Aims and Scope

Journal of Trauma and Injury (J Trauma Inj, JTI) is the official journal of the Korean Society of Traumatology. JTI was launched in June 1988 with publications in both Korean and English, and eventually became an English-only journal. As an international, peer-reviewed, open access journal, JTI aims to facilitate communication and information exchange on trauma, as well as provide education and training in the field to ultimately save patients' lives.

JTI publishes original basic and clinical research on a range of trauma-associated medical fields, such as surgeries (including general surgery, chest surgery, orthopedic surgery, neurosurgery, plastic surgery, and head and neck surgery), gynecology and ophthalmology, emergency medicine, anesthesia, neuropsychiatry, rehabilitation medicine, and radiology (including interventional radiology). Due to the special circumstances Korea is under with North Korea, JTI also publishes basic and clinical research on battlefield trauma unique in Korea and has established ties with the Armed Forces Medical Command and Armed Forces Capital Hospital.

JTI covers all topics closely related to medicine, disasters, emergency departments, emergency medical technicians and nurses, social infrastructures and systems, and government policies and supports. JTI publishes original articles, case reports/case series, review articles, editorials, correspondences, and articles commissioned by the Editorial Board that are related to basic or clinical research on trauma.

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Penetrating trauma and “The Wound Man”

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A famous Japanese politician was recently shot twice in the neck, which caused hypovolemic shock, and he showed no vital signs on arrival to the hospital. The weapon was a hand-made gun (do-it-yourself gun). This case reveals that gun violence cannot be totally eliminated even in countries with tough gun laws, where citizens are prohibited from buying or owning firearms.

Gunshot wounds are the second most common cause of penetrating trauma, following stab wounds. Stab wounds occur four times more often than gunshot wounds in the United Kingdom, but the reported mortality rate associated with stabbing is 0% to 4% because 85% of stab wounds only affect subcutaneous tissue [1].

This tragic affair of a penetrating injury reminded me of an unforgettable drawing, “The Wound Man,” which I saw years ago in the Wellcome Library, near the British Library (London, UK) (Fig. 1).

“The Wound Man” is a surgical diagram that is enigmatic and troubling. A man’s skin is covered in bleeding cuts and lesions, stabbed and sliced by knives, spears, and swords of various sizes, many of which remain in the skin. The violence and illness shown on the man’s body are all-consuming and total. This diagram first appeared in European medical manuscripts of the 14th and 15th centuries. The illustration served as an annotated table of contents to guide the reader through various injuries and diseases, the cures for which could be found on the text’s nearby pages. The image first appeared in a printed book in 1491, when it was included in the Venetian Fasciculus medicinae, which was likely Europe’s first printed medical miscellany. It circulated widely in printed books until well into the 17th century [2].

The basis of “The Wound Man” is thought to be regional anatomy and physiology. Regarding the importance of functional anatomy in gunshot wounds, a story about Ambroise Paré (1510–1590) has been transmitted. Dr. Paré, in the French army, used a novel technique to aid in bullet extraction. During a battle, a courtier (Maréchal de Brissac, 1505–1563) was shot in the shoulder. When finding the bullet seemed impossible, Dr. Paré had the idea of asking the victim to put himself in the exact position he was in when shot. The bullet was then found and removed [3]. I think this pioneer of modern trauma surgery also read “The Wound Man” and applied it in his practice as a barber surgeon.

Trauma surgeons need a handy atlas and manual. If we make a booklet including the regional...
anatomy for each penetrating wound in a two-dimensional diagram, as well as a three-dimensional visualization, this book would be a successor to “The Wound Man.”

NOTES

Ethical statements
Not applicable.

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

Funding
This study was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (No. NRF-2020R1I1A2054761).

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Analysis of procedural performance after a pilot course on endovascular training for resuscitative endovascular balloon occlusion of the aorta

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Purpose: As resuscitative endovascular balloon occlusion of the aorta (REBOA) is performed in an extremely emergent situation, achieving competent clinical practice is mandatory. Although there are several educational courses that teach the REBOA procedure, there have been no reports evaluating the impact of training on clinical practice. Therefore, this study is aimed to evaluate the effects of the course on procedural performance during resuscitation and on clinical outcomes.

Methods: Patients who were managed at a regional trauma center in Dankook University Hospital from August 2016 to February 2018 were included and were grouped as precourse (August 2016–August 2017, n=9) and postcourse (September 2017–February 2018, n=9). Variables regarding injury, parameters regarding REBOA procedure, morbidity, and mortality were prospectively collected and reviewed for comparison between the groups.

Results: Demographics and REBOA variables did not differ between groups. The time required from arterial puncture to balloon inflation was significantly shortened from 9.0 to 5.0 minutes (P=0.003). There were no complications associated with REBOA after the course. Mortality did not show any statistical difference before and after the course.

Conclusions: The endovascular training for REBOA pilot course, which uses a modified form of flipped learning, realistic simulation of ultrasound-guided catheter insertion and balloon manipulation, and competence assessment, significantly improved procedural performance during resuscitation of trauma patients.

Keywords: Wounds and injuries; Aorta; Balloon occlusion; Education; Outcome assessment

INTRODUCTION

Resuscitative endovascular balloon occlusion of the aorta (RE-BOA) is an alternative to resuscitative thoracotomy followed by aortic cross clamping in patients with hemorrhagic shock [1]. REBOA has recently gained wide acceptance as a potentially
life-saving procedure; however, implementation of REBOA remains limited, and the procedure is regarded as difficult for physicians who have had limited exposure to endovascular techniques. Proper training is mandatory for its successful usage, and the risk of an unsuccessful balloon location is higher in patients whose physicians have not completed training in REBOA [2].

There are several educational courses that teach the REBOA procedure; however, the best methods for training and ensuring competence are not clear [3]. The endovascular training for REBOA (ET-REBOA) course was developed and conducted in Korea [1]. The pilot course of ET-REBOA consists of a modified form of flipped learning, with ultrasound-guided femoral access training and a realistic sensation of balloon catheter manipulation. For the competence assessment, a 13-item procedure checklist, self-reported confidence score of precourse and postcourse, and time taken to complete the procedure were obtained. Although procedural time was substantially decreased among the participants during the course, there is no evidence that this results in proficient placement during clinical application. To the best of our knowledge, there have been no reports evaluating the impact of the REBOA training program in clinical practice. Therefore, this study aimed to evaluate the effects of ET-REBOA pilot course on clinical procedures and patient outcomes.

METHODS

This study was approved by the Institutional Review Board of Dankook University Hospital (No. DKUH 201902006). Written informed consent was waived. Sixteen residents and 12 specialists from Dankook University Hospital with no prior experience in performing the REBOA procedure participated in the ET-REBOA pilot course in September 2017. For patient outcome analysis, patients who were treated by the participant practitioners at a regional trauma center in Dankook University Hospital from August 2016 to February 2018 were included. Patients were grouped as precourse (August 2016–August 2017, n = 9) and postcourse (September 2017–February 2018, n = 9).

Variables regarding injury such as Injury Severity Score, injury site, systolic blood pressure (SBP) before REBOA, and cardiopulmonary resuscitation before REBOA were collected for the analysis. Data regarding the size of the balloon, zone where the balloon was inflated, and method of occlusion (intermittent vs. partial) were also collected. To evaluate the effect of the ET-REBOA course on procedural performance, the time required to decide whether to perform REBOA was defined as the time from patient arrival to arterial puncture, and the time required for the REBOA procedure was defined as the time from arterial puncture to balloon inflation. All parameters were documented during the REBOA procedure using a REBOA recording sheet [4]. REBOA-related complications, 24-hour mortality, and in-hospital mortality were analyzed to evaluate patient outcomes.

For comparison, chi-square tests or Fisher exact tests were used. Statistical significance was set at P < 0.05. All statistical analyses were performed using IBM SPSS ver. 19.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Demographics and REBOA variables
Sex, median age, and body mass index showed no statistical difference between the precourse and postcourse groups. Median Injury Severity Score (29.0 ± 16.7 vs. 38.0 ± 10.8, respectively), SBP before REBOA (56.0 ± 13.8 vs. 53.0 ± 18.3 mmHg, respectively), and the number of patients with cardiopulmonary resuscitation before REBOA were also similar among two groups. The size of the balloon used for REBOA, the zone where the balloon was inflated, percentage of partial occlusion, and SBP after REBOA did not show any difference (Table 1).

Performance change after ET-REBOA course
Median time required to decide whether to perform REBOA was shortened from 33.0 to 15.0 minutes after ET-REBOA course, although statistical significance was not shown (P = 0.104). The time required from arterial puncture to balloon inflation was significantly shortened from 9.0 to 5.0 minutes (P = 0.003) (Table 2).

Diversification of the operators
The number of operators who performed REBOA increased from two to four. For procedural assistance, five physicians, including the residents from the emergency department, were newly involved. A total of six physicians who had no previous experience with REBOA participated in clinical practice after the ET-REBOA course.

Patient outcome
There was one probable complication related to REBOA in the precourse patient group (one patient with skin necrosis of the right dorsum). There were no statistical differences in 24-hour mortality or in-hospital mortality rates for the precourse and postcourse patients.
DISCUSSION

As REBOA is performed in an extremely emergent clinical situation, competence is a prerequisite for the procedure. Evidence-based training and assessment of operator skills are essential for successful implementation and patient safety. However, there have been limited guidelines or consensus regarding the ideal modality for training, educational content, and validated assessment tools for REBOA until recently.

It has been stated that ultrasound-guided percutaneous access to the common femoral artery along with surgical cutdown as needed, sheath and device management, appropriate positioning of the catheter, management of inflation volumes, avoidance of catheter migration, decision making, and team training must be included in the REBOA skill training [5]. Acquiring femoral access can be a time-consuming step because the procedure is often performed in patients with profound hypotension. When combined with obesity, obtaining femoral access can become more challenging; however, this is not covered in all education courses [6,7]. The ET-REBOA course provided ultrasound-guided femoral access training and a realistic sensation of balloon catheter manipulation.

Table 1. Comparison of characteristics regarding injury and REBOA procedure

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Precourse (n=9)</th>
<th>Postcourse (n=9)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex</td>
<td>6 (66.7)</td>
<td>6 (66.7)</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>48.0±19.1 (7.0–74.0)</td>
<td>52.0±19.5 (26.0–89.0)</td>
<td>0.285</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>24.7±3.0 (18.3–27.0)</td>
<td>24.1±2.7 (20.3–29.3)</td>
<td>0.487</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>29.0±16.7 (17.0–75.0)</td>
<td>38.0±10.8 (16.0–50.0)</td>
<td>0.792</td>
</tr>
<tr>
<td>Injury site</td>
<td></td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Pelvis</td>
<td>4 (44.4)</td>
<td>1 (11.1)</td>
<td></td>
</tr>
<tr>
<td>Mesentery and spleen</td>
<td>3 (33.3)</td>
<td>1 (11.1)</td>
<td></td>
</tr>
<tr>
<td>Liver</td>
<td>1 (11.1)</td>
<td>2 (22.2)</td>
<td></td>
</tr>
<tr>
<td>Multiorgan</td>
<td>1 (11.1)</td>
<td>5 (55.6)</td>
<td></td>
</tr>
<tr>
<td>SBP before REBOA (mmHg)</td>
<td>56.0±13.8 (40.0–85.0)</td>
<td>53.0±18.3 (0–60.0)</td>
<td>0.513</td>
</tr>
<tr>
<td>Preprocedure CPR</td>
<td>3 (33.3)</td>
<td>3 (33.3)</td>
<td>&gt;0.999</td>
</tr>
<tr>
<td>Balloon size</td>
<td></td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>12F</td>
<td>1 (11.1)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>7F</td>
<td>8 (88.9)</td>
<td>9 (100)</td>
<td></td>
</tr>
<tr>
<td>Zone</td>
<td></td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>6 (66.7)</td>
<td>7 (77.8)</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>3 (33.3)</td>
<td>2 (22.2)</td>
<td></td>
</tr>
<tr>
<td>REBOA</td>
<td></td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Intermittent</td>
<td>4 (44.4)</td>
<td>3 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Partial</td>
<td>5 (55.6)</td>
<td>6 (66.7)</td>
<td></td>
</tr>
<tr>
<td>SBP after REBOA (mmHg)</td>
<td>104.0±16.1 (66.0–129.0)</td>
<td>99.0±25.7 (75.0–168.0)</td>
<td>0.775</td>
</tr>
</tbody>
</table>

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

REBOA, resuscitative endovascular balloon occlusion of the aorta; NA, not applicable; CPR, cardiopulmonary resuscitation; SBP, systolic blood pressure.

Table 2. Comparison of procedural performance and patient outcome

<table>
<thead>
<tr>
<th>Variable</th>
<th>Precourse (n = 9)</th>
<th>Postcourse (n = 9)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time from arrival to arterial puncture (min)</td>
<td>33.0±48.1 (20–280)</td>
<td>15.0±24.8 (8–87)</td>
<td>0.104</td>
</tr>
<tr>
<td>Time from arterial puncture to balloon inflation (min)</td>
<td>9.0±4.6 (5–13)</td>
<td>5.0±1.9 (2–9)</td>
<td>0.003</td>
</tr>
<tr>
<td>Procedure-related complication</td>
<td>1 (11.1)</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>24-Hour mortality</td>
<td>4 (44.4)</td>
<td>7 (77.7)</td>
<td>0.335</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td>6 (66.7)</td>
<td>8 (88.9)</td>
<td>0.576</td>
</tr>
</tbody>
</table>

Values are presented as median±standard deviation (range) or number (%).
Assessment tools that have been previously used for REBOA training are pre-knowledge and post-knowledge tests, self-evaluated procedural confidence, procedure time, and performance rating. There are limitations to these tools; pre-knowledge and post-knowledge testing does not provide any evidence of procedural competence [3,8]. In addition, obtaining a confidence score from the trainee is not accurate, and it may overestimate the effect of the education as it compares “something” with “nothing.” Several studies have adopted the time taken to complete the procedure for the educational outcome as an assessment tool, including the ET-REBOA course; however, improvement in speed does not guarantee the quality and safety of the procedure performed [8]. Reports of an internationally developed tool for assessing procedural competence has only been published recently [9,10].

In the ET-REBOA course a 13-item checklist was developed to assess competence. Participants were allowed repeated attempts to complete the checklist until they satisfied all items correctly. All participants fulfilled the checklist items on the second attempt, including seven participants who failed at the first attempt [1].

In addition to these efforts, procedural performance during clinical practice was compared before and after the course. The time required to decide whether to perform REBOA was decreased to 50%. Increased self-confidence and preparedness may have minimized hesitation, or the time required to gather proficient team members may have shortened. The time taken to perform the REBOA procedure was significantly decreased, suggesting that the competence of the participants, some of whom had no prior experience in endovascular procedures, improved after training. Residents from surgical and emergency departments who were trained also actively participated in the procedure, making the procedure more efficient. In the study, there was only one complication possibly related to REBOA, which occurred in the precourse group.

To the best of our knowledge, this is the first report evaluating the impact of the REBOA training program in actual clinical practice, however, there are several limitations. First, an internationally developed tool [9,10] was not available for assessing procedural competence in this course. Second, shortening of the procedural time may have been influenced by other factors in addition to the effectiveness of the education provided. Repetitive lectures regarding REBOA were given to various departments of the institute, including nurses and radiologic technicians. Accumulation of experience of the REBOA procedure itself may have influenced the time taken for the REBOA. Third, the number of patients included in the study is relatively small. Lastly, since REBOA is rarely performed, a decline in proficiency level with time must be expected [3]. The results do not contain any information regarding REBOA skill retention. Training may start to wane at 6 months in the absence of clinical REBOA cases, but the study’s results were based on a knowledge test and subjective comfort score [11]. Evaluation of the appropriate interval of the repetitive education is required based on the validated assessment tool for competence.

In conclusion, the ET-REBOA pilot course which uses a modified form of flipped learning, realistic simulation of ultrasound-guided catheter insertion and balloon manipulation, and competence assessment, might have significantly improved procedural performance in clinical practice. The ET-REBOA course could be an effective curriculum for the development of endovascular skills for performing REBOA.

NOTES

Ethical statements
This study was approved by the Institutional Review Board of Dankook University Hospital (No. DKUH 201902006). Written informed consent was waived.

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

Funding
None.

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

REFERENCES


INTRODUCTION

Intracranial hemorrhage is a life-threatening crisis that can appear after an acute traumatic brain injury (TBI). Massive hematoma causes a rise in intracranial pressure (ICP), which can result in brain injury, a permanent vegetative state, or death. Decompressive craniectomy (DC) is performed to reduce ICP; in rare cases, this can result in the appearance and expansion of a contralateral hematoma after surgery. If this possibility is neglected, a poor prognosis may occur [1–5].

Imaging is a necessity of the TBI diagnostic process, and computed tomography (CT) is the most significant test in the acute posttrauma phase [6]. Due to advances in ultrasound technology over the past decade, several authors have well visualized adult cerebral arteries, veins, parenchyma, and ventricular systems through a transtemporal approach using B-mode ultrasonography [7–10].

Therefore, we hypothesized that transcranial sonography...
(TCS) during DC procedures could be used to evaluate brain anatomy. To test the hypothesis, the consistency between TCS during surgery and postoperative CT was evaluated and visualized in terms of the diameter of focal hematoma lesions, lateral ventricle, contralateral subdural hematoma (SDH), and midline shift (MLS).

METHODS

Ethical statements
We investigated patients who presented to the hospital and underwent DC between January 1, 2017 and April 30, 2020. A retrospective cross-sectional study was performed of 35 patients who had a small amount of SDH present on the opposite side in the initial CT scan and underwent TCS during surgery. The study was approved by the Research Ethics Board of the Pusan National University Hospital (No. 2008-003-093). Since both ultrasound and CT scans are part of routine practice for patients during surgery at our hospital, written informed consent was not required. Postoperative CT was evaluated by a neuroradiologist and compared with the TCS results.

Technical methods
TCS was performed by a single operator using a GE logiqE device (GE Healthcare, Milwaukee, WI, USA) and a standard abdominal convex phased-array probe with an average median frequency of 4 MHz and abdominal settings. A dynamic range of 45 to 50 dB was used. After applying a small amount of sterile ultrasound gel, the probe was gently placed on the dura mater so that the ICP did not increase. Scanning was performed at a depth of 16 cm, and the entire brain was scanned in B-mode (Fig. 1).

Midline structure shift
In the axial plane, the midline was evaluated as the line between the two lateral ventricles. After localizing the falx cerebri in the frontal lobe, the distance between the septum pellucidum and the lateral margin of the right ventricle was measured. The distance between the septum pellucidum and the lateral margin of the left ventricle was measured in the same way (Fig. 2A). The difference between the two measured values is the MLS. The consistency between CT and TCS was investigated.

Evaluation of focal hematoma lesions
Intracerebral hemorrhage (ICH) appears as a homogenous, sharply demarcated mass on TCS. We measured the maximum diameter of this mass (Fig. 2A). Focal hematoma lesions are divided into low density and high density according to their density on CT scans. The maximum diameter of ICH confirmed as having high density in the axial plane of the CT scan was measured (Fig. 2B). We investigated the consistency between CT and TCS in evaluating the diameter of the main axis of high-density lesions.

Evaluation of contralateral subdural hematoma lesions
The depth of the contralateral SDH was measured through intraoperative TCS and postoperative CT scans (Fig. 3A, B). We compared the depth measurements between the two devices.

Evaluation of the ventricular system
In patients with an intact skull, the lateral ventricle was studied using the method described by Seidel et al. [11]. By moving the ultrasound beam slightly upward from the midbrain plane, the frontal horn of the lateral ventricle can be detected. The lateral ventricle was always easily visualized by TCS. The distance between the body of lateral ventricle and septum pellucidum was measured (Fig. 2A, B).

Statistical analysis
For statistical analysis, MedCalc ver. 18.11.6 (MedCalc Software, Ostend, Belgium) was used. To study the consistency between CT and TCS in measurements of the MLS, focal lesion size, and the size of the lateral ventricles, the paired t-test or Wilcoxon

Fig. 1. Transcranial sonography was performed during surgery.
Fig. 2. The frontal horns of the lateral ventricle (asterisk) and focal hematoma lesion (arrow) on (A) transcranial sonography and (B) computed tomography (CT) are shown. An excellent linear correlation was found between CT and transcranial sonography in the diameter of (C) the focal hematoma lesion and (D) ventricle size. ICH, intracerebral hemorrhage; US, ultrasonography.

Fig. 3. A subdural hematoma (SDH) was clearly visible on (A) transcranial sonography (TCS) as a hyperechogenic lesion (between the two plus signs) on the opposite side of the craniectomy. (B) A corresponding computed tomography (CT) is shown. (C) An excellent linear correlation was found between CT and TCS in the diameter of the contralateral SDH lesion.
signed-rank test was performed depending on whether the data satisfied the assumption of a normal distribution. The consistency between the techniques was assessed by Bland-Altman plots and intraclass correlation coefficients (ICCs), with an ICC of 0.75 indicating a good correlation. A P-value of less than 0.05 was considered to indicate statistical significance.

RESULTS

Midline shift
MLS was found on TCS in 31 cases. All cases were confirmed on CT, and a good correlation between these two techniques was found (Table 1). The mean difference between the two methods was –1.33 mm (95% confidence interval [CI], –2.00 to –0.65), the ICC was 0.96 (95% CI, 0.88 to 0.99), and no systematic bias was observed in the Bland-Altman plot (Fig. 4).

The diameter of the focal hematoma lesion
In 16 patients, lesions were observed on TCS scans (Fig. 2A). All high-density lesions were visualized on CT (Fig. 2B), and a good correlation was found between TCS and CT (Table 1). The mean diameter difference between the two methods was –2.21 mm (95% CI, –4.32 to –0.09), the ICC was 0.99 (95% CI, 0.99 to 1.00), and no systematic bias was observed in the Bland-Altman plot (Fig. 2C).

Depth of the contralateral subdural hematoma lesion
In 35 patients, lesions were observed on TCS scans (Fig. 3A). All high-density lesions were visualized on CT (Fig. 3B), and a good correlation was found between TCS and CT (Table 1). The mean diameter difference between the two methods was –0.77 mm (95% CI, –1.64 to 0.09), the ICC was 0.96 (95% CI, 0.92 to 0.98), and no systematic bias was observed in the Bland-Altman plot (Fig. 3C).

