Manual examination confirmed peripheral pulses in both lower extremities, and neurological examination revealed no motor or sensory deficits.

A full suite of abdominal, pelvic, and lower extremity computed tomographic angiography (CTA) examinations were conducted to assess additional organ injury and detect arterial pathology. Intravenous Ringer lactate infusion and tetanus prophylaxis were administered as medication, and a transfusion of 2 units of erythrocyte suspension was initiated. The blood and blood products necessary for the operation were urgently prepared. CTA images were promptly evaluated in collaboration with urology, general surgery, orthopedics, and emergency medicine specialists. No pathologies, such as intra-abdominal organ perforation, rectal perforation, or ureter injury, were observed. Additionally, no free fluid or intraperitoneal air was noted in the abdomen. However, active contrast extravasation from the superior gluteal artery (SGA) branch of the internal iliac artery was detected along with pelvic hematoma (Fig. 1). Due to further deterioration of the patient's hemodynamics and the development of deep shock, an emergency diagnostic laparotomy, rather than an interventional procedure, was performed by our team in the emergency department operating room. Following mini median laparotomy under general anesthesia, the left common iliac artery, external iliac artery, and internal iliac artery were identified and secured with slings. The ureter was suspended, and no defects were observed. Only left internal iliac artery ligation was performed (Fig. 2). No retroperitoneal bleeding was noted. The concurrent urology team evacuated the pelvic hematoma. A drain was placed, and the laparotomy incisions were closed. The patient was then placed in the prone position; by this point, his bleeding had decreased dramatically (Fig. 2). Upon expansion of the gluteal incision, a reduced amount of active bleeding was observed from the SGA and its branches. The incision was 10 cm deep. Associated bleeding was stopped with simple sutures and clips. After ensuring that all bleeding was under control, the wound area was washed with 3,000 mL of isotonic solution and 500 mg of rifocin. Drains were placed in the wound areas (Fig. 3).

The patient was monitored in the intensive care unit, where broad-spectrum antibiotics were administered along with colloid and crystalloid fluid replacements. Four hours after surgery, and

Fig. 1. (A, B) Abdominal computed tomography scan displaying pelvic hematoma and contrast extravasation (arrows).

Fig. 2. Surgical images. (A) Preoperative view of a 3×5-cm incision in the left gluteal region, with the patient in the prone position. (B) Following mini median laparotomy, the left common iliac artery was clamped, and the left internal iliac artery was ligated.
with all hemodynamic parameters under evaluation, he was extubated. On the 1st postoperative day, we observed no signs of bleeding or additional complications. Hemodynamic and laboratory parameters were normal. On the 2nd postoperative day, the patient was mobilized. By that time, dramatic improvement was observable, eliminating the need for blood products. The patient did not experience any penile numbness or erectile dysfunction. With no further issues at inpatient follow-ups, the patient was discharged on the sixth postoperative day. During the 1st month of outpatient follow-up, CTA revealed that the pelvic hematoma had been resorbed and no active bleeding focus was evident. At the 6-month follow-up, the patient exhibited no motor deficits, urinary incontinence, or erectile dysfunction, and he was able to resume his normal life.

**Ethics statement**
Written informed consent was obtained from the patient for the publication of this case report and any accompanying images.

**DISCUSSION**

Penetrating gluteal injuries account for 2% to 3% of all penetrating injuries seen in emergency services admissions [4,5]. Presently, the literature indicates a mortality risk of up to 4% for any gluteal penetrating injury based on studies conducted at trauma centers [5]. Moreover, short- and long-term morbidity in patients with penetrating gluteal trauma can range from 0% to 33% [5]. In fact, our patient presented to the emergency department in shock, and his overall condition was critical.

The structures most commonly damaged following a penetrating hip injury include the SGA, rectum, small intestine, and colon. Injuries to the iliac artery and/or vein are diagnosed less frequently, and sciatic or lumbosacral nerve injuries are extremely rare. All patients with isolated penetrating injuries should undergo surgery at experienced centers. In the present case, the successful management of a young patient with an isolated penetrating gluteal artery injury, in collaboration with experienced urology and general surgery specialists, directly contributed to survival. Delays and errors in diagnosing and treating such cases may, unfortunately, contribute to mortality.

Bleeding from damaged vessels, gluteal aneurysm or pseudoaneurysm, gluteal compartment syndrome, perirectal hematoma, injuries to the rectum or small intestine, long-term ileus or temporary obstruction, soft tissue or urinary tract infections, sciatic nerve or lumbosacral plexus injury, impotence, and pressure sores are the most common complications of similar injuries. However, our case involved only an isolated artery injury, avoiding potential morbidities that can arise from additional pathologies.

When a patient presents to the emergency room exhibiting signs of hemodynamic instability, hypovolemic shock, and acute internal bleeding, resuscitation and emergency intervention may be necessary [6]. The SGA is more commonly injured in penetrating trauma, while the inferior gluteal artery is more frequently affected by blunt trauma. In patients with hemodynamically unstable gluteal region injuries, it is crucial to promptly investigate intra-abdominal and intrapelvic organ injuries as well as intrapelvic vessel damage. Rapid implementation of diagnostic methods and concurrent consultation with relevant specialists can be lifesaving. CTA is a leading rapid diagnostic technique and was the method of choice for the patient in this case, who presented with shock. A multidisciplinary approach led to the decision for a median laparotomy and left internal iliac artery ligation, which was made approximately 15 minutes after the patient’s arrival at the emergency department. While methods such as interventional angiography and coil embolization of the affected vessels may be suitable for some patients, the hemodynamic situation and clinical presentation led us to the decision of open surgery in this case. In similar patients presenting with shock, an exploratory laparotomy may be required after pressure packing is placed in the wound; alternatively, it may be necessary to ligate the internal iliac artery or its branches using an extraperitoneal approach to control ongoing external hemorrhage [7]. The vital role of vascular surgeons in this process cannot be overstated.