Table 1. Results of clinical tests

<table>
<thead>
<tr>
<th>Clinical test</th>
<th>TCS</th>
<th>CT</th>
<th>Mean difference (95% CI)</th>
<th>ICC (95% CI)</th>
<th>P-valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midline shift (mm)</td>
<td>5.15±6.23</td>
<td>6.48±6.18</td>
<td>–1.33 (–2.00 to –0.65)</td>
<td>0.96 (0.88 to 0.99)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Focal hematoma lesion (mm)</td>
<td>17.97±41.08</td>
<td>20.18±47.05</td>
<td>–2.21 (–4.32 to –0.09)</td>
<td>0.99 (0.99 to 1.00)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Contralateral SDH lesion (mm)</td>
<td>9.04±6.17</td>
<td>9.82±6.72</td>
<td>–0.77 (–1.64 to 0.09)</td>
<td>0.96 (0.92 to 0.98)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ventricle size (mm)</td>
<td>5.35±1.87</td>
<td>5.42±2.04</td>
<td>–0.07 (–0.44 to 0.30)</td>
<td>0.92 (0.84 to 0.96)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.

TCS, transcranial sonography; CT, computed tomography; CI, confidence interval; ICC, intraclass correlation coefficient; SDH, subdural hemorrhage.

Evaluation of the ventricular system (ventricle size)
A very good correlation was found between TCS and CT (Table 1). The mean difference between the two methods was –0.07 mm (95% CI, –0.44 to 0.30), the ICC was 0.92 (95% CI, 0.84 to 0.96), and no systematic bias was observed in the Bland-Altman plot (Fig. 2D).

DISCUSSION

It is rare for a new hematoma to form on the contralateral side after hematoma removal or for an existing hematoma to expand. The causes of hematoma growth are rupture of a meningeal artery branch, low-tension bleeding, or venous laceration that causes a skull fracture [1]. In general, neurological deterioration, pupillary dilation in response to hematoma, seizure, and intractably increased ICP are critical signs of de novo hematoma formation or volume expansion of a contralateral hematoma after surgery [5,12]. Neurosurgeons depend on CT scans after surgery when he-
matoma formation or expansion is predicted, such as in patients with previous contralateral cranial fractures or hematomas or severe brain escape after removal of the ipsilateral hematoma [1].

Early identification and decompression of the contralateral hematoma can reduce the secondary insult to the normal brain but may lead to safety issues related to CT scanning, surgical wound closure, and transport to the CT room [1]. Some authors have suggested exploratory burr-hole trephination on the other side during the first operation [12], but this is regarded as too invasive a way to prove the probability of hematoma expansion or formation. CT during surgery is an excellent diagnostic tool that is used at some institutions, but it has many limitations, such as economic considerations, preparation and surgical time, and the risk of radiation exposure [1]. Therefore, TCS was considered as an alternative diagnostic tool for TBI patients during surgery, and this study was conducted to confirm the consistency of the results.

The main finding of this study was that TCS during surgery was effective in evaluating ICH, MLS, contralateral subdural hemorrhage, and the dimensions of the ventricular system in patients with DC, just like CT. With ongoing developments in ultrasound technology, TCS has been regarded as a reliable tool to evaluate brain parenchyma in patients with an appropriate acoustic temporal window [7,8,13,14]. In 1993, Becker et al. [14] first reported an accurate functional description of the ultrasound portrayal of brain anatomy; subsequently, several authors have found similar results, and TCS has been extensively studied in many other contexts, such as cerebral perfusion imaging [15–19]. However, few reports have described the application of TCS during DC surgery [20–22].

TCS during surgery has some benefits as a diagnostic tool. First, it can provide meaningful images of the brain. Precise functional descriptions of the ultrasound portrayal of brain anatomy have been given in the literature. Some reports have suggested that low-frequency probes can be used to detect hematoma, intermediate line movements, and ventricle enlargement in the temporal bone of an intact skull [16,17,23,24]. The quality of the lateral images of DC patients is good and the accuracy is not compromised by epidural implantation [20–22]. Furthermore, after bone flap removal, the frequency of the probe may be higher than that of TCS [25]. Thus, an excellent image of the surface area of the brain parenchyma can be acquired. Furthermore, in the event of a large amount of brain herniation during surgery, TCS can be specifically effective in distinguishing various ipsilateral pathologies that require surgery, such as brain hematoma with edema or SDH.

Second, TCS during surgery decreases the time and effort required for imaging compared to postoperative CT and does not need surgical wound closure and transport to the CT room. The application of TCS also decreases the risk of patient aggravation during transport and reduces the time needed for decision-making.

Third, the apparatus required for TCS during surgery is quickly accessible at most institutions. Ultrasonography is generally used by anesthesiologists and can be converted to B-mode ultrasonography by adding a probe to the Doppler sonography machine, which is widely used in neurovascular surgery. Furthermore, TCS has no hazard of radiation exposure to patients or health care providers.

Fourth, when planning an operation to remove a hematoma or insert an instrument for intraventricular pressure measurement when ICH is confirmed on preoperative CT, most of them use navigation CT to determine the location of the lesion or ventricle before and during surgery [26]. However, in patients who have undergone DC, there may be an error in the navigation system due to the phase difference of the parenchyma between the CT image before surgery and the skull after removal. In this case, the location of the hematoma can be reconfirmed using TCS. Also, the insertion of an intraventricular pressure measurement device can be safely performed under TCS guidance.

However, a disadvantage of TCS during surgery is that the image quality is limited compared to that of CT. Caricato et al. [23] described the nonvisualization of low-density ischemic lesions and the posthemorrhage stage in CT scans in 11 patients monitored using bedside TCS. Niesen et al. [24] reported that three out of 25 SDH cases (12%) were missed when using TCS as a poor temporal bone window. TCS also has more limited visibility than CT, so the operator must tilt and move the probe to obtain a complete image of the brain [23,24]. As reported by Kim et al. [1], an epidural hematoma on the opposite side of the frontal lobe may be missed if clinicians do not anticipate the presence of a hematoma due to the presence of an existing left frontal fracture. Since TCS is a user-dependent technique, the operator should be properly trained in accurate evaluation of the brain.

Therefore, TCS cannot completely substitute for CT. Nevertheless, we suggest that TCS during surgery may be an effective diagnostic tool, especially in cases of TBI when time-consuming assessments are limited because of possible systemic compromise and the need for prompt decision-making. Prospective studies are needed to improve our understanding of the usefulness and limitations of TCS compared to CT.

In this study, due to the small number of enrolled patients,
there are some limitations in comparing CT and TCS. We com-
pared and analyzed MLS, focal ICH, contralateral SDH, and ven-
tricle size. The results of TCS showed statistical significance
when compared with CT. TCS during surgery is considered an
effective diagnostic tool for the detection of intraoperative paren-
chymal changes in TBI patients.

NOTES

Ethical statements
The study was approved by the Research Ethics Board of the Pu-
san National University Hospital (No. 2008-003-093). Since both
ultrasound and computed tomography scans are part of routine
practice for patients during surgery at our hospital, written in-
formed consent was not required.

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

Funding
None.

Author contributions
Conceptualization: BCK; Data curation: MH, JHL; Methodolo-
gy: HJC, BCK; Writing–original draft: MH, BCK, JHL; Writing–
review & editing: SHY, HJC. All authors read and approved the
final manuscript.

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Can parents prevent tooth loss related to dental avulsion? An assessment of knowledge related to permanent teeth

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**Purpose:** Dental avulsion injuries have a poor prognosis that largely depends on the immediate steps taken to manage the avulsed tooth. A lack of knowledge about the initial management can lead to tooth loss, with further adverse implications for esthetics, phonetics, and overall growth and function. Hence, the present study aimed to assess parents’ knowledge regarding dental avulsion and the variables associated with their knowledge of avulsion injuries.

**Methods:** A series of closed-ended questions on parents’ knowledge regarding avulsion, such as immediate management, storage media, handling, and urgency of visiting the dentist, was asked. Univariate associations between the outcomes were assessed using the Pearson chi-square test. The chi-square goodness-of-fit test was used to check whether the sample data were representative of the population.

**Results:** In total, 211 mothers and 149 fathers were included, of whom 46.7% had experienced dental trauma during their own childhood. Sixty-one percent of mothers believed that they knew everything necessary about tooth avulsion and its management. A significant number of participants who thought that they had a good level of knowledge about avulsion chose water, tissue, or paper wrap to transport the tooth, and preferred tap water, alcohol, or antiseptic to clean the avulsed tooth.

**Conclusions:** Both mothers and fathers had poor knowledge about tooth avulsion, indicating that there is an immediate need for educational programs focusing on this issue. Since a substantial proportion of participants believed incorrect information, it is vital to disseminate accurate information.

**Keywords:** Tooth dislocation; Tooth luxations; Tooth loss; Dental education

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https://doi.org/10.20408/jti.2021.0094
ciation of Dental Traumatology (IADT), avulsion injuries have a poor prognosis that largely depends on the immediate steps taken to manage the avulsed tooth [1]. Parents, guardians, and primary educators who commonly witness avulsion injuries should have adequate knowledge regarding the initial management, how to handle the tooth, how to transport the tooth, and when to seek appropriate dental care to prevent unnecessary tooth loss. A lack of knowledge can lead to tooth loss, with further adverse implications on esthetics, phonetics, and overall growth and function. Despite the significance of the problem, parents’ knowledge regarding dental avulsion and its management seems to be low in international cohorts [2–4].

Several earlier studies have identified parents’ knowledge about traumatic dental injuries and their management [5–9]; however, few studies have reported comparative findings between mothers and fathers in relation to the variables associated with their knowledge about tooth avulsion [4,9–11]. In addition, no such studies have been conducted in Bahrain. Dental treatments in Bahrain are provided by the Ministry of Health primary care dental clinics that primarily focus on the management of dental emergencies. All dental consultations are free of charge and there are numerous dental outpatients who need to be addressed within a limited time period. There is also a considerable shortage of dental practitioners who can provide the best possible treatment for avulsed teeth within the limited time allocated for each patient. Considering this unique setting in Bahrain, the extrapolation of results from international studies may not be accurate. Adequate knowledge regarding dental avulsion and accurate initial management by parents can help dentists provide successful management of avulsed teeth within the limited time available in our setting. The data collected from this study will be used to establish future educational programs that can positively influence the quality of life of young patients by preventing tooth loss due to avulsion. Hence, the aim of the present study was to assess parents’ knowledge regarding tooth avulsion and the variables associated with their knowledge about avulsion injuries.

METHODS

Ethical statements

The present study is reported according to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [12] for the presentation of cross-sectional studies. The study protocol was approved by the Ministry of Health Primary Care Ethics Committee. Written informed consent was obtained from all the study participants.

Study sample

The study was conducted at five primary care dental clinics, one from each of the five regions in Bahrain. The health centers were chosen based on convenience. In total, 360 mothers or fathers who had at least one child younger than 13 years of age were included. This age group was determined based on evidence that avulsion injuries are more common in this age group. The participants were selected through convenience sampling.

Questionnaire used in the study

A descriptive two-part questionnaire was prepared for the study. The first part consisted of questions on the demographic data of study participants such as age, education level, and sex, as well as any previous history of dealing with dental trauma. The second part of the questionnaire consisted of a case scenario of an avulsed permanent right central incisor with a clinical photograph. A series of closed-ended questions to understand respondents’ knowledge regarding avulsion, such as immediate management, storage media, handling, and urgency of visiting the dentist, were asked. This questionnaire was validated by independent subject experts and pretested on 10 participants. Any ambiguities in the questions or responses were corrected before the actual study.

Statistical analyses

Descriptive statistics were used to analyze the demographic data. Considering a proportion of at least 30% of the population that would fit the inclusion criteria and visit the included primary care dental clinics, at a 95% confidence interval and 5% margin of error, a total sample of 323 was the minimum necessary. Hence, 360 participants were included. Univariate associations between the categorical outcomes and the variables assessed in this study were evaluated using the Pearson chi-square test. The chi-square goodness-of-fit test was used to check whether the sample data were representative of the population. All statistical tests were performed using GraphPad Instat ver. 3.1 (GraphPad Software, San Diego, CA, USA).

RESULTS

Demographic data of the study participants

In total, 211 mothers and 149 fathers were included in this study. The mean ± standard deviation age of study participants was 34.5 ± 1.23 years. Most of the mothers (64.9%) were under 30 years of age. The majority of the study participants had a higher secondary or graduate level of education. Furthermore, 46.7% of
the participants had experienced dental trauma during their own childhood, and 61% of the mothers thought they knew everything necessary about tooth avulsion and its management. Other demographic data are presented in Table 1.

Responses to case scenario

In total, 275 participants correctly identified and named the avulsed tooth from the clinical photograph, of whom 60% were mothers. Although 69.1% of the study participants thought that the avulsed tooth could be saved, only 10% of the participants believed that they would be able to replant the teeth back into the socket. The others would seek the help of a dentist to replant the tooth. As a material to store the avulsed tooth, 23.8% chose water and 25.8% chose paper or tissue wrap. Slightly fewer than half of the participants (45.8%) believed that they should seek help from a dentist within 30 minutes following tooth avulsion. Furthermore, 44.1% preferred antiseptic or alcohol and 36.6% preferred tap water to rinse the avulsed tooth before transport. Detailed responses to the case scenario are presented in Table 2.

Association between the variables assessed in the study

Three variables (the choice of storage medium, method of handling an avulsed tooth, and urgency of undertaking a dental intervention) were assessed for goodness-of-fit using the chi-square test. The P-value was statistically significant, showing that the sample data adequately represented the population that was studied (Table 3). Mothers were significantly more likely than fathers to report correct answers for identification of the tooth, saving an avulsed tooth, and the ability to replant an avulsed tooth. Participants who previously experienced dental trauma were significantly more likely to believe that they would be able to replant a tooth back into the socket. Participants with a higher education or a graduate degree were significantly more likely to think that they knew everything necessary about avulsed teeth, to be able to correctly identify the avulsed tooth, and to think that a dental intervention is mandatory within 30 minutes following avulsion. However, a significant number of participants who thought that they had a good level of knowledge about avulsion were willing to save the tooth, chose water, tissue, or paper wrap to store and transport the tooth, and preferred tap water, alcohol, or antiseptic to clean the avulsed tooth. The P-values for the associations between the variables are presented in Table 4.

DISCUSSION

The present study aimed to assess the variables associated with the knowledge of Bahraini mothers and fathers regarding tooth avulsion. In total, 211 mothers and 149 fathers participated in the study. The questionnaire that was provided was simple, with multiple closed-ended questions based on a case scenario and clinical photograph.

The results from the present study indicate that although 254 of the participants (70.5%) believed that they had a good level of knowledge about tooth avulsion and its initial management, their knowledge regarding the storage medium and how to handle an avulsed tooth was inaccurate. It is critical to have accurate knowledge about these important parameters, which substantially affect the prognosis of avulsed teeth. This finding is similar to the results obtained from previous studies on the knowledge of parents, caregivers, primary educators, and other personnel dealing with children [4–6,10,11]. This information is vital, and it is important that future training programs for parents and those dealing with children should specifically focus on how to handle

Table 1. Variables assessed in this study

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of participants (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>211 (58.6)</td>
</tr>
<tr>
<td>Father</td>
<td>149 (41.3)</td>
</tr>
<tr>
<td>Age (yr)</td>
<td></td>
</tr>
<tr>
<td>&gt;30</td>
<td>243 (67.5)</td>
</tr>
<tr>
<td>≤30</td>
<td>117 (32.5)</td>
</tr>
<tr>
<td>Mother</td>
<td>76 (64.9)</td>
</tr>
<tr>
<td>Father</td>
<td>41 (35.0)</td>
</tr>
<tr>
<td>Education degree</td>
<td></td>
</tr>
<tr>
<td>Graduate/college</td>
<td>120 (33.3)</td>
</tr>
<tr>
<td>Higher secondary school</td>
<td>194 (53.8)</td>
</tr>
<tr>
<td>Elementary school</td>
<td>46 (12.7)</td>
</tr>
<tr>
<td>No. of children ≤13 yr</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2.27</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.33</td>
</tr>
<tr>
<td>Standard error of mean</td>
<td>0.07</td>
</tr>
<tr>
<td>Had previous experience with any dental trauma</td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>88 (57.9)</td>
</tr>
<tr>
<td>Father</td>
<td>64 (42.1)</td>
</tr>
<tr>
<td>Own dental trauma during childhood</td>
<td>71 (46.7)</td>
</tr>
<tr>
<td>Dental trauma of one of their children</td>
<td>68 (44.7)</td>
</tr>
<tr>
<td>Dental trauma of other family members or friends</td>
<td>63 (41.4)</td>
</tr>
<tr>
<td>Thought they had good knowledge about teeth avulsion</td>
<td></td>
</tr>
<tr>
<td>Mother</td>
<td>155 (61.0)</td>
</tr>
<tr>
<td>Father</td>
<td>99 (38.0)</td>
</tr>
</tbody>
</table>
Table 2. Responses to the case scenario

<table>
<thead>
<tr>
<th>Case scenario</th>
<th>Total (n=360)</th>
<th>Mother (n=211)</th>
<th>Father (n=149)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Able to correctly identify and name the avulsed permanent central incisor from the clinical photograph</td>
<td>275 (75.4)</td>
<td>165 (60.0)</td>
<td>110 (40.0)</td>
</tr>
<tr>
<td>Attitude towards avulsed tooth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discard</td>
<td>111 (30.8)</td>
<td>51 (45.9)</td>
<td>60 (54.0)</td>
</tr>
<tr>
<td>Save</td>
<td>249 (69.1)</td>
<td>160 (64.2)</td>
<td>89 (35.7)</td>
</tr>
<tr>
<td>Ability to replant teeth in case of avulsion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can replace teeth back into the socket</td>
<td>36 (10.0)</td>
<td>30 (83.3)</td>
<td>6 (16.6)</td>
</tr>
<tr>
<td>Cannot replant, seek help from the dentist</td>
<td>324 (90.0)</td>
<td>181 (55.8)</td>
<td>143 (44.1)</td>
</tr>
<tr>
<td>Storage medium of choice</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>86 (23.8)</td>
<td>49 (56.9)</td>
<td>37 (43.0)</td>
</tr>
<tr>
<td>Milk</td>
<td>45 (12.5)</td>
<td>30 (66.6)</td>
<td>15 (33.3)</td>
</tr>
<tr>
<td>Saliva</td>
<td>16 (4.4)</td>
<td>9 (56.2)</td>
<td>7 (43.7)</td>
</tr>
<tr>
<td>Wrapped in tissue or paper</td>
<td>93 (25.8)</td>
<td>54 (58.0)</td>
<td>39 (41.9)</td>
</tr>
<tr>
<td>Cloth wrapping</td>
<td>50 (13.8)</td>
<td>30 (60.0)</td>
<td>20 (40.0)</td>
</tr>
<tr>
<td>Carry it in a sandwich bag or any plastic bag</td>
<td>70 (19.4)</td>
<td>54 (77.1)</td>
<td>16 (22.8)</td>
</tr>
<tr>
<td>Urgency to visit a dentist after avulsion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within 30 min</td>
<td>165 (45.8)</td>
<td>99 (60.0)</td>
<td>66 (40.0)</td>
</tr>
<tr>
<td>Within 1 hr</td>
<td>56 (15.5)</td>
<td>35 (62.5)</td>
<td>21 (37.5)</td>
</tr>
<tr>
<td>The following day</td>
<td>18 (5.0)</td>
<td>4 (22.2)</td>
<td>14 (77.7)</td>
</tr>
<tr>
<td>Only when there is pain</td>
<td>74 (20.5)</td>
<td>26 (35.1)</td>
<td>48 (64.8)</td>
</tr>
<tr>
<td>Not sure of any specific time limit</td>
<td>47 (13.0)</td>
<td>12 (25.5)</td>
<td>35 (74.4)</td>
</tr>
<tr>
<td>First place to contact following avulsion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General hospital</td>
<td>120 (33.3)</td>
<td>102 (85.0)</td>
<td>18 (15.0)</td>
</tr>
<tr>
<td>Dental clinic</td>
<td>240 (66.6)</td>
<td>109 (45.4)</td>
<td>131 (54.5)</td>
</tr>
<tr>
<td>Handling avulsed tooth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scrub the tooth gently with toothbrush</td>
<td>55 (15.2)</td>
<td>32 (58.1)</td>
<td>23 (41.8)</td>
</tr>
<tr>
<td>Rinse tooth under tap water</td>
<td>132 (36.6)</td>
<td>84 (63.6)</td>
<td>48 (36.3)</td>
</tr>
<tr>
<td>Do not touch the tooth</td>
<td>14 (3.8)</td>
<td>9 (64.2)</td>
<td>5 (35.7)</td>
</tr>
<tr>
<td>Wash with alcohol or antiseptic</td>
<td>159 (44.1)</td>
<td>87 (54.7)</td>
<td>72 (45.2)</td>
</tr>
<tr>
<td>Follow-up appointment with the dentist (yes)</td>
<td>360 (100)</td>
<td>211 (100)</td>
<td>149 (100)</td>
</tr>
</tbody>
</table>

Table 3. Chi-square goodness-of-fit test for the categorical outcomes assessed in this study (n=360)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Observed</th>
<th>Test proportion</th>
<th>Expected</th>
<th>Contribution to chi-square</th>
<th>Difference</th>
<th>Chi-square</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choice of storage medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>86</td>
<td>0.16</td>
<td>60</td>
<td>11.26</td>
<td></td>
<td>68.16</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Milk</td>
<td>48</td>
<td>0.16</td>
<td>60</td>
<td>2.40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saliva</td>
<td>15</td>
<td>0.16</td>
<td>60</td>
<td>33.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tissue or paper wrap</td>
<td>92</td>
<td>0.16</td>
<td>60</td>
<td>17.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloth wrap</td>
<td>49</td>
<td>0.16</td>
<td>60</td>
<td>2.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic bag</td>
<td>70</td>
<td>0.16</td>
<td>60</td>
<td>1.66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urgency to visit a dentist following avulsion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>172.91</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Within 30 min</td>
<td>165</td>
<td>0.20</td>
<td>72</td>
<td>120.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within 1 hr</td>
<td>56</td>
<td>0.20</td>
<td>72</td>
<td>3.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Only in pain</td>
<td>74</td>
<td>0.20</td>
<td>72</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Following day</td>
<td>18</td>
<td>0.20</td>
<td>72</td>
<td>40.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not sure of the time</td>
<td>47</td>
<td>0.20</td>
<td>72</td>
<td>8.68</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handling avulsed tooth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>150.28</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Scrub the tooth gently with toothbrush</td>
<td>55</td>
<td>0.25</td>
<td>90</td>
<td>13.61</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rinse tooth under tap water</td>
<td>132</td>
<td>0.25</td>
<td>90</td>
<td>19.60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do not directly touch the tooth with hand</td>
<td>14</td>
<td>0.25</td>
<td>90</td>
<td>64.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wash with alcohol or antiseptic</td>
<td>159</td>
<td>0.25</td>
<td>90</td>
<td>52.90</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P≤0.05.
Table 4. Associations between the variables assessed in the study

<table>
<thead>
<tr>
<th>Variable</th>
<th>P-value&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Able to correctly identify and name the avulsed permanent central incisor from the clinical photograph</td>
<td>0.049*</td>
</tr>
<tr>
<td>Previous dental trauma experience</td>
<td>0.814</td>
</tr>
<tr>
<td>Thought they had good knowledge regarding avulsion</td>
<td>0.152</td>
</tr>
<tr>
<td>Saving avulsed teeth</td>
<td>0.001*</td>
</tr>
<tr>
<td>Choice of storage medium</td>
<td>0.978</td>
</tr>
<tr>
<td>Ability to replant teeth</td>
<td>0.002*</td>
</tr>
<tr>
<td>Urgency to undertake dental intervention following avulsion</td>
<td>0.503</td>
</tr>
<tr>
<td>Handling avulsed tooth</td>
<td>0.496</td>
</tr>
<tr>
<td>Any previous dental trauma experience</td>
<td></td>
</tr>
<tr>
<td>Able to correctly identify and name the avulsed permanent central incisor from the clinical photograph</td>
<td>0.139</td>
</tr>
<tr>
<td>Thought they had good knowledge regarding avulsion</td>
<td>0.379</td>
</tr>
<tr>
<td>Saving avulsed teeth</td>
<td>0.666</td>
</tr>
<tr>
<td>Choice of storage medium</td>
<td>0.993</td>
</tr>
<tr>
<td>Ability to replant teeth</td>
<td>0.016*</td>
</tr>
<tr>
<td>Urgency to undertake dental intervention following avulsion</td>
<td>0.116</td>
</tr>
<tr>
<td>Handling avulsed tooth</td>
<td>0.173</td>
</tr>
<tr>
<td>Education level</td>
<td></td>
</tr>
<tr>
<td>Able to correctly identify and name the avulsed permanent central incisor from the clinical photograph</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Thought they had good knowledge regarding avulsion</td>
<td>0.036*</td>
</tr>
<tr>
<td>Saving avulsed teeth</td>
<td>0.547</td>
</tr>
<tr>
<td>Choice of storage medium</td>
<td>0.564</td>
</tr>
<tr>
<td>Ability to replant teeth</td>
<td>0.479</td>
</tr>
<tr>
<td>Urgency to undertake dental intervention following avulsion</td>
<td>0.024*</td>
</tr>
<tr>
<td>Handling avulsed tooth</td>
<td>0.232</td>
</tr>
<tr>
<td>Thought they had good knowledge regarding avulsion</td>
<td></td>
</tr>
<tr>
<td>Able to correctly identify and name the avulsed permanent central incisor from the clinical photograph</td>
<td>0.176</td>
</tr>
<tr>
<td>Saving avulsed teeth</td>
<td>0.001*</td>
</tr>
<tr>
<td>Choice of storage medium</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Ability to replant teeth</td>
<td>0.316</td>
</tr>
<tr>
<td>Urgency to undertake dental intervention following avulsion</td>
<td>0.914</td>
</tr>
<tr>
<td>Handling avulsed tooth</td>
<td>0.038*</td>
</tr>
</tbody>
</table>

<sup>a</sup>Pearson chi-square test for association.

avulsed teeth, including the ideal storage medium. Our study identified that parents believed incorrect information, for which reason it is vital to disseminate the correct information to parents to prevent tooth loss due to avulsion. According to the IADT trauma guidelines, avulsed permanent teeth should be picked up by the crown, rinsed gently in milk, saline, or saliva and immediately replanted back into the socket. An avulsed primary tooth must never be replanted due to the possibility of damaging the permanent tooth germ [1]. This underscores the importance of parents’ ability to differentiate between permanent and primary teeth. This knowledge is extremely important in order to prevent damage to the permanent tooth in cases of primary tooth avulsion, which is why this topic was included in our questionnaire.

The mothers in this study had significantly better knowledge than fathers regarding tooth identification and had a positive attitude towards saving the avulsed tooth. A significant number of mothers believed that they would be able to replant the tooth back into the socket. These results are similar to previous studies showing that mothers displayed better knowledge than fathers [4–6]. However, incorrect knowledge and beliefs regarding the storage medium and handling avulsed teeth were identified in the present study, which would be detrimental to the overall...
prognosis. The majority of the parents chose tissue or paper wrap to transport an avulsed tooth, although leaving the tooth dry by wrapping it in a tissue or paper is extremely detrimental to the prognosis. The periodontal ligament becomes necrotic with limited or no ability to regenerate, leading to replacement resorption as a sequela [1].

Another crucial determinant of the prognosis of an avulsed tooth is the extraoral time. An extraoral time of greater than 60 minutes is associated with a considerably poorer prognosis according to the IADT trauma guidelines [1]. Ninety percent of the parents believed that they would not be able to replant the tooth back into the socket and indicated that they would let the dentist perform the replantation. This would increase the extraoral time, and if the tooth is not properly handled and stored in an appropriate storage medium, the prognosis is extremely poor.

Considering the amount of time that is available for dentists in the primary care dental clinic setting in Bahrain, it is crucial for parents to have thorough knowledge about the initial management of avulsed teeth. The results from the present study indicate that this knowledge is poor among both mothers and fathers, indicating that there is an immediate need for education programs that focus on this issue. A dentist will be unable to save the tooth if the initial management is inappropriate. The proposed education program uses the IADT "Save a Tooth" poster [13], which will be used to educate mothers and fathers. The effect of using these posters on their knowledge will be tested in our future study. The present study is limited by the fact that we did not evaluate the potential impact of any previous dental avulsion education on parents, although this could have potentially influenced the study results.

NOTES

Ethical statements
The study protocol was approved by the Ministry of Health Primary Care Ethics Committee. Written informed consent was obtained from all the study participants.

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

Funding
None.

Author contributions
Conceptualization: all authors; Data curation: all authors; Formal analysis: all authors; Methodology: all authors; Project administration: all authors; Visualization: GS, DA, AAS; Writing—original draft: GS; Writing—review & editing: all authors. All authors read and approved the final manuscript.

REFERENCES


Effect of trauma center operation on emergency care and clinical outcomes in patients with traumatic brain injury

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Department of Emergency Medicine, Wonju Severance Christian Hospital, Yonsei University Wonju College of Medicine, Wonju, Korea

Purpose: Traumatic brain injury (TBI) directly affects the survival of patients and can cause long-term sequelae. The purpose of our study was to investigate whether the operation of a trauma center in a single tertiary general hospital has improved emergency care and clinical outcomes for patients with TBI.

Methods: The participants of this study were all TBI patients, patients with isolated TBI, and patients with TBI who underwent surgery within 24 hours, who visited our level 1 trauma center from March 1, 2012 to February 28, 2020. Patients were divided into two groups: patients who visited before and after the operation of the trauma center. A comparative analysis was conducted. Differences in detailed emergency care time, hospital stay, and clinical outcomes were investigated in this study.

Results: On comparing the entire TBI patient population via dividing them into the aforementioned two groups, the following results were found in the group of patients who visited the hospital after the operation of the trauma center: an increased number of patients with a good functional prognosis ($P<0.001$ and $P=0.002$, respectively), an increased number of surviving discharges ($P<0.001$ and $P<0.001$, respectively), and a reduction in overall emergency care time ($P<0.05$, for all item values). However, no significant differences existed in the length of intensive care unit stay, ventilator days, and total length of stay for TBI patients who visited the hospital before and after the operation of the trauma center.

Conclusions: The findings confirmed that overall TBI patients and patients with isolated brain injury had improved treatment results and emergency care through the operation of a trauma center in a tertiary general hospital.

Keywords: Trauma centers; Brain injuries; Emergency treatment
INTRODUCTION

In Korea, trauma is the fourth leading cause of death and the most common cause of death for people under 40 years of age. Transportation accidents are the third leading cause of death among adolescents and young adults aged 10 to 39 years [1]. In addition, based on the Statistical Yearbook of the National Emergency Medical Center, as of December 31, 2020, 34,318 trauma patients visited 17 medical institutions designated as regional trauma centers in Korea. The most frequent anatomical sites that received treatment were the head and neck (68.1%) [2]. This finding suggests that patients with head injury account for a large proportion of patients treated at trauma centers. As such, traumatic brain injury (TBI) is a disease that can pose a significant threat to life and has a high possibility of causing life-long functional sequelae after an accident [3].

The development of the trauma care system, which started in developed countries such as the United States and Canada, has contributed to reducing preventable trauma deaths and increasing the survival rate of trauma patients. Moreover, based on previous studies, the importance of specialized trauma teams and trauma centers in charge of treating patients with severe trauma is understood, and the positive effects of trauma centers and trauma teams on overall trauma patient treatment outcomes have been demonstrated [4–6].

Interest in treating trauma patients has increased in Korea; therefore, regional trauma centers have been opened and operating since 2012, and, partially because of these efforts, the preventable mortality rate of patients with severe trauma is on the decline [7]. Patients with TBI have an increased survival rate when treated at trauma centers, compared to nontrauma centers [8]. However, in Korea, the effect of operating a regional trauma center on patients with TBI remains unknown. Therefore, in this study, we aimed to investigate how the operation of a trauma center affects the emergency treatment process and outcomes of patients with TBI.

METHODS

Ethical statements
This study was approved by the Institutional Review Board Wonju Severance Christian Hospital (No. 2022-0441-001). Informed consent was waived due to the retrospective nature of the study.

Study design
This study featured an observational cohort design and prospective data collection. From March 1, 2012 to February 28, 2021, among trauma patients who visited a regional trauma center, the patients who were issued an injury code related to TBI were set as the population, and the data were collected retrospectively. To compare differences in patient care, based on the operation of the trauma centers, patients were categorized into two groups according to the admission date: (1) the before trauma center group, comprising patients admitted between March 2012 and December 2014 and (2) the after trauma center group, comprising patients admitted between January 2015 and February 2021. The inclusion criteria were patients with traumatic head injuries of at least 2 points on the Abbreviated Injury Scale (AIS) and who visited the emergency department within 24 hours after the accident. Patients with head trauma who were transferred from the emergency department to another hospital were excluded because their prognosis was unknown.

The data were obtained from electronic medical records, the National Emergency Department Information System (NEDIS), and the Korean Trauma Data Bank (KTDB). The NEDIS and KTDB were developed to serve as national data repositories managed by the Korean government. Level I trauma centers are required to register with the NEDIS and KTDB. To know the basic characteristics of the patients, the following were investigated: age, sex, history, visit route, visit method, accident mechanism, and time from accident occurrence until the emergency department visit. In addition, among the clinical data, the following were also investigated immediately after the emergency department visit: consciousness level, pupil reflex, pupil size, Glasgow Coma Scale (GCS) total score, head and neck AIS, and Injury Severity Score (ISS) items. Among these, patients with incorrect or missing values were excluded from the analysis.

Study outcome
The study’s primary outcome was the difference in disability and mortality between the two groups. The Glasgow Outcome Scale (GOS) was checked on discharge to determine the patients’ disability rate. A patient’s mortality was confirmed, based on the patient’s discharge date. For the secondary outcome, we attempted to investigate the time elements related to emergency care and length of stay. Time elements related to care included the time from the emergency department visit until the decision to activate the trauma team, the time from the emergency department visit until the involvement of the neurosurgeon, the time from the emergency department visit until the neurosurgeon’s first prescription, the time from the emergency department visit until undergoing a head computed tomography (CT) scan, the time...
from the emergency department visit until the issuance of the in-
patient admission, the time from the emergency department visit
until the ward admission, and the time from the emergency de-
partment visit until entering the operating room. Our hospital
had been operating a trauma team before the trauma center was
opened; therefore, comparing differences in activation time of
the trauma team before and after the opening of the trauma cen-
ter was possible. Neurosurgeon care was defined as the care ad-
ministered when the trauma team’s on-call neurosurgeon arrived
at the emergency department and left a medical record. In the
situation in which patients visiting the hospital had head CT data
obtained at another hospital, the head CT scan time data were
not included. In addition, the ventilator days of patients and the
length of stay in the hospital or the intensive care unit (ICU) were
checked.

Statistical analysis
The difference in injury severity between the two groups (i.e., be-
fore and after the operation of the trauma center) was adjusted
through propensity score matching for the entire TBI patient
group, the isolated TBI patient group, and the isolated TBI pa-
tient group who underwent surgery within 24 hours. The prop-
sensity score was estimated using logistic regression, and prop-
sensity score matching was conducted in the caliper 0.2 to 1:1 ra-
tio for the after trauma center group, based on the covariates and
the calculated propensity score. Continuous variables were com-
pared in the form of the mean ± standard deviation, using the
Student t-test and chi-square test. Fisher exact test was used, as
appropriate, for the categorical variables. A P-value of less than
0.05 was interpreted as statistically significant. Statistical analysis
was conducted using IBM SPSS ver. 25.0 (IBM Corp., Armonk,
NY, USA).

RESULTS
The total number of patients with TBI enrolled in the study was
3,339. After conducting propensity score matching in a 1:1 ratio,
775 patients were in the before trauma center group and 775 pa-
tients were in the after trauma center group (Fig. 1).

The mean age, sex, transport route, and mechanism of injury
did not differ between the two groups (Table 1). With regard to
transportation, the number of patients transferred to emergency
medical services was higher in the after trauma center group
than in the before trauma center group, but the number of pa-
tients who visited by themselves such as by car was decreased in
the after trauma center group (P = 0.014). The GCS score, ISS
score, AIS score, the response on arrival at the emergency depart-
ment, the presence or absence of pupil reflexes in the right and
left eyes, and the surgery performed on the patients were not sig-
nificantly different between the two groups. However, the pro-
portion of subdural hemorrhage patients has increased since the
operation of trauma centers, which can be interpreted as an in-
crease in the number of transfer cases of patients with TBI who
are considered as requiring urgent surgery at other hospitals.

When comparing the clinical results between the two groups,
the posttrauma center group had more patients with good recov-
ery, based on GOS score at discharge, and more surviving pa-
tients than did the before trauma center group (P < 0.001 and
P < 0.001, respectively) (Table 2). In the after trauma center
group, the time from the patient's visit to the emergency depart-
ment until the activation of the trauma team, the time until see-
ing a neurosurgeon, the time until undergoing a head CT scan,
the time until the issuance of inpatient admission, the time to
hospitalization, and the time until entering the operating room
were all decreased (P = 0.001, P < 0.001, P < 0.001, P = 0.020,
P < 0.001, P < 0.01, and P = 0.030, respectively). However, differ-
ces in ICU stay, ventilator days, and the total ICU stay between
the two groups were not statistically significant. In addition, no
difference existed between the two groups in the time from the
occurrence of an injury until the emergency department visit and
the ISS score.

The subgroup analysis of patients with isolated TBI with an
AIS score of ≤ 2 in areas other than the head and neck area re-
vealed that 621 patients visited before the operation of the tra-
uma center, and 605 patients visited after. In the after trauma cen-
ter group, the number of patients with a good recovery increased
(P = 0.002). The proportion of survivors was increased in the af-
ter trauma center group (P < 0.001), compared to the before trau-

![Fig. 1. Study flowchart detailing the selection of traumatic brain in-
jury patients in our facility. AIS, Abbreviated Injury Score; ED, emer-
gency department.](https://doi.org/10.20408/jti.2022.0049)
Table 1. Demographic characteristics of the patients with traumatic brain injury (n=1,550)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Before trauma center group (n=775)</th>
<th>After trauma center group (n=775)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td>0.130</td>
</tr>
<tr>
<td>Male</td>
<td>590 (76.1)</td>
<td>563 (72.6)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>185 (23.9)</td>
<td>212 (27.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Age (yr)</strong></td>
<td>51.4±22.4</td>
<td>51.5±22.3</td>
<td>0.921</td>
</tr>
<tr>
<td><strong>Transport route</strong></td>
<td></td>
<td></td>
<td>0.855</td>
</tr>
<tr>
<td>On-scene transport</td>
<td>429 (55.4)</td>
<td>423 (54.6)</td>
<td></td>
</tr>
<tr>
<td>Interhospital transport</td>
<td>343 (44.3)</td>
<td>350 (45.2)</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>3 (0.4)</td>
<td>2 (0.3)</td>
<td></td>
</tr>
<tr>
<td><strong>Transport method</strong></td>
<td></td>
<td></td>
<td>0.014</td>
</tr>
<tr>
<td>EMS ambulance</td>
<td>323 (41.7)</td>
<td>361 (46.6)</td>
<td></td>
</tr>
<tr>
<td>Hospital or other ambulance</td>
<td>282 (36.4)</td>
<td>299 (38.6)</td>
<td></td>
</tr>
<tr>
<td>Car or walk-in</td>
<td>146 (18.8)</td>
<td>79 (10.2)</td>
<td></td>
</tr>
<tr>
<td>Air transport</td>
<td>24 (3.1)</td>
<td>36 (4.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Injury mechanism</strong></td>
<td></td>
<td></td>
<td>0.271</td>
</tr>
<tr>
<td>TA by car/van/jeep/truck/bus/train</td>
<td>141 (18.2)</td>
<td>230 (29.7)</td>
<td></td>
</tr>
<tr>
<td>TA by bike/motorcycle/pedestrian</td>
<td>179 (23.1)</td>
<td>110 (14.2)</td>
<td></td>
</tr>
<tr>
<td>Fall</td>
<td>148 (19.1)</td>
<td>164 (21.2)</td>
<td></td>
</tr>
<tr>
<td>Slip down</td>
<td>146 (18.8)</td>
<td>97 (12.5)</td>
<td></td>
</tr>
<tr>
<td>Struck by person or object</td>
<td>123 (15.9)</td>
<td>113 (14.6)</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>17 (2.2)</td>
<td>4 (0.5)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>21 (2.7)</td>
<td>57 (7.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Glasgow Coma Scale</strong></td>
<td></td>
<td></td>
<td>0.156</td>
</tr>
<tr>
<td>Head and neck</td>
<td>3.1±0.9</td>
<td>3.1±0.9</td>
<td>0.867</td>
</tr>
<tr>
<td>Face</td>
<td>0.6±0.9</td>
<td>0.7±0.9</td>
<td>0.161</td>
</tr>
<tr>
<td>Chest</td>
<td>0.6±1.2</td>
<td>0.7±1.2</td>
<td>0.561</td>
</tr>
<tr>
<td>Abdomen</td>
<td>0.3±0.8</td>
<td>0.3±0.7</td>
<td>0.194</td>
</tr>
<tr>
<td>Pelvis and extremity</td>
<td>0.5±0.9</td>
<td>0.7±1.1</td>
<td>0.001</td>
</tr>
<tr>
<td>External</td>
<td>0.1±0.3</td>
<td>0.0±0.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Injury Severity Score</strong></td>
<td></td>
<td></td>
<td>0.186</td>
</tr>
<tr>
<td>Head and neck</td>
<td>3.1±0.9</td>
<td>3.1±0.9</td>
<td></td>
</tr>
<tr>
<td>Face</td>
<td>0.6±0.9</td>
<td>0.7±0.9</td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td>0.6±1.2</td>
<td>0.7±1.2</td>
<td></td>
</tr>
<tr>
<td>Abdomen</td>
<td>0.3±0.8</td>
<td>0.3±0.7</td>
<td></td>
</tr>
<tr>
<td>Pelvis and extremity</td>
<td>0.5±0.9</td>
<td>0.7±1.1</td>
<td></td>
</tr>
<tr>
<td>External</td>
<td>0.1±0.3</td>
<td>0.0±0.2</td>
<td></td>
</tr>
<tr>
<td><strong>Abbreviated Injury Score</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head and neck</td>
<td>3.1±0.9</td>
<td>3.1±0.9</td>
<td>0.867</td>
</tr>
<tr>
<td>Face</td>
<td>0.6±0.9</td>
<td>0.7±0.9</td>
<td>0.161</td>
</tr>
<tr>
<td>Chest</td>
<td>0.6±1.2</td>
<td>0.7±1.2</td>
<td>0.561</td>
</tr>
<tr>
<td>Abdomen</td>
<td>0.3±0.8</td>
<td>0.3±0.7</td>
<td>0.194</td>
</tr>
<tr>
<td>Pelvis and extremity</td>
<td>0.5±0.9</td>
<td>0.7±1.1</td>
<td>0.001</td>
</tr>
<tr>
<td>External</td>
<td>0.1±0.3</td>
<td>0.0±0.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>Response on ED arrival</strong></td>
<td></td>
<td></td>
<td>0.853</td>
</tr>
<tr>
<td>Unresponsive</td>
<td>34 (4.4)</td>
<td>40 (5.2)</td>
<td></td>
</tr>
<tr>
<td>Painful response</td>
<td>94 (12.1)</td>
<td>96 (12.4)</td>
<td></td>
</tr>
<tr>
<td>Verbal response</td>
<td>188 (24.3)</td>
<td>178 (23.0)</td>
<td></td>
</tr>
<tr>
<td>Alert</td>
<td>459 (59.2)</td>
<td>461 (59.5)</td>
<td></td>
</tr>
<tr>
<td><strong>Pupil reflex</strong></td>
<td></td>
<td></td>
<td>0.167</td>
</tr>
<tr>
<td>Righta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>438 (87.6)</td>
<td>560 (88.2)</td>
<td></td>
</tr>
<tr>
<td>Sluggish</td>
<td>4 (0.8)</td>
<td>10 (1.6)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>52 (10.4)</td>
<td>51 (8.0)</td>
<td></td>
</tr>
<tr>
<td>Non-checkable</td>
<td>6 (1.2)</td>
<td>14 (2.2)</td>
<td></td>
</tr>
<tr>
<td>Average pupil size (mm)</td>
<td>3.06±1.30</td>
<td>2.70±0.98</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Leftb</td>
<td></td>
<td></td>
<td>0.238</td>
</tr>
<tr>
<td>Yes</td>
<td>436 (87.7)</td>
<td>563 (88.5)</td>
<td></td>
</tr>
<tr>
<td>Sluggish</td>
<td>4 (0.8)</td>
<td>7 (1.1)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>54 (10.9)</td>
<td>57 (9.0)</td>
<td></td>
</tr>
<tr>
<td>Non-checkable</td>
<td>3 (0.6)</td>
<td>9 (1.4)</td>
<td></td>
</tr>
<tr>
<td>Average pupil size (mm)</td>
<td>3.06±1.37</td>
<td>2.67±0.99</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