Penetrating gluteal injuries are potentially fatal wounds. Most patients who are hemodynamically stable can benefit from stan-
standard wound care and selective nonsurgical treatment. However, when a gluteal artery injury is confirmed or suspected, early CTA examination provides the most accurate diagnosis. For patients experiencing hypovolemic shock and exhibiting signs of internal bleeding, immediate lifesaving open surgery is the gold-standard treatment option. Penetrating injuries to the buttocks are serious pathologies that must be regarded as potentially life-threatening and should be managed with a multidisciplinary approach in trauma centers.

ARTICLE INFORMATION

Author contributions
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The authors have no conflicts of interest to declare.

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Data sharing is not applicable as no new data were created or analyzed in this study.

REFERENCES

Bilateral distal femoral epiphyseal detachment in a young adult: a case report

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INTRODUCTION

Epiphyseal detachments are common injuries in children and adolescents, accounting for 30% of fractures observed in this age group [1]. Because these injuries involve the growth plate, they are associated with a high risk of growth disturbance, leg length discrepancies, and angular deformities. Furthermore, distal femoral physeal fractures have a high incidence of growth arrest [2].

Unilateral or bilateral distal femoral physeal fractures and fracture dislocations are relatively rare, accounting for only 2% to 4% of all cartilage injuries [1,3]. Furthermore, young adults nearing the end of the growth phase are typically not affected by these types of injuries [4]. In this report, we present a case of bilateral distal femoral epiphyseal detachment in a healthy young man.

CASE REPORT

A 21-year-old young adult worker with no prior medical history presented to the emergency room. He had experienced closed trauma to both knees due to a road accident occurring 48 hours earlier. The patient had been struck by an oncoming vehicle, with the mechanism of injury being a posterior-anterior impact to the knees while he was standing, causing hyperextension. Consequently, the patient became trapped between two vehicles and experienced pain and complete functional impairment of the lower limbs. Upon initial clinical examination, painful bilateral swelling of the knees with abduction and external rotation was observed (Fig. 1).

Upon clinical examination at the hospital, no skin or vascular complications were observed. Standard radiographs revealed a bilateral distal femoral epiphyseal detachment, with a Salter I...
fracture on the left and a Salter II fracture on the right. Additionally, an anterior tilt of the distal fragment was noted (Fig. 2).

No attempt had been made at reduction prior to the patient’s admission to our unit. Routine laboratory tests and blood calcium levels were found to be normal. An open reduction was carried out 5 days after admission. The procedure took place in the operating room under general anesthesia, utilizing a lateral approach to the femur. Following the open reduction, double cross-pinning was performed, and immobilization was then achieved using a posterior plaster cast. Postoperative x-rays revealed a satisfactory reduction (Fig. 3).

Following surgery, a brace was applied for 6 weeks. The patient received analgesic treatment, antibiotics, and antithrombosis prophylaxis. He remained in the hospital for 10 days and continued to receive local care as an outpatient. Rehabilitation began at 6 weeks, involving mobilizations and physiotherapy, with full weight-bearing permitted at 3 months. At 20 months posttrauma, the patient exhibited good consolidation, bilateral painless support, and no limb length inequality. However, there was a limitation in knee flexion and a residual valgus estimated at 10° in the right knee (Fig. 4).

**Ethics statement**

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

**DISCUSSION**

Epiphyseal detachments and fractures are common injuries in children and adolescents [4,5]. Few cases have been reported of bilateral femoral epiphyseal detachment in healthy young adults. In adults, these injuries are typically associated with metabolic disorders [6]. Peterson et al. [4] described two cases of epiphyseal detachments in patients over 20 years old, but both had endo-
Our patient had no notable medical history, suggesting that the bilateral detachment was likely due to the injury mechanism of direct back-to-front impact in a standing individual with late physeal fusion. Closed reduction using external movements and pinning is the treatment method most commonly recommended to minimize the risk of complications [7–10]. However, this closed-focus approach should be performed promptly to ensure its effectiveness. The relatively long delay in managing the patient necessitated an open reduction and pinning instead. In fact, we could not achieve reduction without exposing the fracture site and directly manipulating the fragments. We chose pinning because it provides stable fixation and helps prevent complications related to the growth plate, such as physeal damage [9]. This delay was due to the patient’s financial difficulties, as he lacked health insurance. Despite these challenges, our chosen method allowed for anatomical reduction and proper stabilization, leading to successful healing. The progression of distal femoral detachment fractures is characterized by a substantial risk of growth disorders, angular deviations, and joint stiffness due to the high growth potential of the affected area [5,11]. Salter II and IV fractures carry a higher risk of growth failure than other injury types [3]. This was confirmed in our patient, who had a Salter II fracture on the right side and subsequently developed an axis defect and mobility limitations during the course of the disease. These issues were likely related to the type of injury and delayed postoperative mobilization. Although the patient’s functional discomfort was not severe, it is important to recognize the potential for complications in the progression of these injuries, even with appropriate treatment.

In conclusion, bilateral distal femoral epiphyseal detachment is an uncommon injury. It typically occurs in young adults due to severe trauma and is associated with delayed closure of the growth plate. Although attentive treatment can result in recovery, considerable risk of functional complications exists.

ARTICLE INFORMATION

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Data sharing is not applicable as no new data were created or analyzed in this study.

REFERENCES

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