(Continued on the next page)
Table 1. (Continued)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Before trauma center group (n=775)</th>
<th>After trauma center group (n=775)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Past history</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>128 (16.5)</td>
<td>209 (27.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>63 (8.1)</td>
<td>110 (14.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Neurovascular disease</td>
<td>9 (1.2)</td>
<td>8 (1.0)</td>
<td>0.807</td>
</tr>
<tr>
<td>Cardiovascular disease</td>
<td>2 (0.3)</td>
<td>18 (2.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Respiratory disease</td>
<td>6 (0.8)</td>
<td>12 (1.5)</td>
<td>0.235</td>
</tr>
<tr>
<td>Hepatic disease</td>
<td>4 (0.5)</td>
<td>18 (2.3)</td>
<td>0.004</td>
</tr>
<tr>
<td>Chronic renal disease</td>
<td>2 (0.3)</td>
<td>8 (1.0)</td>
<td>0.108</td>
</tr>
<tr>
<td>Hematology-oncology disease</td>
<td>3 (0.4)</td>
<td>32 (4.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Laboratory exam result</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>7.40±0.09</td>
<td>7.40±0.09</td>
<td>0.687</td>
</tr>
<tr>
<td>P0₂ (mmHg)</td>
<td>110.7±45.8</td>
<td>124.2±48.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>PCo₂ (mmHg)</td>
<td>34.4±7.8</td>
<td>34.9±7.0</td>
<td>0.292</td>
</tr>
<tr>
<td>Base excess (mmol/L)</td>
<td>-3.19±4.36</td>
<td>-2.98±4.48</td>
<td>0.411</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
<td>2.7±2.0</td>
<td>3.1±2.3</td>
<td>&lt;0.016</td>
</tr>
<tr>
<td>White blood cell (10⁹/L)</td>
<td>12.63±7.65</td>
<td>12.34±5.67</td>
<td>0.405</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>13.4±2.1</td>
<td>13.5±2.1</td>
<td>0.858</td>
</tr>
<tr>
<td>Platelet (10⁹/L)</td>
<td>245.5±79.3</td>
<td>243.5±79.2</td>
<td>0.599</td>
</tr>
<tr>
<td>Prothrombin time INR</td>
<td>1.03±0.45</td>
<td>1.08±0.53</td>
<td>0.085</td>
</tr>
<tr>
<td>Partial prothrombin time (sec)</td>
<td>30.2±6.4</td>
<td>27.2±6.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Glucose (mg/dL)</td>
<td>150.0±57.5</td>
<td>151.7±60.6</td>
<td>0.584</td>
</tr>
<tr>
<td>Main diagnosis</td>
<td></td>
<td></td>
<td>0.008</td>
</tr>
<tr>
<td>Epidural hemorrhage</td>
<td>99 (12.8)</td>
<td>77 (9.9)</td>
<td></td>
</tr>
<tr>
<td>Subdural hemorrhage</td>
<td>245 (31.6)</td>
<td>280 (36.1)</td>
<td></td>
</tr>
<tr>
<td>Intracranial hemorrhage</td>
<td>166 (21.4)</td>
<td>144 (18.6)</td>
<td></td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>109 (14.1)</td>
<td>138 (17.8)</td>
<td></td>
</tr>
<tr>
<td>Skull fracture</td>
<td>148 (19.1)</td>
<td>120 (15.3)</td>
<td></td>
</tr>
<tr>
<td>No visible finding on CT</td>
<td>8 (1.0)</td>
<td>16 (2.1)</td>
<td></td>
</tr>
<tr>
<td>Operation¹</td>
<td></td>
<td></td>
<td>0.492</td>
</tr>
<tr>
<td>Decompressive craniectomy</td>
<td>70 (51.9)</td>
<td>51 (55.4)</td>
<td></td>
</tr>
<tr>
<td>Craniotomy</td>
<td>28 (20.7)</td>
<td>13 (14.1)</td>
<td></td>
</tr>
<tr>
<td>Burr hole trephination</td>
<td>12 (8.9)</td>
<td>12 (13.0)</td>
<td></td>
</tr>
<tr>
<td>Others (skull elevation, etc.)</td>
<td>25 (18.5)</td>
<td>16 (17.4)</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as number (%) or mean±standard deviation.
EMS, emergency medical services; TA, traffic accident; ED, emergency department; INR, international normalized ratio; CT, computer tomography.
¹Before trauma center group, n=500; after trauma center group, n=635. ²Before trauma center group, n=497; after trauma center group, n=636. ³Before trauma center group, n=135; after trauma center group, n=92.

ma center group (Table 3). All factors related to treatment time also decreased statistically significantly. No difference existed between the before trauma center and after trauma center groups in ICU stay and ventilator days (P = 0.647 and P = 0.302, respectively), but the total length of stay decreased slightly in the after trauma center group (P = 0.013).

Finally, a subgroup analysis of patients with isolated TBI who underwent surgery within 24 hours of visiting the emergency department was conducted (Table 4). No difference existed in the severity in the before trauma center and after trauma center groups, based on the ISS (20.7 ± 7.7 vs. 20.7 ± 7.2, P = 0.987). Contrary to previous results, the before trauma center and after trauma center groups had no significant difference in the GOS score at discharge and survival at discharge (P = 0.197 and P = 0.444, respectively). No differences existed between the two groups in ICU stay, number of days on a ventilator, and length of stay (P = 0.329, P = 0.167, and P = 0.426, respectively).

In the time items related to emergency care, the time from visiting the emergency department until receiving a prescription from a neurosurgeon and the time taken to make the decision to
Table 2. Clinical outcomes of before and after trauma center groups (n=1,550)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Before trauma center group (n=775)</th>
<th>After trauma center group (n=775)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From injury to ED visit</td>
<td>182.1±265.0</td>
<td>181.9±250.9</td>
<td>0.985</td>
</tr>
<tr>
<td>From ED visit to trauma team call</td>
<td>15.83±26.3</td>
<td>8.15±13.9</td>
<td>0.001</td>
</tr>
<tr>
<td>From ED visit to NS specialist consultation</td>
<td>23.9±29.4</td>
<td>13.0±16.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>From ED visit to order documentation by NS physician</td>
<td>185.2±270.6</td>
<td>121.0±158.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>From ED visit to brain CT acquisition</td>
<td>103.4±527.0</td>
<td>44.2±32.4</td>
<td>0.020</td>
</tr>
<tr>
<td>From ED visit to admission decision</td>
<td>195.5±214.1</td>
<td>118.8±312.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>From ED visit to admission</td>
<td>385.4±343.9</td>
<td>289.8±508.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>From ED visit to operation room</td>
<td>1,640.4±4,751.5</td>
<td>4,931.4±13,801.8</td>
<td>0.030</td>
</tr>
<tr>
<td>Length of ICU stay (day)</td>
<td>6.6±14.0</td>
<td>6.5±13.7</td>
<td>0.892</td>
</tr>
<tr>
<td>Ventilation (day)</td>
<td>2.2±6.9</td>
<td>2.3±7.4</td>
<td>0.889</td>
</tr>
<tr>
<td>Length of hospital stay (day)</td>
<td>25.1±35.2</td>
<td>22.7±31.3</td>
<td>0.182</td>
</tr>
<tr>
<td>GOS score at discharge\g)</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>5 (Good recovery)</td>
<td>86 (33.1)</td>
<td>287 (48.9)</td>
<td></td>
</tr>
<tr>
<td>4 (Moderate disability)</td>
<td>105 (40.4)</td>
<td>174 (29.6)</td>
<td></td>
</tr>
<tr>
<td>3 (Severe disability)</td>
<td>32 (12.3)</td>
<td>82 (14.0)</td>
<td></td>
</tr>
<tr>
<td>2 (Vegetative)</td>
<td>2 (0.8)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1 (Dead)</td>
<td>35 (13.5)</td>
<td>44 (7.5)</td>
<td></td>
</tr>
<tr>
<td>Prognosis</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Survival</td>
<td>593 (76.5)</td>
<td>685 (88.4)</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>72 (9.3)</td>
<td>48 (6.2)</td>
<td></td>
</tr>
<tr>
<td>Dead on arrival</td>
<td>3 (0.4)</td>
<td>6 (0.8)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>107 (13.8)</td>
<td>36 (4.6)</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation or number (%).
ED, emergency department; NS, neurosurgeon; CT, computer tomography; ICU, intensive care unit; GOS, Glasgow Outcome Scale.
\a)Before trauma center group, n=150; after trauma center group, n=509. \b)Before trauma center group, n=103; after trauma center group, n=452. \c)Before trauma center group, n=575; after trauma center group, n=605. \d)Before trauma center group, n=435; after trauma center group, n=166. \e)Before trauma center group, n=622; after trauma center group, n=720. \f)Before trauma center group, n=135; after trauma center group, n=92. \g)Before trauma center group, n=260; after trauma center group, n=587.

be hospitalized were decreased in the after trauma center group (P = 0.001 and P = 0.001, respectively), but no difference existed otherwise.

**DISCUSSION**

The purpose of our study was to investigate whether the operation of a trauma center in a single tertiary general hospital has improved emergency care and clinical outcomes of patients with TBI. Our findings confirmed that the establishment of trauma centers has had a beneficial effect on treatment results and the emergency care of patients with traumatic brain injuries. We believe this study is the first study in Korea to confirm the effect of establishing trauma centers on patients with TBIs.

In previous studies, age, GCS, pupil reflex, and CT findings were strong predictors of treatment outcomes in patients with TBI [9]. In our study, propensity score matching was conducted so that no statistical difference existed in these baseline characteristics in the groups before and after the operation of the trauma center. Moreover, we identified an improvement in the disability and survival rates of patients with a TBI in the after trauma center group, even with the selection bias reduced through propensity score matching. Some reports have shown that patients with severe TBI treated at a level I trauma center had better survival rates and clinical outcomes than patients treated at a lower level trauma center [10,11]. Our study also showed that the survival rate and the functional prognosis of patients with TBI improved after the operation of the trauma center, which was consistent with results reported in previous study [4]. The difference in prognosis was not statistically significant between the two groups in patients with isolated TBI who underwent surgery 24 hours after visiting the emergency department, although the proportion of patients who survived and were discharged after the operation of the trauma center was higher than that before the
operation of the trauma center. The proportion slightly increased (before, 75.6% vs. after, 80.0%).

One purpose of this study was to investigate in more detail how a trauma center affects the emergency treatment process of trauma patients via the analysis of time items related to emergency treatment. It was observed that the time from the visit of the trauma patient until the activation of the trauma team and the treatment and prescription by the neurosurgeon was faster after the operation of the trauma center, which is presumedly because of improvement in the trauma team activation system. In our hospital, after starting the trauma center, the trauma care system was improved in such a way that surgical specialists from each department, including neurosurgeons belonging to the trauma team, could quickly treat patients and make treatment plans immediately after visiting trauma patients in the emergency department. As a result, discussions among specialists regarding the initial diagnosis and treatment plan of trauma patients have become active, and the actual treatment start time seems to have been shortened.

An accepted fact is that patients with TBI need a head CT scan as immediately as possible to confirm the degree of brain damage and to determine whether the lesion requires surgical treatment [12]. Furthermore, a CT scan significantly shortens the time spent in the emergency department, including the time for interventions such as surgery [13,14]. In addition, based on the results of a previous study, the mortality rate in patients with TBI aged 70 years or older increases in proportion to a delay in brain injury diagnosis [13]. To reduce the waiting time for CT scans, a CT scan room for trauma patients was newly established in the trauma center. In addition, this CT imaging room is operated with the highest priority for trauma patients visiting the emergency department and patients admitted to the trauma ward via coop-

| Table 3. Clinical outcomes of before and after trauma center groups except for patients with area other than the head AIS≤2 (n=1,226) |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| **Outcome**                                      | **Before trauma center group (n=621)**          | **After trauma center group (n=605)**            | **P-value**                                     |
| Time (min)                                       |                                                 |                                                 |                                                 |
| From injury to ED visit                         | 192.7±275.3                                    | 187.6±262.6                                     | 0.744                                           |
| From ED visit to trauma team call               | 17.1±25.7                                      | 9.2±14.7                                        | 0.004                                           |
| From ED visit to NS specialist consultation     | 26.2±30.0                                      | 14.0±16.2                                       | <0.001                                          |
| From ED visit to order documentation by NS physician | 181.6±272.2                                  | 116.6±158.7                                     | <0.001                                          |
| From ED visit to brain CT acquisition           | 107.6±518.1                                    | 43.7±34.0                                       | 0.022                                           |
| From ED visit to admission decision             | 186.3±206.2                                    | 133.4±350.0                                     | 0.003                                           |
| From ED visit to admission                      | 371.4±335.7                                    | 310.7±562.5                                     | 0.022                                           |
| From ED visit to operation room                 | 1,335.4±3,749.6                                 | 4,987.7±12,403.8                                | 0.018                                           |
| Length of ICU stay (day)                        | 5.7±13.6                                       | 5.3±13.3                                        | 0.647                                           |
| Ventilation (day)                               | 1.7±6.5                                        | 1.4±5.1                                         | 0.302                                           |
| Length of hospital stay (day)                   | 23.5±33.4                                      | 19.0±26.3                                       | 0.013                                           |
| GOS score at discharge                          |                                                 |                                                 | 0.002                                           |
| 5 (Good recovery)                               | 77 (35.8)                                      | 245 (52.9)                                       |                                                 |
| 4 (Moderate disability)                         | 91 (42.3)                                      | 137 (29.6)                                      |                                                 |
| 3 (Severe disability)                           | 27 (12.6)                                      | 54 (11.7)                                       |                                                 |
| 2 (Vegetative)                                  | 2 (0.9)                                        | 0                                              |                                                 |
| 1 (Dead)                                        | 18 (8.4)                                       | 27 (5.8)                                        |                                                 |
| Prognosis                                       |                                                 |                                                 | <0.001                                          |
| Survival                                        | 496 (79.9)                                     | 545 (90.1)                                      |                                                 |
| Death                                           | 35 (5.6)                                       | 28 (4.6)                                        |                                                 |
| Dead on arrival                                 | 1 (0.2)                                        | 2 (0.3)                                         |                                                 |
| Unknown                                         | 89 (14.3)                                      | 30 (5.0)                                        |                                                 |

Values are presented as mean±standard deviation or number (%).
AIS, Abbreviated Injury Score; ED, emergency department; NS, neurosurgeon; CT, computer tomography; ICU, intensive care unit; GOS, Glasgow Outcome Scale.

*Before trauma center group, n=100; after trauma center group, n=356. **Before trauma center group, n=69; after trauma center group, n=317. ***Before trauma center group, n=458; after trauma center group, n=464. ****Before trauma center group, n=352; after trauma center group, n=127. *****Before trauma center group, n=495; after trauma center group, n=561. ******Before trauma center group, n=109; after trauma center group, n=71. *******Before trauma center group, n=215; after trauma center group, n=463.

https://doi.org/10.20408/jti.2022.0049
eration with the hospital’s computer system and radiology department. Based on the results of one study, the reduction in CT waiting time for trauma patients after visiting a trauma center may reflect the development of facilities and systems for trauma patient treatment [15]. In addition, the time from visiting the emergency department until a hospital admission letter was issued and the length of hospitalization were shortened via establishing a ward dedicated to trauma patients.

However, no significant difference existed between the two groups in the length of ICU stay, number of days on a ventilator, and the length of hospital stay. Nevertheless, one reason that the operation of a trauma center improved the overall survival rate and the functional prognosis of patients with TBI was that the waiting time until the hospitalization of trauma patients was shortened by the establishment of a general ward and an ICU exclusively for trauma patients. This situation has made it possible to provide early overall monitoring and high-quality care for trauma patients. In general, patients with severe TBI require professional care such as real-time intracranial pressure monitoring, and cerebral perfusion pressure management, in addition to the monitoring conducted in the ICU [12].

The survival rate of patients with severe TBI requiring urgent surgical intervention is time-dependent [16]. However, in this study, survival rates did not differ between the groups of patients who underwent surgery within 24 hours before and after the opening of the trauma center. One of the main reasons for this result is the failure to effectively reduce the time from the emergency department visit to the operating room. This reflects one problem of the head injury-treatment system at this trauma center; therefore, robust quality management is required to improve the prognosis of patients with life-threatening head injuries who require surgery within 24 hours.

Table 4. Clinical outcomes of before and after trauma center groups except for patients with area other than the head AIS≤2 and surgery done within 24 hours (n=180)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Before trauma center group (n=90)</th>
<th>After trauma center group (n=90)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (min)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>From injury to ED visit</td>
<td>157.0±249.1</td>
<td>175.9±218.1</td>
<td>0.590</td>
</tr>
<tr>
<td>From ED visit to trauma team call</td>
<td>6.0±4.7</td>
<td>6.6±9.2</td>
<td>0.751</td>
</tr>
<tr>
<td>From ED visit to NS specialist consultation</td>
<td>12.8±7.9</td>
<td>14.3±16.2</td>
<td>0.690</td>
</tr>
<tr>
<td>From ED visit to order documentation by NS physician</td>
<td>137.1±168.9</td>
<td>66.8±91.0</td>
<td>0.001</td>
</tr>
<tr>
<td>From ED visit to brain CT acquisition</td>
<td>52.0±101.5</td>
<td>41.5±30.0</td>
<td>0.512</td>
</tr>
<tr>
<td>From ED visit to admission decision</td>
<td>107.5±118.0</td>
<td>58.5±67.0</td>
<td>0.001</td>
</tr>
<tr>
<td>From ED visit to admission</td>
<td>201.9±163.7</td>
<td>177.9±153.1</td>
<td>0.312</td>
</tr>
<tr>
<td>From ED visit to operation room</td>
<td>345.5±312.1</td>
<td>325.3±274.0</td>
<td>0.987</td>
</tr>
<tr>
<td>Length of ICU stay (day)</td>
<td>17.6±24.6</td>
<td>27.4±91.9</td>
<td>0.329</td>
</tr>
<tr>
<td>Ventilation (day)</td>
<td>5.5±6.2</td>
<td>7.4±9.7</td>
<td>0.167</td>
</tr>
<tr>
<td>Length of hospital stay (day)</td>
<td>46.3±53.3</td>
<td>56.3±106.9</td>
<td>0.426</td>
</tr>
<tr>
<td>GOS score at discharge</td>
<td></td>
<td></td>
<td>0.197</td>
</tr>
<tr>
<td>5 (Good recovery)</td>
<td>8 (25.0)</td>
<td>12 (27.9)</td>
<td></td>
</tr>
<tr>
<td>4 (Moderate disability)</td>
<td>5 (15.6)</td>
<td>11 (25.6)</td>
<td></td>
</tr>
<tr>
<td>3 (Severe disability)</td>
<td>7 (21.9)</td>
<td>11 (25.6)</td>
<td></td>
</tr>
<tr>
<td>2 (Vegetative)</td>
<td>3 (9.4)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1 (Dead)</td>
<td>9 (28.1)</td>
<td>9 (20.9)</td>
<td></td>
</tr>
<tr>
<td>Prognosis</td>
<td>&lt;0.444</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Survival</td>
<td>68 (75.6)</td>
<td>72 (80.0)</td>
<td></td>
</tr>
<tr>
<td>Death</td>
<td>15 (16.7)</td>
<td>13 (14.4)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>7 (7.8)</td>
<td>5 (5.6)</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation or number (%).
AIS, Abbreviated Injury Score; ED, emergency department; NS, neurosurgeon; CT, computer tomography; ICU, intensive care unit; GOS, Glasgow Outcome Scale.

After trauma center group, n=89.
Before trauma center group, n=25; after trauma center group, n=68.
Before trauma center group, n=20; after trauma center group, n=64.
Before trauma center group, n=84; after trauma center group, n=80.
Before trauma center group, n=48; after trauma center group, n=22.
Before trauma center group, n=89; after trauma center group, n=89.
Before trauma center group, n=32; after trauma center group, n=43.

https://doi.org/10.20408/jti.2022.0049
This study had several limitations. First, in this study, factors influencing the prognosis of patients with TBI after the operation of the trauma center were primarily associated with the time factor. Therefore, additional research is warranted because surgery or ICU treatment also affects the prognosis of patients with TBI. Second, the clinical results comparing the isolated TBI patient group who underwent surgery 24 hours after visiting the emergency department included 180 of 3,339 study participants who met the aforementioned criteria. Thus, the sample size was small. Therefore, future multicenter studies should be considered. Third, many values were missing in the data related to trauma patients before the operation of the trauma center, primarily until early 2013. Therefore, care should be taken in interpreting the results.

In this study, the survival rate was increased and a good recovery rate in the GOS score was higher in the after trauma center group than in the before trauma center group. In addition, the emergency treatment time for patients with TBI who visited the hospital was significantly reduced through the operation of the trauma center. However, the survival and disability rates for patients who underwent brain surgery within 24 hours did not improve. Future studies should focus on finding ways to improve the prognosis of patients with TBI who require surgical treatment within a short time in this regard.

NOTES

Ethical statements
This study was approved by the Institutional Review Board of Wonju Severance Christian Hospital (No. 2022-0441-001). Informed consent was waived due to the retrospective nature of the study.

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

Funding
None.

Acknowledgments
The authors thank ChanYoung Kang, BS (Wonju Severance Christian Hospital) for his assistance in preparing the manuscript.

Author contributions
Conceptualization: HKK, KHL, OHK; Data curation: HKK, YSL, WJJ, HK, OHK; Formal analysis: HKK, KHL, YSC, KCC, SOH; OHK; Methodology: HK, KHL, SOH; Visualization: KHL, OHK; Writing—original draft: HKK, YSL, WJJ; Writing—review & editing: all authors. All authors read and approved the final manuscript.

REFERENCES

Severity of grinder injuries and related factors compared with other high-rotation cutting tool injuries: a multicenter retrospective study from 2011 to 2018

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Purpose: This study aimed to identify the characteristics of patients injured by high-rotation cutting tools and the factors related to the severity of their injuries.

Methods: Adult patients (≥18 years), who presented to the emergency department (ED) after a high-rotation cutting tool injury and who were registered in the Korean Emergency Department-based Injury In-Depth Surveillance (2011–2018) database, were included. Patients’ demographic characteristics, injury-related factors, and Injury Severity Scores were collected. All included cases were categorized into two groups according to the tool that caused the injury: grinder versus nongrinder. The characteristics of the two groups were compared, and the factors associated with the severity of injuries were investigated.

Results: Among 8,697 ED visits, 4,603 patients had been using a grinder and 4,094 had been using a nongrinder tool. The most frequently injured body part while using a grinder was the hand (46.4%), followed by the head (23.0%). While using a nongrinder tool, the most frequently injured body part was also the hand (64.0%), followed by the lower leg (11.4%). The odds of a severe injury were affected by patient age (odds ratio [OR], 1.024; 95% confidence interval [CI], 1.020–1.028) and using a grinder (OR, 2.073; 95% CI, 1.877–2.290). The odds of a severe injury using a grinder were higher in arm injuries (OR, 1.60; 95% CI, 1.40–1.83) and multiple-part injuries (OR, 1.998; 95% CI, 1.630–2.437). The odds of a severe injury using a grinder were lower for head injuries (OR, 0.481; 95% CI, 0.297–0.781).

Conclusions: Injuries from grinders were more likely to affect the head and neck than nongrinder injuries, despite the lower severity. The current lack of regulations on grinders in occupational safety and health standards warrants relevant legislation and the development of applicable safety equipment.

Keywords: Head injuries; Personal protective equipment; Industrial accident; Occupational injuries
INTRODUCTION

A high-rotation cutting tool is a collective term that refers to machinery used to cut, push, and polish the surface of hard materials such as metal, rocks, or concrete. Many workers present to the emergency department (ED) with injuries from these tools. The number of injuries has increased as the use of grinders has increased in recent years, in part because grinders are compact and easy to use, making them suitable for use as personal tools in the industrial field or at home. While current regulations on industrial safety and health standards mandate the installation of contact prevention equipment on electric saws, such as circular saws and bandsaws, there is a lack of regulation on grinders [1]. Machinery can be easily purchased without meeting specific safety requirements, and there is no legal enforcement of preventive measures such as safety training prior to use, aside from those mandated in workplaces that require training. Furthermore, according to a survey on the workplace environment conducted by the Korean Statistical Information Service, 10.7% of manufacturing workers did not use protective equipment [2].

Previous studies on grinders focused on case reports involving kickback injuries to the head and neck regions. A kickback injury occurs when a rapidly rotating saw blade catches on material that is not firmly fastened and that the blade is unable to cut through, causing the material to twist and launch (or “kick”) back from the blade at high speed [8]. A study of 133 participants demonstrated the frequency of facial damage caused by high-rotation cutting tools such as grinders (62%), chainsaws (32%), and rotary saws (15%) [3,4]. Based on these results, this study aimed to determine the relative risk of grinders compared to other high-rotation cutting tools by investigating patients who had visited the ED in the past few years. In particular, the study focused on head and neck injuries sustained from high-rotation cutting tools.

METHODS

The study was approved by the Institutional Review Board of Gachon University Gil Medical Center (No. GBIRB2021-202). The need for informed consent was exempted due to the retrospective nature of the study. This retrospective study used data from the Korean Emergency Department-based Injury In-depth Surveillance (EDIIS) conducted as part of the hospital injury monitoring system of the Korea Disease Control and Prevention Agency [5].

The study analyzed patients who presented to the participating ED between January 2011 and December 2018 and were evaluated for suspected injuries from manually operated high-rotation cutting tools, such as electric chainsaws and grinders. Of the 9,244 individuals whose data were collected, 33 who were under 18 years of age, 342 with an unspecified area of injury, and 172 with missing data on the severity of the injury were excluded. In total, 8,697 participants were included in the final analysis (Fig. 1).

Participants were divided into two groups: patients who sustained injuries from grinders and those injured by tools other than grinders. The general characteristics of the participants were collected, including age, sex, means of transportation to the hospital, place of injury, activity during injury, time of injury, diagnostic results, and whether surgery was performed. The place of injury was divided into industrial workplace, home, and miscellaneous, while the activity at the time of injury was divided into working, nonworking, and miscellaneous. Considering different work shifts, time of injury was divided into four time periods: morning (06:00–11:59), afternoon (12:00–17:59), evening (18:00–23:59), and night (00:00–05:59). The ED outcomes were divided into discharge, transfer, admission to the general ward, admission to the intensive care unit (ICU), death, and miscellaneous. Subgroups were created within transfers based on the following: lack of rooms in the general ward, lack of rooms in the ICU, inability to provide immediate emergency surgery or care, transfer to tertiary hospitals for specialized emergency care, transfer to primary and secondary medical institutions because severity of the injury was low, transfer to specialized long-term care facilities, personal requests, and miscellaneous. Up to 10 diagnoses were investigated per patient, with each assigned to one of 10 categories based on the location of the injury: head, neck, thorax, abdomen, upper arm, lower arm, hand, upper leg, lower leg, and foot; with the addition of four subgroups of areas (the

Fig. 1. Selection process of participants recruited during 2011 to 2018. EDIIS, Emergency Department-based Injury In-depth Surveillance; ISS, Injury Severity Score.
head and neck, torso, upper limb, and lower limb) for comparison.

The Excessive Mortality Ratio-adjusted Injury Severity Score (EMR-ISS) uses the S and T codes from the International Classification of Disease (ICD), and after rating the severity of each diagnosis on a scale of 1 to 5, the three highest-scoring codes, regardless of the area of injury, are taken, squared, and then added to produce a final score [6]. Major or severe trauma is most often defined as a score of ≥ 16 when assessing severity. For the purposes of this study, EMR-ISS scores of 1 to 8 were defined as mild trauma, 9 to 15 as moderate trauma, and ≥ 16 as severe trauma [7,8]. Additional divisions of EMR-ISS scores (1–8 and ≥ 9) were added to enable multivariate analysis of the severity of injury. Calculating the Injury Severity Score (ISS) requires a detailed assessment of the injury. There are many items that must be carefully evaluated by a specialized assessor. This study collected data based on the EDIIS guidelines. The data were collected by an emergency responder, not a clinician, who interviewed the patient, and the EMR-ISS inevitably used the emergency room diagnosis because evaluation data after hospitalization were not available. The EMR-ISS is basically derived from the ICD, as is the ICD-derived Injury Severity Score (ICISS). However, these systems calculate specific values differently and, according to previous studies, the EMR-ISS demonstrated better calibration and discrimination power for prediction of death than the ICISS in most injury groups [6]. This study presented severity by utilizing the EMR-ISS national data, as collected by the Korea Disease Control and Prevention Agency.

For statistical analysis, the nominal variables of descriptive data were described in numbers and percentages and univariate analysis was performed using the chi-square test. Multivariate logistic regression analysis was used to compare severity, with the variables that showed a P-value < 0.1 in the univariate analysis as input variables. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated and P < 0.05 was used as the threshold for statistical significance. Statistical analysis was performed using IBM SPSS ver. 24.0 (IBM Corp., Armonk, NY, USA).

RESULTS

General characteristics and location of injury in patients injured by high-rotation cutting tools

As shown in Tables 1 and 2, a total of 8,697 participants were included in this study. Injuries from high-rotation cutting tools occurred more often in male patients for both categories of injuries (grinder injuries, 4,523 [98.3%]; nongrinder injuries, 3,955 [96.6%]) than in female patients (grinder injuries, 80 [1.7%]; nongrinder injuries, 139 [3.4%]). In the grinder group, 1,502 injuries (32.6%) occurred in the morning, 2,360 (51.3%) in the afternoon, 635 (13.8%) in the evening, and 106 (2.3%) at night. In the nongrinder group, 1,319 injuries (32.2%) occurred in the morning, 2,183 (53.3%) in the afternoon, 489 (11.9%) in the evening, and 103 (2.5%) at night. The number of patients injured during work was 3,920 (85.2%) in the grinder group and 3,229 (78.9%) in the nongrinder group, with the rest having occurred in activities outside of work. Similarly, the number of injuries at

Table 1. Characteristics of patients with injuries from cutting tools (n=8,697)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. of patients (%)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>4,523 (98.3)</td>
<td>3,955 (96.6)</td>
</tr>
<tr>
<td>Female</td>
<td>80 (1.7)</td>
<td>139 (3.4)</td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning (06:00–11:59)</td>
<td>1,502 (32.6)</td>
<td>1,319 (32.2)</td>
</tr>
<tr>
<td>Afternoon (12:00–17:59)</td>
<td>2,360 (51.3)</td>
<td>2,183 (53.3)</td>
</tr>
<tr>
<td>Evening (18:00–23:59)</td>
<td>635 (13.8)</td>
<td>489 (11.9)</td>
</tr>
<tr>
<td>Night (00:00–05:59)</td>
<td>106 (2.3)</td>
<td>103 (2.5)</td>
</tr>
<tr>
<td>Place</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Workplace</td>
<td>3,553 (77.2)</td>
<td>2,575 (62.9)</td>
</tr>
<tr>
<td>Home</td>
<td>538 (11.7)</td>
<td>554 (13.5)</td>
</tr>
<tr>
<td>Etc.</td>
<td>512 (11.1)</td>
<td>965 (23.6)</td>
</tr>
<tr>
<td>During work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>3,920 (85.2)</td>
<td>3,229 (78.9)</td>
</tr>
<tr>
<td>No</td>
<td>679 (14.8)</td>
<td>845 (20.6)</td>
</tr>
<tr>
<td>Etc.</td>
<td>4 (0.0)</td>
<td>20 (0.5)</td>
</tr>
<tr>
<td>Results at emergency department</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td>3,196 (69.4)</td>
<td>2,292 (56.0)</td>
</tr>
<tr>
<td>Transfer</td>
<td>408 (8.9)</td>
<td>564 (13.8)</td>
</tr>
<tr>
<td>ADM to ward</td>
<td>968 (21.0)</td>
<td>1,196 (29.2)</td>
</tr>
<tr>
<td>ADM to intensive care unit</td>
<td>26 (0.6)</td>
<td>36 (0.9)</td>
</tr>
<tr>
<td>Death</td>
<td>1 (0.0)</td>
<td>3 (0.0)</td>
</tr>
<tr>
<td>Etc.</td>
<td>4 (0.0)</td>
<td>3 (0.0)</td>
</tr>
<tr>
<td>Surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>664 (14.4)</td>
<td>715 (17.5)</td>
</tr>
<tr>
<td>No</td>
<td>2,970 (64.5)</td>
<td>2,290 (55.9)</td>
</tr>
<tr>
<td>Etc.</td>
<td>969 (21.1)</td>
<td>1,089 (26.6)</td>
</tr>
<tr>
<td>Severity (EMR-ISS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild (1–8)</td>
<td>2,995 (65.1)</td>
<td>3,186 (77.8)</td>
</tr>
<tr>
<td>Moderate (9–15)</td>
<td>1,512 (32.8)</td>
<td>817 (20.0)</td>
</tr>
<tr>
<td>Severe (16–75)</td>
<td>96 (2.1)</td>
<td>91 (2.2)</td>
</tr>
</tbody>
</table>

ADM, administration; EMR-ISS, Excessive Mortality Ratio-adjusted Injury Severity Score.
The outcomes in the grinder group were 3,196 discharge (79.4%), 968 admission to the general ward (21.0%), and 408 transfer (9.8%). The outcomes in the nongrinder group similar-
ly included 3,229 discharge (56.0%), admission to the 1,196 general ward (29.2%), and 564 transfer (13.8%). In the grinder group, mild trauma was found in 2,995 patients (65.1%), moderate trauma in 1,512 (32.8%), and severe trauma in 96 (2.1%). Meanwhile, in the nongrinder group, mild trauma was found in 3,186 patients (77.8%), moderate trauma in 817 (20.0%), and severe trauma in 91 (2.2%). The average age was 50.0 years old in the grinder group and 52.7 years old in the nongrinder group.

Univariate analysis was conducted to compare the severity of injury between the two groups based on EMR-ISS scores: <9, mild severity; ≥ 9, moderate to severe severity. Age, sex, activity during the injury, place of injury, and use of grinders were used to analyze the collected variables. The results indicated differences in severity depending on age, sex, activity during injury, and usage of a grinder.

**Risk factors associated with EMR-ISS scores**

As presented in Table 3, the risk for a severe injury (using an EMR-ISS score of 9 as the standard) was compared using logistic regression analysis. Sex, age, grinder usage, and activity during the injury were analyzed. In all patients, higher risk was associated with multiple injuries (two or more injured body parts), older age (OR, 1.027; 95% CI, 1.018–1.036) and grinder usage (OR, 1.998; 95% CI, 1.639–2.437). In patients with head and neck injuries, the risk increased with age (OR, 1.027; 95% CI, 1.012–1.043) but decreased with grinder usage (OR, 0.481; 95% CI, 0.297–0.781). The risk of a severe torso injury increased with age (OR, 1.096; 95% CI, 1.023–1.176). Patients with arm injuries had an increased risk of a severe injury with age (OR, 1.015; 95% CI, 1.004–1.027) and grinder usage (OR, 1.60; 95% CI, 1.40–1.83). In patients with leg injuries, a lower risk for a severe injury was found if the injury occurred during work (OR, 0.481; 95% CI, 0.297–0.781).

**DISCUSSION**

This study aimed to provide a foundation for the establishment of injury prevention strategies by conducting an analysis of patients with injuries sustained from high-rotation cutting tools. Previous international studies on injuries caused by grinders have been limited to case studies focusing on head and neck injuries alone [9]. They described the characteristics of the tools causing the injury (type, size and rotation speed of the saw blade, facial area hit by the blade, and the distance between the patient and machine) and emphasized the need to prevent injuries through education on proper usage of the tools [10]. Other case
studies illustrated the management and treatment of injuries resulting from the use of angle grinders [11]. The objective risks associated with grinders have not been statistically measured due to the lack of statistical data and the limitations of measuring severe injuries. Therefore, previous studies did not deal with the relative risk of the grinder, but simply described its safe use and the treatment of grinder injuries.

Among the limited number of previous Korean studies, a case report on disorders of peripheral blood vessels and the peripheral nervous system of the hands and fingers caused by the use of vibrating tools such as grinders was published in the Journal of the Korean Society of Occupational and Environmental Medicine [12]. Another study by the Korean Society of Manufacturing Process Engineers investigated grinder tools capable of angle adjustment [13]. Thus, our current study emphasized the significance of evaluating the risks associated with the use of high-rotation cutting tools in Korea.

There was a higher occurrence of head injuries in the grinder group than in the nongrinder group, likely due to head injuries resulting from kickback by grinders. Grinders are prone to produce more kickback than other high-rotation cutting tools. To date, research has been conducted on the safety features of other high-rotation cutting tools such as rotary saws or chainsaws (e.g., saw stops that program machines to stop upon detection of conductive materials such as fingers near the vicinity of the saw blade); however, no protective function has been applied to grinders. Despite reported incidents, the lack of legal mandates on safety equipment for grinders, such as protective covers that reduce kickback, is concerning. In contrast, regulations have been placed on other high-rotation cutting tools, consequently contributing to the higher incidence of kickback injuries in grinder use. Nonetheless, regulations on grinders are still overlooked in occupational safety and health standards.

Risk increased with age in patients with multiple injuries (i.e., in more than two areas), as well as for patients with torso or arm injuries. While previous research has attributed a decrease in workplace performance to decreasing physical abilities [14, 15], this study found the difference in risk related to age was small and statistically insignificant.

Despite the initial assumption that a higher proportion of head and neck injuries in the grinder group would indicate higher severity than in the nongrinder group, the former had less severe head and neck injuries. The higher number of head and neck injuries observed in the grinder group raises concerns about survival bias. Severe head and neck injuries often result in death at the scene before the patient can be transported to the ED and resuscitated, despite the prehospital communication between rescue services personnel and the medical team. This would result in patients with injuries severe enough to cause death being excluded from the EDISS, which would lower the severity of injuries in the grinder group. It is also possible that the severity could be lowered during the EMR-ISS scoring process. Head and neck injuries are not given higher severity scores than other injuries in the EMR-ISS, as the scale does not incorporate the area of injury in its assessment and depends solely on the severity of the injury itself: 1, minor injury; 2, moderate injury; 3, serious injury; 4, severe injury; 5, critical injury; and 6, maximal/untreatable injury. The EMR-ISS also has a limited ability to evaluate the severity of

Table 3. Risk factors associated with Excessive Mortality Ratio-adjusted Injury Severity Score

<table>
<thead>
<tr>
<th>Variable</th>
<th>Adjusted odds ratio</th>
<th>95% Confidence interval</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male sex</td>
<td>1.263</td>
<td>0.905–1.763</td>
<td>0.170</td>
</tr>
<tr>
<td>Age</td>
<td>1.024</td>
<td>1.020–1.028</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Grinder</td>
<td>2.073</td>
<td>1.877–2.290</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>During work</td>
<td>0.788</td>
<td>0.653–0.951</td>
<td>0.013</td>
</tr>
<tr>
<td>Head and neck</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male sex</td>
<td>1.923</td>
<td>0.526–7.035</td>
<td>0.323</td>
</tr>
<tr>
<td>Age</td>
<td>1.027</td>
<td>1.012–1.043</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Grinder</td>
<td>0.481</td>
<td>0.297–0.781</td>
<td>0.003</td>
</tr>
<tr>
<td>During work</td>
<td>1.172</td>
<td>0.553–2.488</td>
<td>0.679</td>
</tr>
<tr>
<td>Torso</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male sex</td>
<td>NA</td>
<td>NA</td>
<td>1.000</td>
</tr>
<tr>
<td>Age</td>
<td>1.096</td>
<td>1.023–1.176</td>
<td>0.010</td>
</tr>
<tr>
<td>Grinder</td>
<td>5.535</td>
<td>1.128–25.153</td>
<td>0.027</td>
</tr>
<tr>
<td>During work</td>
<td>0.250</td>
<td>0.026–2.424</td>
<td>0.232</td>
</tr>
<tr>
<td>Arm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male sex</td>
<td>1.330</td>
<td>0.529–3.343</td>
<td>0.544</td>
</tr>
<tr>
<td>Age</td>
<td>1.015</td>
<td>1.004–1.027</td>
<td>0.006</td>
</tr>
<tr>
<td>Grinder</td>
<td>1.775</td>
<td>1.327–2.320</td>
<td>&lt;0.001</td>
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<td>0.622–1.846</td>
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<tr>
<td>Age</td>
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<tr>
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<tr>
<td>During work</td>
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<td>0.645–1.355</td>
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</table>

NA, not assessed.
puncture wounds which can be caused by kickback injuries [8]. A final possibility is that grinder injuries may indeed have lower severity because grinders are powered by batteries rather than the high voltage alternating current used by other high-rotation cutting tools, resulting in a comparatively lower cutting speed and strength.

There were several limitations to this study. First, the data used were collected from only 23 hospitals, not from all institutions in Korea, making it difficult to generalize the results as representative of all Korean patients injured by high-rotation cutting tools. Second, there was potential for sampling bias in the comparison of grinder and nongrinder groups, since the use of protective equipment that lowered the likelihood of injuries produced a unique personal characteristic that was not accounted for in this study. Third, the retrospective design prevented the analysis of data missing from the EDIIS. In particular, there were missing data on protective equipment (because it was optional) and on whether the safety and health training for the use of the tool was completed. Another limitation was the possible removal of a part of the diagnostic T-code that represents injuries to unspecified body parts, causing errors in the total number of multiple injuries. Fourth, it was not possible to subjectively account for the risk associated with each tool, making it difficult to compare injury severity with usage risk, which would have been useful in analyzing the high frequency and low severity observed for head and neck injuries in the grinder group. Finally, a limitation of the EMR-ISS is that it lacks an appropriate stratification for injuries in the same body part. For example, even if two or more injuries occur in the same area of the body, there is a problem that only one injury is applied to the severity calculation. In severe trauma cases, the EMR-ISS does not measure the severity of injury as well as the ISS, which can evaluate the depth of injury, the extent of injury, and the functional deficits resulting from the injury. However, in this study, there were few patients who could be classified as having severe trauma, so we would expect little difference in our results if the ISS had been used for evaluation. In the case of grinders and rotary cutting tools, most of the injuries that would have been considered as severe trauma were likely to have caused death at the scene of an accident or during transport.

In conclusion, injuries from grinders were more likely to affect the head and neck than nongrinder injuries, despite their lower severity. The current lack of regulations on grinders in occupational safety and health standards warrants relevant legislation and the development of applicable safety equipment.

NOTES

Ethical statements
The study was approved by the Institutional Review Board of Gachon University Gil Medical Center (No. GBIRB2021-202). The need for informed consent was exempted due to the retrospective nature of the study.

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

Funding
None.

Author contributions
Conceptualization: YBJ, JHJ; Methodology: JS, YBJ, JHJ, JSC; Data curation: JSC, JYC; Formal analysis: JSC, JYC, JHJ; Writing–original draft: JS, JHJ; Writing–review&editing: WSC, JSC, YBJ, JHJ, JYC. All authors read and approved the final manuscript.

REFERENCES


Sports injuries: a 5-year review of admissions at a major trauma center in the United Kingdom

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2Department of Rehabilitation Medicine, Addenbrooke’s Hospital, Cambridge, UK
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Purpose: Sports offer several health benefits but are not free of injury risk. Activity dynamics vary across sports, impacting the injury profile and thereby influencing healthcare resource utilization and health outcomes. The purpose of this study was to investigate sports-related major trauma cases and compare differences across sports and activity groups.

Methods: A retrospective case notes review of sports-related major traumas over a 5-year period was conducted. Demographic, hospital episode-related, and health outcome-related data were analyzed, and differences were compared across sports and activity groups. The Glasgow Outcome Scale (GOS) at discharge was used as the primary outcome measure and the length of hospital stay as the secondary outcome measure.

Results: In total, 76% of cases had good recovery at discharge (GOS, 5), 19% had moderate disability (GOS, 4), and 5% had severe disability (GOS, 3). The mean length of hospital stay was 11.2 days (range, 1–121 days). The most severely injured body region was the limbs (29.1%) and vertebral/spinal injuries were most common (33%) in terms of location. A significant difference (P<0.05) existed in GOS across sports groups, with motor sports having the lowest GOS. However, no significant differences (P>0.05) were found in other health-outcome variables or injury patterns across sports or activity groups, although more competitive sports cases (67%) required admission than recreational sports cases (33%).

Conclusions: Spinal injuries are the most frequent sports injuries, bear the worst health outcomes, and warrant better preventive measures. Head injuries previously dominated the worst outcomes; this change is likely due to better preventive and management modalities. Competitive sports had a higher injury frequency than recreational sports, but no difference in health outcomes or injury patterns.

Keywords: Athletic injuries; Sports medicine; Health care outcome assessment; Demographics; Statistics
INTRODUCTION

The benefits of sports and exercise on physical, mental, and social health are well-known and documented [1,2]. The National Institute for Health and Care Excellence (NICE) recommends regular exercise as a primary prevention measure against cardiovascular diseases. Exercise also offers prophylactic benefits against autoimmune, malignant, degenerative, and psychiatric diseases [3]. In today's postindustrial developed world, electronic devices and increasing automation reduce the prevalence of physical activity, with resulting adverse effects on physical and mental health [4]. Sports activities act as a means of entertainment and have added physical, mental, and social health benefits [5].

People in the United Kingdom (UK) participate in a wide variety of recreational and competitive sports. The top 15 most popular sports activities, defined by the proportion of participants, across all age groups in 2016 and 2017, in order of popularity, were running, fitness classes, gym workouts, swimming, exercise machines, climbing/mountaineering, football, weight-lifting, golf, badminton, tennis, rowing, and boxing [6]. Moreover, national sports participation statistics estimate that between 2016 and 2020, across all age groups, approximately 56,000 people participated in regular motor sports, 281,400 people participated in equestrian sports, and 955,000 people participated in combat sports at least twice a month. These statistics indicate the popularity of a variety of sports activities in the UK population and warrant further research into the hazards of these sports.

Sports-related injuries impede the physical and psychosocial health benefits of exercise due to physical and psychological damage, disability, rehabilitation, and hospitalization and can tax healthcare resources [7–9]. The National Health Service Hospital episode statistics recorded 367,093 emergency department attendances due to sports-related injuries in 2014 to 2015 (1.9% of all emergency attendances and 7.7% of all trauma-related attendances) [10]. The frequency of sports-related hospital visits is even higher in the pediatric population [11]. Furthermore, sports-related injuries account for approximately 7,000 deaths annually in Europe [11] and about 90,000 life-threatening events annually in the USA [12]. Research into the causes, mechanisms, management, and preventive measures is imperative to minimize the harms of sports injuries and ensure a sustained healthy lifestyle [12].

Sports have unique dynamics depending on the type of activity. Variable factors such as participant’s physique, health, skill set, technique, sporting equipment, environment, and kinetics contribute to unique injury profiles [13]. Variations exist in terms of the mechanism of injury, the extent of damage, and patterns of affected body parts. These factors influence the time and resources spent on management, rehabilitation, and health outcomes.

Long-term statistical reports on population sports injuries in literature are few, and even fewer describe major trauma cases related to sports. The available reports are limited in terms of either the type of sport or injury or population or the use of descriptive variables [14,15]. An Australian study conducted over 10 years and covering a population of 6 million people provided the most comprehensive statistical information about injuries in various sports. Thoracic injuries were most frequent, followed by spine and head injuries across all sports groups in that study. A similar pattern existed in motor sports and cycling; however, in equestrian sports, the spine was the most common injured region, followed by the thorax and head. Interestingly, in Australian football, the abdomen was the most common injured body region, followed by the spine and head [15]. Furthermore, a Danish epidemiological study described sports participation statistics and injury rates but did not include detailed injury profiles and health outcomes [7]. No such study has been concluded so far in the UK across all age groups [11]. There is a gap in the information that can be used to guide prevention and management strategies as well as to reduce healthcare costs and disability. One such prospective study is being conducted and the results are awaited [8]. Our study aimed to examine injury-related, health episode-related, and health outcome-related data concerning major trauma-related sports injuries at a major trauma center in the UK.

METHODS

This study was registered and conducted as a clinical service evaluation at Addenbrooke’s Hospital (No.1048868). Ethical approval and patient consent were not needed due to the retrospective nature of the study. No direct patient case or patient identifiable data was used. We used a retrospective descriptive study design and identified sports-related major trauma cases from the hospital trauma registry and electronic healthcare records at Addenbrooke’s Hospital between June 15, 2015 and December 15, 2020. We used NICE’s definition of major trauma [16]. NICE defines major trauma as “an injury or a combination of injuries that are life-threatening and could be life-changing because it may result in long-term disability.” Addenbrooke’s Hospital serves as a major trauma center for the East of England region and provides specialist trauma services to a population of up to 6.5 million in-
RESULTS

In total, 6,906 patients were admitted with trauma-related injuries at the major trauma center between June 15, 2015 and December 15, 2020. The ISS ranged from 1 to 75. Out of these, 78 patients (1.1%) met the inclusion criteria. Male patients were more commonly affected, constituting of 64 admissions (82%), with female patients comprising a minority of admissions (n = 14, 18%; male to female ratio, 4.5:1). Patients’ age ranged between 11 to 88 years, with a mean ± SD of 33.89 ± 16.5 years.

The mean ± SD initial GCS of those with intracranial injuries (n = 15) was 13.8 ± 3.26, and the median GCS of all injuries was 15 (range, 3–15). The mean ± SD ISS was 13.0 ± 8.23 with 24 patients (30%) requiring admission to the ICU, with a median duration of ICU admission of 4 days (range, 1–32 days).

The majority of patients (n = 43; 55%) did not require surgery during admission and were treated conservatively. Twenty-six patients (32.9%) underwent a single operation, nine (11.3%) underwent one operation, and one (1.2%) underwent three operations. Across all sports groups, the most severely affected body region (defined by the ISS) was the limbs (n = 23, 29%), followed by the spine (n = 22, 28%), and the least severely affected region was the face (n = 3, 3%). Table 1 outlines the distribution of severely affected body regions. Among patients with a head injury, there was one case of severe traumatic brain injury (GCS < 9 on admission), resulting from a motor sports accident (patient’s age, 53 years; initial GCS, 3; ISS, 45; length of stay, 121 days; and GOS, 4 [moderate disability] at discharge).

The admission survival rate was 100% and the majority of patients were discharged home (n = 71, 91.0%), with smaller proportion discharged to a spinal cord injury center (n = 5, 6.4%), rehabilitation unit (n = 1, 1.2%), or a local hospital (n = 1, 1.2%). GOS on discharge indicated a good recovery (i.e., no disability) in three-quarters of cases (n = 59, 76%), with most of the remaining cases (n = 15, 19%) having a moderate disability on discharge (i.e., minor deficits that did not affect function). Four patients (5%) had severe disabilities.

A comparison between sports groups found a significant difference in GOS on discharge (P = 0.003), with motor sports having the lowest mean GOS, but there was no significant difference in GOS between activity groups (P = 0.491). Fig. 1 compares the
A variety of sports were implicated in patients who were admitted for rehabilitation in the RAAR service. Spinal injuries were the most common (n = 125). Spinal injuries were the most frequent for cases involving spinal injuries, and one case of concurrent abdominal injury (n = 1, 1.3%). Severe disability (Glasgow Outcome Scale 3) most frequent for cases involving spinal injuries and one case of concurrent abdominal injury.

Distribution of the GOS according to the most severely injured body region.

Rehabilitation in the RAAR service was required in 14 cases (18%), with a mean ± SD length of stay of 37.6 ± 3.17 days. The overall mean ± SD length of stay was 18.15 days. No significant difference existed in total length of hospital stay among sports groups (P = 0.630) or among activity groups (P = 0.953).

Table 2 presents a description and comparison of continuous and discrete variables between sports groups. Table 3 provides a description and comparison between activity groups.

A total of 125 injuries were identified. Spinal injuries were the most common injury (n = 41, 33%), followed by orthopedic injuries (n = 23, 18%), while facial injuries (n = 9, 7%) were the least common. No significant difference (P > 0.05) existed in injury patterns among sports groups or activity groups. Patterns of injuries with a comparison among sports groups are presented in Table 4 and Fig. 2 and among activity groups in Table 5 and Fig. 3.

A variety of sports were implicated in patients who were admitted, with motor sports being the most common sport leading to the most number of injuries (n = 43, 34%) and also, the most serious injuries (n = 23, 29.1%), based on the ISS score, requiring admission. Racket sports caused the least serious injury requiring admission (n = 1, 1.3%).

DISCUSSION

Sports and recreation have known health benefits but are not free of injury risk [2]. These injuries can be hazardous to individual well-being, social health, and resources. Our study identified sports or recreation-related major trauma (excluding equestrian sports) cases to be 1.1% of all trauma-related admissions with a male preponderance (male to female ratio, 4.5:1). This is approximately consistent with previous epidemiological studies [11, 15, 20]. Interestingly, our group's study of equestrian sports had a reversed male to female ratio (1:2.5), due to equestrian sports' higher popularity among women [17].

Most of the cases had very good outcomes, with no fatalities and good recovery in 76% of cases. Furthermore, 92% of cases were discharged home and the median length of ICU stay was only 4 days. The overall good health outcomes can be attributed to (1) better-commissioned healthcare services for trauma-related injuries [11] such as trauma networks, air-ambulance services, specialist major trauma units, and RAAR services [19], and (2) a lower incidence of traumatic brain injuries, which are canonically associated with the worst health outcomes, compared to spinal and orthopedic injuries [21].

Only 3.8% of cases had severe disability on discharge and 100% of these cases involved injuries of the spinal cord and were transferred to a spinal injury rehabilitation center. This indicates the burden of spinal injuries on individual and social health outcomes. This differs from a few decades ago, when traumatic brain injuries had the highest incidence and were associated with the worst health outcomes. Better preventive and management strategies have reduced the incidence and morbidity associated with head injuries. Such measures are not fully applicable to spinal injuries; for example, no cervical spine injury preventive device is available, unlike the protective headgear that is commonly used in a wide variety of sports [21].

The sports group with the most spinal injuries and the worst GOS was motor sports, followed by contact sports, which corresponds with previous studies [15, 22]. We studied quad-bike racing as a motor sport, and spinal injuries were the most common, with similar injury patterns and ISS as for other motor sports. This differed from commercial quad-biking accidents in Australia, where limbs and head injuries were more frequent [23]. High kinetic forces and high speeds in motor sports create greater injury risks for drivers [22, 24]. This calls for better preventive measures to be implemented in motor sports to prevent permanent disability resulting from spinal injuries. The preventive measures for motor sports include but are not limited to ensuring a license...
<table>
<thead>
<tr>
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<th>Contact sports</th>
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<th>Board sports</th>
<th>Water sports</th>
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<td>5</td>
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<td>2</td>
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<td>25.0±16.9</td>
<td>41.3±16.1</td>
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<td>34.2±22.1</td>
<td>60.5±14.85</td>
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<td>5.94</td>
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<td>15</td>
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<td>15</td>
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<td>15</td>
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<td>22.0±5.7</td>
<td>13.3±8.5</td>
<td>10.8±5.16</td>
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<td>4.5±10.2</td>
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<td>8–16</td>
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<td>GOS Mean±SD</td>
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<td>1 (25)</td>
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</table>

Means and standard errors across sports groups were compared using one-way analysis of variance and the differences are shown as P-values. There was a statistically significant difference in GOS with motor sports having the worst GOS at discharge.

NA, not applicable; SD, standard deviation; SE, standard error; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; ICU, intensive care unit; GOS, Glasgow Outcome Scale.
for motor sports, adequate protective gear, safe vehicle and track design, better training for participants, better awareness about these injuries in the population, and better training and practices for healthcare providers [24].

Likewise, similar preventive and management measures can be

<table>
<thead>
<tr>
<th>Table 3. Patterns of injured body regions across sports groups</th>
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<tr>
<td>Thoracic</td>
</tr>
<tr>
<td>Abdomen/pelvis</td>
</tr>
<tr>
<td>Facial</td>
</tr>
<tr>
<td>Fetal</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

Table 4. Comparison of demographics and health-outcome data across activity groups

<table>
<thead>
<tr>
<th>Outcome variable</th>
<th>Competitive sports (n=53)</th>
<th>Recreational sports (n=25)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>Mean±SD</td>
<td>31.0±12.86</td>
<td>40.4±20.65</td>
</tr>
<tr>
<td></td>
<td>Standard error</td>
<td>1.76</td>
<td>4.04</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>13–58</td>
<td>11–88</td>
</tr>
<tr>
<td>Initial GCS</td>
<td>Mean±SD</td>
<td>14.68±1.70</td>
<td>14.92±0.27</td>
</tr>
<tr>
<td></td>
<td>Standard error</td>
<td>0.24</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>3–15</td>
<td>14–15</td>
</tr>
<tr>
<td>ISS</td>
<td>Mean±SD</td>
<td>12.70±7.40</td>
<td>13.09±8.60</td>
</tr>
<tr>
<td></td>
<td>Standard error</td>
<td>1.18</td>
<td>1.46</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>4–29</td>
<td>3–45</td>
</tr>
<tr>
<td>Length of stay (day)</td>
<td>ICU</td>
<td>Mean±SD</td>
<td>2.24±6.20</td>
</tr>
<tr>
<td></td>
<td>Standard error</td>
<td>0.86</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>0–32</td>
<td>0–28</td>
</tr>
<tr>
<td></td>
<td>Hospital</td>
<td>Mean±SD</td>
<td>11.29±20.8</td>
</tr>
<tr>
<td></td>
<td>Standard error</td>
<td>2.80</td>
<td>2.21</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>2–121</td>
<td>1–52</td>
</tr>
<tr>
<td>GOS</td>
<td>Mean±SD</td>
<td>4.70±0.61</td>
<td>4.60±0.58</td>
</tr>
<tr>
<td></td>
<td>Standard error</td>
<td>0.08</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>3–5</td>
<td>3–5</td>
</tr>
<tr>
<td>Most severely injured body part (%)</td>
<td>NA</td>
<td>Limb</td>
<td>17 (32)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spine</td>
<td>13 (25)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Head</td>
<td>8 (15)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thorax</td>
<td>6 (11)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Abdomen/pelvis</td>
<td>5 (9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Face</td>
<td>2 (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multiple</td>
<td>2 (4)</td>
</tr>
</tbody>
</table>

Patterns of injuries across sports groups were compared using the chi-square test (by observed and expected frequencies) and the difference calculated as P-value. No statistically significant difference existed in injury patterns across sports groups.

Means and standard errors of healthcare and health outcome variables across activity groups were compared using unpaired t-test and the difference shown as P-value. No statistically significant difference in health outcomes was found across activity groups.

NA, not applicable; SD, standard deviation; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; ICU, intensive care unit; GOS, Glasgow Outcome Scale.
implemented in contact sports such as rugby and football to prevent serious injuries. For instance, a change in tackling rules in American football resulted in a reduction of catastrophic spinal injuries [12] and such changes in rules can be considered for other sports groups to minimize the risk of major injuries.

The incidence of head injuries and traumatic brain injuries was relatively low (12%), and among patients with head injuries, 66.6% had a good recovery (GOS, 5) and 33.3% had moderate disability (GOS, 4). This is consistent with previous studies [20,25]. Sports groups with the most head injuries were bicycle and ball sports. The relatively low prevalence and relatively better GOS is attributed to widespread awareness regarding traumatic brain injury in the population, better preventive measures in sports activity, such as restricting dangerous moves,

Table 5. Patterns of injured body regions across activity groups

<table>
<thead>
<tr>
<th>Injury pattern</th>
<th>Competitive sports</th>
<th>Recreational sports</th>
<th>Total</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cases</td>
<td>53</td>
<td>25</td>
<td>78</td>
<td>-</td>
</tr>
<tr>
<td>No. of injuries (%)</td>
<td>84 (67)</td>
<td>41 (33)</td>
<td>125 (100)</td>
<td>-</td>
</tr>
<tr>
<td>Intracranial</td>
<td>10 (12)</td>
<td>5 (12)</td>
<td>15 (12)</td>
<td>0.585</td>
</tr>
<tr>
<td>Spinal</td>
<td>27 (32)</td>
<td>14 (34)</td>
<td>41 (33)</td>
<td>0.868</td>
</tr>
<tr>
<td>Orthopedic</td>
<td>17 (20)</td>
<td>6 (15)</td>
<td>23 (18)</td>
<td>0.657</td>
</tr>
<tr>
<td>Thoracic</td>
<td>12 (14)</td>
<td>5 (12)</td>
<td>17 (14)</td>
<td>0.496</td>
</tr>
<tr>
<td>Abdomen/pelvis</td>
<td>11 (13)</td>
<td>7 (17)</td>
<td>18 (14)</td>
<td>0.618</td>
</tr>
<tr>
<td>Facial</td>
<td>6 (7)</td>
<td>3 (7)</td>
<td>9 (7)</td>
<td>0.609</td>
</tr>
<tr>
<td>Other</td>
<td>1 (1)</td>
<td>1 (2)</td>
<td>2 (2)</td>
<td>0.548</td>
</tr>
</tbody>
</table>

Patterns of injuries across activity groups were compared using binomial exact test and difference calculated as P-value. No statistically significant difference existed in injury patterns across activity groups. The number of cases and the total number of injuries may differ as cases can have more than one injured body part.

Fig. 2. Injury patterns across sports groups.

Fig. 3. Injury patterns among activity groups.
tackles, better training of players use of appropriate headgear, and better healthcare services for immediate management of head injuries [19,21]. Still, there is a need to sustain the present practices and further improve the services such as encouraging headgear use in motor sports, contact and ball sports, and bicycle sports (as has been in practice for routine motorcycle use) [13,26].

The limbs were the most severely injured site across all sports groups, which corresponds to previous studies across multiple sports groups [7,15,20]. Most patients (n = 18, 95.5%) with severe limb injuries had good recovery (GOS, 5) at discharge. Although no specific limb injury preventive practices exist across most sports groups included in our study, better health outcomes could be due to improved management and the generally less severe nature of these injuries. Nonetheless, better public awareness about preventive measures such as bone/muscle fitness, endurance, technique, and strength training can reduce the incidence of such injuries.

Recreational sports are activities that are primarily for participation, with the associated goals of improving physical fitness, recreation, and being social. Competition, on the other hand, is more about achieving goals and competing besides physical fitness and social interaction. Competitive sports are presumed to have higher intensity and activity levels and consequently more injuries (and worse outcomes) than recreational sports. However, recreational sports are usually performed in a casual way and uncontrolled environments, with less compliance in terms of protective equipment and less enforcement of rules and regulations, and therefore can result in more injuries and worse health outcomes. Studies comparing the injury-related data between competitive and recreational sports are scarce and limited to individual sports groups. A couple of studies have demonstrated significantly higher rates of injuries in competitive running and cycling than in recreational versions of these sports [13,27]. In our study as well, the percentage of admissions related to competitive sports (n = 53, 67%) was significantly higher than the number of admissions for injuries sustained while engaging in recreational sports (n = 25, 33%), but the health outcomes and injury patterns did not differ significantly among these activity groups (Tables 3, 5, Fig. 3).

Statistical studies on injury prevention measures are scarce and existing studies are limited to the type of sports and mostly address competitive sports. Studies focusing on injury preventive measures in recreational sports are almost nonexistent. This creates a gap in information regarding the prevalence and efficacy of injury prevention practices in the population [28], especially in the context of recreational sports. This information can dictate improvements in the implementation of injury prevention practices and consequently reduce the injury rates and the overall burden on healthcare resources [22,28].

Our study has several limitations. Firstly, the data are from a single center, which may limit generalizability. Secondly, the retrospective study design creates information bias. Thirdly, our sample size was small, as we only included cases that required hospital admission and excluded equestrian injuries. This underestimates the actual burden of sports-related injuries because a majority of sports injuries are minor injuries with an ISS of less than 4 and do not require hospital stay [25]. The small sample size also reduces the significance of comparative statistics. Further, as only data for admitted cases were taken, no comparisons were possible between types of sports and admission rates. Lastly, we used the GOS as a functional health-outcome tool representing the overall extent of functional recovery at discharge. It was designed for traumatic brain injury cases, and its functionality for other injuries has not been optimized yet. It is not a generic disability score such as the Barthel index or the Extended Rehabilitation Complexity Score and lacks adequate resolution and validity to detect resulting disability in the non-traumatic brain injury population. The retrospective nature of our study also limits the additional objective assessments we can carry out. Further studies are, therefore, recommended to address these limitations.

In conclusion, immense popularity of sports and recreation activities warrant comprehensive studies to address information gaps about injury prevention and management. While sport-related major trauma is uncommon, motor sports are associated with the highest rate of major injuries requiring hospital admission, and are associated with worse health outcomes than other sports. Spinal cord injuries are a major cause of disability, necessitating better preventive measures. Comparative analysis of demographical and health-outcome data shows a significant difference in GOS across sports groups, but no significant difference in the length of ICU or hospital stays and in injury patterns across sports groups. Competitive sports accounted for a higher proportion of major trauma cases than recreational sports, but the health outcomes did not differ significantly; however, the existing literature is inadequate and needs more studies covering wider periods and sports groups. Furthermore, better information on injury prevention practices and their efficacy is needed to reduce the burden of these injuries on individual and population well-being and healthcare resources.
ETHICAL STATEMENTS

This study was registered and conducted as a clinical service evaluation at Addenbrooke’s Hospital (No.1048868). Ethical approval and patient consent were not needed due to the retrospective nature of the study.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

FUNDING

None.

AUTHOR CONTRIBUTIONS

Conceptualization: AH, AAG, FA; Data curation: AH; Formal analysis: AH, AAG, FA; Methodology: AH, AG, FA; Project administration: AH, FA; Visualization: all authors; Writing—original draft: AH; Writing—review & editing: all authors. All authors read and approved the final manuscript.

ACKNOWLEDGMENTS

We acknowledge all help from Jacques Bowman in curating hospital admissions statistics data.

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Successful surgical intervention in traumatic carotid artery thrombosis after a motor vehicle accident: a case report

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Blunt carotid artery injury can lead to impaired brain perfusion due to ischemic stroke and thromboembolic events. To reduce the risk of potential neurological complications, it is critical to determine the diagnosis and management protocol as quickly as possible after a detailed clinical examination. This report presents successful surgical treatment of a young male patient who developed a traumatic left common carotid artery thrombosis after a motor vehicle accident.

Keywords: Carotid artery thrombosis; Carotid artery injuries; Carotid arteries; Accidental injuries; Case reports

INTRODUCTION

Motor vehicle accidents are the most common cause of blunt carotid artery injuries (BCAIs) [1]. Carotid artery injury can result in dissection, an intramural thrombus, or pseudoaneurysm, leading to decreased blood flow to the brain and thromboembolic events [2]. Moreover, BCAIs cause delayed neurological injuries, with an estimated mortality risk of 40% and irreversible neurological disorders in more than 10% of cases [3,4]. Early diagnosis and prompt management of BCAIs could dramatically reduce the incidence of thromboembolic events [5]. This report presents the successful surgical treatment of a young male patient who developed a traumatic left common carotid artery thrombosis after a motor vehicle accident.

CASE REPORT

Following a motor vehicle accident, a previously healthy 19-year-old male patient was admitted to the emergency department (ED). On admission, he had stable vital signs, normal mental ability, speech, and cranial nerve examination findings, as well as a Glasgow Coma Scale score of 15. However, he had paresthesia in his right-hand fingertips with no motor dysfunction, and normal sensory and motor examination findings on other extremities. There were also no remarkable findings in other systems. Initial laboratory tests and radiography of the skull, spine, chest, and serial extended focused assessment with sonography for trauma were normal. Finally, no other traumatic lesions were reported. Due to paresthesia in the fingertips, cranial, cervical, and lumbar spine computed tomography and magnetic resonance
imaging examinations were performed as part of the simultaneous evaluation by a neurosurgeon. No neurological pathology requiring surgical intervention was encountered.

The patient was also evaluated using craniocervical and thoracic computed tomography angiography (CTA) with the suspicion of vascular trauma. The patient’s cranial CTA scans revealed a completely normal blood supply to the brain without any signs of hypoperfusion. Cervical CTA showed that the left common carotid artery (CCA) after the first 6-cm segment was totally occluded due to thrombosis (Fig. 1). Subsequently, no flow was observed until the carotid bifurcation (Fig. 1B). The left internal carotid artery and external carotid artery were observed to be patent (Fig. 1C). It was thought that reverse flow occurred in the external carotid artery branches, and consequently, the external carotid artery filled the internal carotid artery retrogradely. An intravenous bolus of heparin (80 IU/kg) was administered immediately, and emergency surgery was decided. Following general anesthesia, the left-sided CCA and its bifurcation were exposed without touching the vessels using standard exposure. Although no shunt was used, hypertension was managed to improve contralateral cerebral perfusion. After longitudinal arteriotomy, there was clearly a 1 × 0.5-cm thrombus without a dissection flap at the level of the left CCA. The organized thrombus material was removed and the simple laceration in the intima was repaired primarily. No other pathology was observed within the lumen of the artery. By removing the clamps, good retrograde and antegrade flows were observed. Metronidazole, ceftriaxone, and low-molecular-weight heparin were started as medications in the intensive care unit. Furthermore, after 3 days, the low-molecular-weight heparin was switched to oral warfarin to ensure long-term thromboembolism prevention. In the postoperative phase, no neurological or hemodynamic problems were observed. The radiologist confirmed that the flow velocities were within normal values during a carotid Doppler ultrasonography (CDUSG) examination. On the 7th postoperative day, the patient was discharged with warfarin therapy without any hemorrhagic complications. A neurological examination after 1 month revealed completely normal motor function and sensations in the extremities, without any other surgical complications. Neither residual stenosis of the left CCA, nor progression of the stenosis of the CCA was documented on carotid CTA (Fig. 2). There was no residual

![Fig. 1. Initial cervical computed tomography angiography (CTA) scan of the axial and three-dimensional sections. (A) Axial CTA of the neck demonstrating thrombosis and occlusion in the left common carotid artery (arrow). (B) Nonopacification was seen at the left internal and external carotid artery bifurcation level (arrow). (C) The left internal carotid artery and external carotid artery showed patency at the level of the C2 vertebra (arrow). (D) Three-dimensional CTA examination of the carotid artery revealing total occlusion before the bifurcation level (arrow).](https://doi.org/10.20408/jti.2021.0095)

![Fig. 2. Postoperative cervical computed tomography angiography (CTA) scan of the axial and three-dimensional sections. (A) Axial CTA of the neck demonstrating the normally contrasted left internal and external carotid arteries (arrow). (B, C) Normally contrasted left common carotid artery (arrows). (D) Sagittal CTA of the neck demonstrating the normally contrasted left common carotid artery (arrow). (E) Three-dimensional CTA examination of the carotid artery revealing no occlusion and completely normal blood flow (arrow).](https://doi.org/10.20408/jti.2021.0095)
stenosis in the results of carotid CDUSG at the 6-month follow-up. Written informed consent for publication of the research details and clinical images was obtained from the patient.

**DISCUSSION**

Vessel stretching can cause intimal damage, which can lead to dissection or intramural thrombus formation, resulting in stenosis or total occlusion after blunt trauma to the neck [5–7]. Moreover, these pathologies lead to impaired brain perfusion due to ischemic stroke and thromboembolic events. Although more than half of BCAI patients may be asymptomatic at the first visit to the ED, delayed neurological complications may occur from 1 hour to 7 days after injury [8]. There was only mild paresthesia on the right-hand fingertips in this patient who was admitted to the ED with multiple trauma. The patient had no motor deficits. After a detailed physical examination without losing time, advanced diagnostic methods were applied to minimize the risk of a potential neurological complication.

Fast and comprehensive screening of the head and neck arteries based on signs has been recommended for early diagnosis and treatment of BCAIs [9]. BCAIs are diagnosed by four imaging techniques: CDUSG, CTA, magnetic resonance angiography, and digital subtraction angiography. Although CTA has often been recommended as a diagnostic method in several reports, digital subtraction angiography remains the gold-standard diagnostic tool for neck artery injuries [5,9]. CDUSG, in contrast, is not widely used for assessing neck trauma and lacks sufficient sensitivity in identifying carotid artery injuries [10]. Since CDUSG is highly operator-dependent and requires experience, CTA was preferred as the primary diagnostic tool in this patient.

BCAI treatment aims to slow the progression of the arterial injury, reduce the risk of ischemic events in asymptomatic cases, and improve the neurological and survival results [11]. Early antithrombotic or anticoagulant therapy was recommended for BCAI patients in previous studies [12]. However, these treatments may be contraindicated in patients who have coagulopathy or intracranial bleeding as a result of blunt multitrauma. Depending on imaging findings, Biffi et al. [13] described what have become the most widely accepted grading criteria for BCAIs. BCAIs can be categorized into five subtypes using this scale: (1) luminal irregularity or dissection with <25% stenosis; (2) dissection or intramural hematoma with ≥25% stenosis; (3) traumatic aneurysm; (4) occlusion; and (5) transection. The present case was classified as subtype IV. Especially, grade IV and grade V injuries are associated with increased morbidity and mortality rate, and survival is related to the severity of neurological injury at the time of diagnosis [14]. Surgical repair of accessible grade IV or grade V BCAIs is recommended by many authors in large cohort studies [9,15]. The patient’s emergency operation was performed 2 hours after admission to the ED. Therefore, it was thought that an early surgical approach would be more appropriate because of total occlusion in the carotid artery and accompanying paresthesia in the extremity after imaging. It was thought that conservative treatment might lead to late neurological complications in this young patient. Primary repair of the simple intimal laceration, along with surgical thrombectomy, was thought to provide the maximal benefit to the patient. An excellent result was obtained in terms of symptomatic regression and survival.

It should never be forgotten that trauma surgery is a crucial part of cardiovascular surgery. With the effective use of early diagnostic methods, performing open surgery instead of conservative treatment prevented a possible permanent neurological deficit in this young patient. However, despite previous cohort studies of the management of carotid trauma, prospective randomized clinical trials with large samples are needed to create more up-to-date treatment algorithms.

In conclusion, BCAI is an uncommon but potentially lethal condition that requires immediate diagnosis and treatment. To reduce the risk of a potential neurological complication, it is critical to determine the diagnosis and management protocol as quickly as possible after a detailed clinical examination.

**NOTES**

**Ethical statements**

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

**Conflicts of interest**

The author has no conflicts of interest to declare.

**Funding**

None.

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INJURIES TO THE AZYGOS VEIN FOLLOWING BLUNT TRAUMA ARE RARE AND ASSOCIATED WITH SIGNIFICANT MORTALITY AND MORBIDITY. WE DESCRIBE THE CASE OF A PATIENT WHO PRESENTED WITH A LACERATION OF THE AZYGOS AND SUPERIOR INTERCOSTAL VEINS SECONDARY TO A MOTORBIKE ACCIDENT.

CASE REPORT

A 38-YEAR-OLD MALE PATIENT PRESENTED WITH HYPOTENSION AND TACHYCARDIA FOLLOWING AN UNSUCCESSFUL ATTEMPTED 8-M JUMP ON AN OFF-ROAD MOTORBIKE. An endotracheal tube was inserted upon presentation to the emergency department and the patient was fluid-resuscitated with a massive exsanguination pack, which consisted of 4 units of red blood cells, 4 units of fresh frozen plasma, and 4 units of platelets. The patient was found to have a large left-sided pneumothorax and large right-sided hemothorax with white-out on the chest radiograph performed on presentation. Bilateral intercostal catheters (ICCs) were inserted. The right ICC had 1,300 mL of blood upon insertion with a further 200 mL over the next hour. The left ICC had 300 mL of output and the patient’s left lung was partially reexpanded. Thoracic surgery was consulted regarding the ongoing high-volume drain tube output from the right-sided ICC. The patient was reviewed by thoracic surgery in the emergency department. Given the uncertainty regarding the etiology of the injury and the patient’s transient improvement in hemodynamic response to fluid resuscitation a decision was made to perform a computed tomography scan of the patient’s chest. This was performed in the brief period of hemodynamic stability following fluid resuscitation. The computed tomography scan showed a persistent large-volume right-sided hemothorax and a persistent left-sided pneumothorax (Fig. 1). The patient was taken to the operating theatre and a clamshell thoracotomy. A laceration in the azygos vein at the confluence of the arch of the azygos and the right superior intercostal vein was identified. Bleeding was controlled at the trifurcation. The patient survived and was discharged home on postoperative day 15.

Keywords: Azygos vein; Thoracic injuries; Case reports

INTRODUCTION

Injuries to the azygos vein following blunt trauma are rare and associated with significant morbidity and mortality. We describe the case of a patient who presented with a laceration of the azygos and superior intercostal veins secondary to a motorbike accident.

CASE REPORT

Azygos vein injuries are rare consequences of blunt trauma. When there is high drainage output from a right-sided intercostal catheter, an azygos injury must be considered in the differential diagnosis. We report the case of a 38-year-old male patient involved in a fall from a height during a motorcycle accident. Computed tomography demonstrated a large right-sided hemothorax and left-sided pneumothorax. The patient was transferred to the operating theatre and underwent a clamshell thoracotomy. A laceration in the azygos vein at the confluence of the arch of the azygos and the right superior intercostal vein was identified. Bleeding was controlled at the trifurcation. The patient survived and was discharged home on postoperative day 15.
Thoracotomy was performed. The pericardium was opened and a sling was placed around the right main pulmonary artery and superior vena cava intrapericardially. The chest was explored and a laceration was identified at the confluence of the azygos vein and the right superior intercostal vein that extended down both veins. The azygos vein was divided and staple-ligated distal to the confluence with the superior vena cava and inferior to its confluence with the superior intercostal vein using an Echelon Flex powered vascular stapler (Johnson & Johnson, New Brunswick, NJ, USA). The superior intercostal vein was divided and staple-ligated superior to its confluence with the azygos vein (Fig. 2).

Other injuries that required surgery during the admission included a displaced and a comminuted fracture of the left ileum and L4 left inferior articular facet joint. Other injuries that did not require intervention were nondisplaced fractures of the left ribs 1–10 posteriorly and anterolaterally, a T3 transverse process fracture, and a T7 spinous process fracture. The patient was extubated on postoperative day 5 and transferred to the ward. He was discharged home on day 15 postoperatively. The patient was well when seen in clinic 1 month postdischarge.

Informed consent was obtained from the patient in line with the Royal Melbourne Hospital Research Governance Unit case report policy. A literature review on traumatic azygos injuries showed that they were associated with a 35% mortality rate [1]. Often, the diagnosis is only made at the time of autopsy. Some patients can be taken to the operating room without a definitive diagnosis for high right-sided ICC output or hemodynamic instability and right-sided chest trauma. In many cases the diagnosis of azygos vein injury is made following computed tomography imaging [1,2]. If a diagnosis of azygos vein injury is made prior to transfer to the operating room, a right-sided thoracotomy would allow appropriate visualization and access to the azygos vein to facilitate control of hemorrhage and repair of injury [2]. However, when a definitive diagnosis has not been made prior to surgery and the location of the injury is unclear, then the decision regarding surgical access becomes more pertinent. In this case, there was concern about potential left-sided injuries given the presence of blood in the left chest and residual pneumothorax. A diagnosis of azygos vein injury was.
only made intraoperatively. Following a brief initial discussion, a decision was made to perform a clamshell thoracotomy with the rationale that with two senior surgeons present in the operating room, it would provide the fastest access to both the right and chest. This decision was made based on the surgeons’ experience with the management of thoracic trauma and the previously published literature [3]. This was thought at the time to be safer and more time-efficient than extending both a right-sided and left-sided thoracotomy. Median sternotomy has been used successfully for access to azygos vein injuries [4]. However, it was the operating surgeons’ opinion that median sternotomy would not have allowed timely visualization of the hilar and posterior mediastinal structures. In retrospect, the authors felt that given the losses, the extent of the injury to the vein, and hemodynamic instability, performing a sternotomy would have added a significant time delay to the identification and control of the injury.

There are multiple potential mechanisms of azygos vein injuries in blunt trauma. These include sheer force injuries at the confluence of the fixed azygos vein and mobile azygos arch, a rapid rise in venous pressure from cardiac compression, and direct injury from fractured vertebrae [2,4]. In this case, given the location of the rupture, the most likely mechanism was a shear force injury, as the location of the injury was at the confluence of the azygos vein and azygos arch [4].

Blunt traumatic injuries of the azygos vein are rare and fatal if not diagnosed and treated promptly. Aggressive fluid resuscitation and early thoracic surgical intervention are crucial for survival. In the appropriate circumstances, a clamshell thoracotomy provides excellent access and exposure to identify unknown thoracic injuries.

NOTES

Ethical statements
Informed consent was obtained from the patient in line with the Royal Melbourne Hospital Research Governance Unit case report policy.

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

Funding
None.

Author contributions
Conceptualization: all authors; Methodology: NY; Visualization: NY; Writing–original draft: NY; Writing–review & editing: BD, PA. All authors read and approved the final manuscript.

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Incidental traumatic right diaphragmatic rupture: a missed case after trauma

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INTRODUCTION

Severe trauma can cause diaphragmatic rupture, along with other abdominal or chest injuries. A ruptured diaphragm is associated with high morbidity and mortality, and its diagnosis is crucial. Hence, many cases in the literature have been published to help identify and manage this rare condition.

CASE REPORT

A 20-year-old female patient known to have asthma presented to Tawam Hospital as a referral for her incidental missed traumatic right diaphragmatic hernia. The patient had a motor vehicle accident in another country 14 years ago. There was no report of her injuries, but according to the family and the patient, she had right hemothorax that was treated with the insertion of a chest tube.

The patient had a recurrent cough, shortness of breath, and fever. The initial assumption was exacerbation of her asthma and her ingestion of raw camel milk.

Initially, a chest X-ray was done, which showed an elevated right hemidiaphragm. Computed tomography (CT) was obtained and it showed a large defect in the right dome of the diaphragm, predominantly in the posterior two-thirds, with herniation of the right lobe of the liver and presence of the small and large bowel in the thoracic cavity. The herniated right lobe of the liver was seen displacing the mediastinum to the left. There was atelectasis of the right middle lobe and near-complete atelectasis of the right lower lobe, while the left dome of the diaphragm was normal in continuity.

The patient was referred to the thoracic surgery department for definitive management, but unfortunately, she was lost to follow-up until recently when she agreed to operative management due to exacerbation of her respiratory symptoms. The decision regarding the operation was to repair the defect through the abdomen. The initial assumption was exacerbation of her asthma and her ingestion of raw camel milk.

Keywords: Trauma; Diaphragmatic hernia; Liver; Incidental findings; Case reports

Traumatic diaphragmatic hernia is among the most uncommon conditions after severe trauma, and it is associated with high morbidity and mortality. The diagnosis is difficult and might be missed, but a multimodal investigation might help in terms of diagnostic yield. In this case report, we present a missed right diaphragmatic rupture 14 years after the trauma.

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domen depending on the CT findings of the liver and other organs in the chest. This was also discussed with the thoracic surgery team, and it was agreed to perform the repair through the abdomen. The patient had a very long-standing diaphragmatic hernia, and was short and obese (body mass index, 31 kg/m²); therefore, we were concerned about possible loss of the domain and we thought that the abdominal cavity might not have enough space to accommodate the abdominal organs after reduction. We were prepared to resect the greater omentum, leave the abdomen open, or even consider partial liver resection if needed. Surgery was started using the laparoscopic technique, which was converted to open surgery with a midline incision because the hernial defect was obscured by the liver. The intraoperative findings showed the full right lobe of the liver, as well as the gallbladder, in the right thoracic cavity and multiple loops of the small bowel and ascending and transverse colon in the right thoracic cavity (Fig. 3). The stomach was redundant, distended, and reached the pelvic cavity. A large right diaphragmatic hernial de-
fect was seen, with the posterior edge of the defect attached to the upper posterior surface of the liver (segments 7 and 8). The portal system ran along the posterior edge of the hernial defect longitudinally and the inferior vena cava and aorta just at the medial edge of the defect.

Adhesiolysis was done by cautery, and all organs were reduced to the abdomen. Primary repair of the diaphragm was done with no tension using 2-0 Prolene continuous sutures and reinforce using a composite mesh cut to an appropriate size. Cholecystectomy was performed, as the wall of the gallbladder was thickened and edematous; pathology later showed chronic cholecystitis. The patient did well after surgery with no further complaints about the respiratory symptoms that she previously experienced before surgery. A chest X-ray was repeated 6 months after surgery and showed no recurrence (Fig. 1B). The patient provided written informed consent for publication of the research details and clinical images.

DISCUSSION

Right traumatic diaphragmatic rupture is a rare condition, which is missed most of the time due to the difficulty in the diagnosis and the need for further investigations [1]. The causes of diaphragmatic rupture can be divided into direct diaphragmatic trauma (penetrating injuries such as a direct stab wound to the diaphragm or a gunshot) and indirect diaphragmatic trauma (blunt trauma) [2]. Injuries contributing to the development of diaphragmatic rupture include motor vehicle accidents (79.5%) and falls from heights (15.9%) [3].

The diagnosis of traumatic diaphragmatic rupture is indicative of severe trauma that has caused the intraabdominal organs to translocate into the thoracic cavity [4]. Up to 3.6% of cases with traumatic diaphragmatic rupture are due to blunt traumas, although around 66% of them are missed [3].

Most cases of diaphragmatic rupture occur on the left side (75%), with the spleen being the most common injured organ [5]. Due to the cushioning effect of the liver on the right side, injuries to the right diaphragm are less traumatic, which is why right diaphragmatic rupture is less common [6]. Nevertheless, an increase in the number of reported cases of right diaphragmatic rupture has been noticed, mostly due to the improvement of posttrauma investigations and high clinical suspicion [5].

The diagnosis of traumatic diaphragmatic hernia is mostly missed. The cases that are not missed are diagnosed either preoperatively (39%) or intraoperatively (45%), during either first-look or second-look surgery [7].

Imaging studies and a high suspicion for these injuries can help in the diagnosis. Initially, a chest X-ray with an abdominal X-ray might show the diaphragmatic rupture by capturing the elevated hemidiaphragm with or without the presence of intraabdominal organs in the chest, while the use of CT might be more appropriate for the diagnosis. A previous study suggested that in up to 59% of cases, a chest X-ray was an inconclusive method, whereas a CT scan showed the defect in the diaphragm [8].

Since the diagnosis of diaphragmatic rupture is important to prevent posttrauma diaphragmatic hernia and other serious complications such as strangulation of the ascended organs [9], other modalities such as ultrasonography and magnetic resonance imaging might be indicated. Nevertheless, the use of magnetic resonance imaging might be limited due to the need for continuous monitoring and the patient’s condition, while the use of

Fig. 3. Intraoperative findings of the liver and the bowel (A) in the thoracic cavity and (B) after reduction.
ultrasonography might be helpful in detecting the functional status of the diaphragm and the presence of intraabdominal organs in the thoracic cavity [10].

The surgical management of ruptured diaphragmatic injury depends on the patient's condition and the presence of other injuries. The surgical approach can be divided into the abdominal approach (laparotomy or laparoscopy), which is appropriate for unstable patients with abdominal injuries, and the thoracic approach (thoracotomy or thoracoscopy) in cases with isolated chest injuries and a late diagnosis [3,5].

The main objective of surgery is to reduce the organs, drain the pleural fluid, and repair the defect with nonabsorbable sutures with or without the placement of mesh [11]. However, there are some cases presented in the literature in which the surgeons preferred using only nonabsorbable sutures without mesh placement due to the elevated risk of infection [12].

In summary, right diaphragmatic rupture is an uncommon condition. A multimodal investigation combined with a high degree of clinical suspicion is indicated for a proper diagnosis. Treatment is surgical and depends on the patient's status and the presence of other injuries.

NOTES

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

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

Funding
None.

Author contributions
Conceptualization: all authors; Formal analysis: all authors; Investigation: all authors; Writing–original draft: FA, SG; Writing–review & editing: all authors. All authors read and approved the final manuscript.

REFERENCES

Experience with the emergency vascular repair of upper limb arterial transection with concurrent acute compartment syndrome: two case reports

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Upper extremity vascular injuries occurring with acute compartment syndrome are very challenging to manage in an emergency context in resource-poor settings. The need to always recognize the likelihood of coexisting compartment syndrome guides surgeons to perform concomitant fasciotomy to ensure a better outcome. We managed three vascular injuries in the upper extremities in two patients with concomitant imminent compartment syndrome observed intraoperatively. The first injury was complete brachial artery disruption following blunt trauma, while the second and third injuries were radial and ulnar artery transection caused by sharp glass cuts. Both patients were treated with vascular repair and fasciotomy. Secondary wound coverage was applied with split-thickness skin grafting, and the outcomes were satisfactory. Concomitant fasciotomy potentially improves the outcomes of vascular repair in emergency vascular surgery and should be considered for all injuries with the potential for acute compartment syndrome.

Keywords: Fasciotomy; Compartment syndromes; Vascular system injuries; Upper extremity; Case reports

INTRODUCTION

Injuries to the extremities are a common component of trauma resulting from road traffic accidents. These injuries may occur in isolation or as part of polytrauma. The extent of injury varies depending on the energy of trauma. Injuries involving neurovascular bundles are also very common; these usually occur in high-energy events, and could readily be missed in cases of low-energy blunt injuries [1]. Penetrating injuries are a commoner cause of neurovascular injuries than blunt trauma [2]. Upper extremity vascular trauma constitutes nearly half of all peripheral vascular injuries [3]. It is a limb-threatening and/or a life-threatening event that requires prompt surgical attention. The need for a timely intervention to prevent limb loss is the major responsibility of the trauma and vascular team.

The occurrence of major vascular injury with acute compartment syndrome could be very challenging both to evaluate and treat. The features of acute compartment syndrome could mimic those of vascular injuries, which could also lead to the former [4]. In a setting where the etiopathogenesis of acute compartment
syndrome involves both a vascular injury with bleeding into the compartment and direct muscle contusion, the onset of signs common to both conditions is rapid, as well as their progression. The common signs are disproportionate pain, paresthesia, palsy, the absence of a distal pulse, and cold extremities [4].

Acute compartment syndrome occurs very commonly in the forearm, although it is less common than in the leg [5]. The commonest cause is trauma with contusion of the muscles and vascular injury. Prompt presentation and treatment are necessary to ensure limb salvage and prevent or reduce the severity of reperfusion injury. The challenges of late presentation and the unavailability of essential instruments for vascular surgery often affect the outcomes of vascular injuries in rural areas in tropical regions [3]. This leads to unfavorable outcomes, especially limb losses.

**CASE REPORTS**

The two patients analyzed in this study were managed about a month apart at the Alex Ekwueme Federal Teaching Hospital Abakaliki. The first was a 19-year-old male patient who presented to the unit about 11 hours following a crush injury of the left upper limb. He was behind a reversing sports utility vehicle that collided with him, pressing his upper limb against a wall. The features of acute compartment syndrome were demonstrated preoperatively, and a neurovascular injury was suspected. There was significant bleeding, and the patient presented with a hematocrit of 29%. He was then resuscitated and transfused with 2 units of blood.

The intraoperative findings were avulsion of the roof of the cubital fossa and the bicipital aponeurosis, complete disruption of the brachial artery and its venae comitantes just above the cubital fossa, sparing of the cephalic vein, intact median and ulnar nerves, and acute compartment tension in the anterior compartment of the forearm, which showed grayish and severely contused muscles. The procedure was performed under general endotracheal anesthesia using a tourniquet applied to the proximal third of the arm, observing strict asepsis. The wound was explored and copiously irrigated with dilute hydrogen peroxide and normal saline.

Fasciotomy was performed, the brachial artery was cannulated with a 5F feeding tube, and irrigation with unfractionated heparin was performed. Approximation of the two ends of the brachial artery was achieved with Prolene 5/0, while dilute heparin irrigation and washout continued (Fig. 1). Sutures were applied at eight points and tied gradually upon removal of the feeding tube. Evidence of perfusion was demonstrated with the return of distal pulses, restoration of redness of the muscles, and recovery of normal temperature and partial oxygen pressure between 96% and 100% in the ensuing 24 hours. The wound was loosely dressed, covered with a crepe bandage, and immobilized with a plaster of Paris back slab at 15° flexion. Low-molecular-weight heparin (enoxaparin) was given subcutaneously at 40 mg daily for 1 week before converting to dabigatran tablets (110 mg daily). Presumptive antibiotics, analgesics, and vitamins A, C, and E were continued in the postoperative period. Alternate-day wound dressings were commenced 48 hours after surgery and converted to daily dressings 5 days prior to split-thickness skin grafting. The postoperative period was uneventful, and wound cover was subsequently achieved with split-thickness skin grafting. Healing was complete, and physiotherapy was employed for elbow rehabilitation. The range of movement of the elbow joint was normal on discharge. The donor-site healing of the split-thickness skin graft was excellent. The patient was lost to outpatient follow-up.

The second patient was a 23-year-old male patient, a right-handed truck driver who sustained a glass cut on the midpoint of the right forearm following a motor vehicle crash. He sustained complete transection of both the ulnar and radial arteries at the mid-forearm (Fig. 2). He bled profusely, presented with a hematocrit of 18%, and only provided 2 units of whole blood 12 hours after the injury. This necessitated conducting the operation with a tourniquet to save the limb. The intraoperative findings confirmed complete disruption of the arteries, sparing of the ulnar...
and median nerves, transection of the muscles of the forearm, and evidence of compartment syndrome. Wound lavage was done with dilute hydrogen peroxide and normal saline. The vessels were cannulated with a size 6 feeding tube and washout was performed with unfractionated heparin (Fig. 3). Vascular coaptation was achieved with Prolene 6/0. Fasciotomy was performed, and the transected muscles were repaired with Vicryl 0 sutures. The wound was loosely dressed with an antibiotic-impregnated petrolatum gel gauze as the contact layer and a gauze absorptive layer was formed by coverage with a crepe bandage. The postoperative management was as in the first case. The outcome was equally gratifying to both the patient and the managing team. Both procedures were performed by the same surgeon. Both patients also gave consent for clinical photographs and the publication thereof.

DISCUSSION

Vascular injuries are often challenging, both to the patient and the managing team, in the tropics due to the lack of both expertise and institutional support in a resource-constrained environment. Patients are often forced to undergo amputation of the extremities. This unfavorable outcome also discourages patients from presenting at tertiary institutions for fear of losing their limbs. The two patients presented herein, in whom three vascular disruptions were managed, were young men and so it was very necessary to salvage the extremities despite all the institutional limitations in the resource-poor setting [6].

Another major challenge is the lack of insurance coverage for most patients in resource-poor settings; coupled with poverty, this reduces the likelihood of patients receiving treatment at the right time [7,8]. As patients apart from government employees pay essentially out of pocket, it takes time to mobilize resources for hospital bills. Furthermore, even with an early presentation, there are certain obligations (e.g., procuring blood) that patients must meet themselves before the procedure is carried out. Both patients in this study bled significantly and needed to be transfused prior to surgery.

Vascular repair was done following the established principles of asepsis and surgical techniques. The coexistence of acute compartment syndrome caused by bleeding into the compartment syndrome.
and/or contusion of the muscles necessitated fasciotomy in all cases, as the ensuing edema could constitute a major obstacle to the success of vascular repair. After fasciotomy, there was evidence of recovery of the muscles intraoperatively. In our setting, where postoperative monitoring is limited to oxygen saturation through pulse oximetry, it is most crucial that every possible mechanical impediment to the flow of blood through the point of coaptation be removed. The wounds were closed secondarily with split-thickness skin grafting. Wound coverage with a split-thickness skin graft was a minor procedure performed after the vascular repair was confirmed to be successful.

The outcome in both patients was excellent at both the donor and the recipient sites, and the patients were discharged within 2 weeks of skin grafting. No significant complications relating to either the vascular repair or the split-thickness skin graft were observed. Both patients were followed up on an outpatient basis. The first patient had an uneventful recovery of function and did not need professional physiotherapy. He regained grossly complete function and continued his educational program. The second patient briefly received physiotherapy to improve power at the wrist joint. He had full recovery of function and returned to his job as a truck driver.

Concurrent fasciotomy with vascular repair in traumatic vascular disruption is an important adjunct to vascular coaptation [9]. Although it requires another session in the operating theater to achieve wound coverage, it is far more rewarding than a single session with attendant failure. Nonetheless, conducting a study with a larger sample would yield more convincing evidence regarding the role of concurrent fasciotomy.

Vascular trauma repair is yet undeveloped in the West African subregion and there are limited publications to that effect. The reason for this is mainly due to poor outcomes, which discourage surgeons in this subregion from embarking on such procedures. Onakpoya et al. [10] recorded a salvage rate of 64.9% and an amputation rate of 25%. However, they did not indicate performing any type of fasciotomy despite its obvious advantages [9,10]. Another published work showed a salvage rate of 80% at a National Cardiothoracic Center of Excellence, but still without any mention of fasciotomy [11]. It is therefore hoped that by sharing this experience, we will motivate surgeons in the West African subregion to use their limited resources to perform limb vascular repair with fasciotomy where indicated, and thereby salvage as many extremities as possible.

In conclusion, emergency vascular repair in the extremities following trauma may have greater success if acute compartment syndrome is addressed and the wound is closed secondarily. It is therefore imperative in every upper extremity neurovascular injury to identify a present or potential acute compartment syndrome before, during, or immediately after neurovascular repair in order to take necessary action for an optimal outcome.

NOTES

Ethical statements
Informed consents for publication of the research details and clinical images were obtained from the patients.

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

Funding
None.

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

Acknowledgments
The authors appreciate the assistance of the ward nurses in the postoperative management of the patients.

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**INTRODUCTION**

Humeral fractures can occur proximally, midshaft, or distally and are categorized as having simple, wedge, or complex (comminuted) patterns. Midshaft humeral fractures account for 2% of all fractures [1]. Since humeral shaft fractures have an excellent consolidation ability due to the rich vascularization by soft tissue and surrounding muscles, the majority of these fractures can be treated conservatively [2]. With nonoperative management, union rates of more than 90% have been described in the literature [2]. Because of the large range of motion of the shoulder and elbow joint, rotatory and angulatory deformities can be compensated for. The most common complications associated with shaft fractures include neurovascular compromise (radial nerve) and non-union.

Nonunion after a humeral fracture presents a challenge for the surgeon and is often debilitating for the patient. Humeral nonunion is defined as the absence of bone healing 6 to 12 months after initial injury [3], and it can be subdivided as atrophic and hypertrophic [4]. After operative treatment of humeral shaft fractures, an incidence of nonunion between 2.5% and 13% has been reported [2]. Compared to plate osteosynthesis, intramedullary nailing may be superior for reducing blood loss and postoperative infections [5]. However, due to more movement at a fracture site with an intramedullary nail, plate fixation is regarded as superior in preventing nonunion in comparison with intramedullary nail fixation [5,6].

The surgical approach for humeral nonunion after operative treatment is extremely challenging because of the complex neurovascular anatomy and the possible necessity of osteosynthesis removal. In this report, a rare case of humeral nail bending after secondary trauma in a patient with preexisting nonunion of the humerus is presented.

**CASE REPORT**

Initially, a 71-year-old, right-hand-dominant male patient presented to the Department of Accidents and Emergency at the...
Haga Teaching Hospital following an ice-skating accident. The patient had made a misstep and fell on his left arm. Directly after the injury, he complained of pain and his upper arm showed a deformation. The neurovascular function of his arm was intact on clinical examination. An X-ray showed a bending wedge fracture of the humeral diaphysis with a butterfly fragment on the medial side (AO-12-B2) (Fig. 1). Closed reduction and internal fixation were performed using a long MultiLoc nail (270 mm) with two screws proximally as well as distally. Adequate reduction could be achieved during this procedure. The butterfly fragment was located sufficiently and the implant position was secured. Postoperatively, no complications occurred. During outpatient follow-up, the bone seemed to be healing well 2 months after surgery (Fig. 2A). After 6 months, his range of motion was unrestricted. An X-ray examination showed delayed union of the fracture (Fig. 2B). Because the patient had no pain or other symptoms at this stage, no intervention was done and a wait-and-see policy was applied.

However, 1 year after initial surgery, the patient experienced a new trauma to his left arm during a second fall while ice-skating. Upon presentation to the Accidents and Emergency Department, he was in pain and had restricted movements of the upper arm. An X-ray revealed a bent humeral nail with nonunion of the humerus (Fig. 3). The image suggested that the nail was intact but had undergone plastic deformation. The patient consented to a second operation.

**Fig. 1.** X-ray showing an oblique fracture of the humeral diaphysis with a butterfly fragment on the medial side.

**Fig. 2.** Postoperative radiographs (A) after MultiLoc fixation (2 months), showing (B) delayed union (6 months).
part of the intramedullary nail could now be removed without any difficulty. The proximal part was left in place because removal of the proximal screws would mean that the patient’s position would have to be changed and additional damage to the soft tissue (and rotator cuff) could occur. Re-assessment of the non-union site showed that compression was possible while using plate fixation. Adequate stability and compression were assessed to be necessary to achieve bone healing. Bone grafting was deemed unnecessary because of the hypertrophic character of the nonunion [7]. Therefore, no bone grafting was applied; however, compression was achieved and the possible shortening of the humerus during this procedure was accepted. Eventually, absolute stability was achieved by using a Zimmer Cable Ready plate fixation system (Zimmer Biomet, Warsaw, IN, USA; eight holes, 246 mm) on the dorsal humerus shaft. Distally, three angle-stable screws were used, while proximally three cortical screws with cable grip fixation were applied so that the proximal part of the nail could be kept in place (6 weeks after surgery) (Fig. 4A). The radial and ulnar nerves were exposed peroperatively and protected during closure. In total, the operation took 2.5 hours and there was 0.4 L of blood loss.

Postoperatively, the patient developed sensory loss in his fifth finger and the ulnar part of the fourth finger without any motor loss. There were no abnormalities of the ulnar nerve on ultrasound localisation. On electromyography, axonal neuropathy was seen. Consequently, his complaints were interpreted as axonotmesis of the ulnar nerve. Due to a Martin-Gruber anastomosis, additional compensation of sensation and function was possible and no peripheral neurosurgery was performed. Approximately 4 months after the operation, partial consolidation was seen (Fig. 4B). One year after surgery, during follow-up in the outpatient clinic, the patient had a full range of motion again and was very satisfied with the results. An X-ray examination and computed tomography scan showed complete healing of the fracture (Fig. 4C). After 2 years, the function of the ulnar nerve had returned to normal.

**DISCUSSION**

Removal of a bent or broken intramedullary nail is a rare but challenging problem. Several case reports have reported the management of this condition in the lower extremity [8,9]. However, to the best of our knowledge, bending of a humeral nail has not previously been reported. Currently, there is no review or algorithm that provides guidance on how to manage patients with this problem.
Various mechanisms have been described as potential causes of intramedullary nail failure [10]. Bending of an intramedullary nail is most commonly linked to trauma, while breakage of the nail primarily occurs in cases of nonunion and unstable or pathologic fractures due to metal fatigue [11,12]. This condition is generally the result of repetitive cycles of stress. Patient characteristics such as age, bone quality, smoking, and alcohol abuse influence this process as well. Nevertheless, in most cases, a fracture of the bone will happen, rather than implant bending itself.

Revision surgery in cases with bending of a nail is complex and challenging. The extraction of a bent nail seems to be more complicated than removing a broken nail because deformation usually results in blockage of the intramedullary canal [13,14]. Furthermore, soft-tissue damage and associated lesions may be expected in these situations. In our case, we chose to partially extract the nail, remove the hypertrophic tissue, and perform open reduction and internal fixation by plate osteosynthesis. Removing the distal part of the nail by sawing it in half was crucial for adequate reduction of the fracture. One should acknowledge that sawing of a nail requires special equipment, and that metal debris, thermal injury, and soft-tissue injury can occur during this process. We advise using a small circular saw and cooling the nail and surrounding tissues with sterile ice water. In our case, we decided to keep the proximal part in place for several reasons. First, plate fixation with a cable fixation system resulted in a compression-type stable situation allowing the hypertrophic nonunion to heal with adequate bone healing. Second, removal of the proximal part of the nail required repositioning of the patient (from prone to supine). This maneuver would possibly be a risky event, since the combination of an unstable humerus and the sharp end of the nail could injure the surrounding soft tissue. Moreover, before the second fall, the patient had recovered without limitations in shoulder function. Therefore, we did not want to risk additional damage to the rotator cuff.

Another major challenge in this injury was the preexisting nonunion. The first principle in this type of nonunion should be removal of the fibrinous tissue at the fracture site, which interferes with bone bridge formation [15]. During exploration of the nonunion site, a hypertrophic nonunion was diagnosed with large bony activity surrounding the nonunion without bridging the gap. The diamond concept was applied for an adequate assessment of compression and stabilization of the nonunion site (and ultimately bone healing). The plate was placed via a posterior triceps-sparing approach (triceps-on) to the humeral shaft allowing adequate exposure of the nonunion. The applied approach was chosen based on the surgeon’s preference, the position of the nonunion, and the bending of the nail. In our case, the plate was placed primarily on the dorsal side. Alternative approaches, such as from the anterior side, could have been considered as well.

In general, we advise discussing these cases in a team with trauma and/or orthopaedic surgeons. Since there is no uniform treatment practice, combining the strengths of various specialists ultimately benefits the patient. Furthermore, hospital-wide support, including peripheral neurology specialists, physiotherapy, and casting technicians, is essential to provide good clinical care for these patients.

This is an exceptional case of humeral nail bending in an older man after re-injury of his left upper arm. A second operation with removal of the distal nail and obtaining absolute stability by cable-ready plate fixation was performed to achieve fracture healing with good clinical results.

Fig. 4. X-ray showing postoperative consolidation of the humeral diaphysis with the dorsal shaft plate and proximal half of the nail in place. Postoperative (A) 6 weeks, (B) 4 months, and (C) 1 year.
NOTES

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

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

Funding
None.

Acknowledgments
We appreciate all the resident doctors of the departments of surgery and anesthesia, the nursing staff in the operating room, intensive care unit and the surgical wards that assisted in the management of this patient.

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

REFERENCES

Bilateral anterior dislocation in the hips: a case report

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The hip is a stable ball-and-socket joint. Bilateral anterior dislocations of the native hip joints account for fewer than 1% of all dislocations. We present a unique case of a bilateral anterior dislocation in a patient who presented to our institution within 6 hours of trauma. The dislocations were promptly reduced under propofol anesthesia in the operating room. The patient did not suffer a concurrent fracture. After the procedure, we performed regular X-ray examinations for 2 years to rule out the development of avascular necrosis of the head of the femur. The course of the patient was unremarkable.

Keywords: Hip dislocation; Diagnosis; Therapy; Rehabilitation; Case reports

INTRODUCTION

The hip is a ball-and-socket joint that can withstand substantial mechanical forces. It is stabilized by the acetabulum’s depth, surrounding ligaments, labrum, and muscles [1]. Acquired unilateral posterior hip dislocation is typical of dashboard accidents and accounts for the vast majority of native hip injuries. Bilateral symmetric hip dislocations are exceedingly uncommon and are frequently accompanied by acetabular fractures [2]. It is imperative that a dislocated hip be reduced within 6 hours to prevent avascular necrosis of the hip [3,4]. The reduction can be either closed or open if associated with a femoral head or acetabular fracture.

We report a unique case of a bilateral anterior dislocation in a patient who presented to NC Medical College & Hospital (Panipat, India) within 6 hours of trauma. The dislocations were immediately reduced in the operating theater under propofol anesthesia.

CASE REPORT

A 50-year-old male laborer presented to our institution with excruciating bilateral hip pain and an inability to walk following a fall off his bike after a head-on collision with a heavy vehicle from behind. According to the patient, he was seated in the rear seat, with both his hips flexed, abducted, and in mild external rotation, with his feet firmly planted on the foot paddles. They were traveling at 32 km/hr. There were no concussions, vomiting, or ear bleeds after the impact. The patient had no prominent family or prior medical history. He was neither intoxicated nor under the influence of any other substance. The patient’s vital signs were steady, and his Glasgow Coma Score was 15. There was no open wound on either lower leg, and both lower limbs were in 85° flexion, abduction, and 35° external rotation.

There were no signs of motor, sensory, or vascular impairment. There were no injuries to the chest, abdomen, or spine. Intravenous line access and portable X-rays were ordered following analgesic administration per the Advanced Trauma Life Support
protocol. An anteroposterior X-ray of the pelvis with both hips revealed bilateral anterior dislocation of both hips (Fig. 1). Due to the position of both heads adjacent to the obturator foramen, the dislocations were classified as obturator type. We recommended a pelvic computed tomography scan to rule out the possibility of an accompanying acetabular fracture. However, due to the arrangement of both lower limbs, he could not undertake the scan (Fig. 2). The patient was then taken to the operating room for closed reduction under anesthesia. We were able to reduce the joints using the Howard maneuver [4].

In this maneuver, longitudinal and lateral traction was applied first to the right lower limb and later to the left. We used external and internal rotation to reduce the hips in conjunction with the traction. The reduction restored the range of motion and alleviated the pain. The neurovascular status was normal, and the clinical examination suggested that the hips were stable. Postreduction joint stability and fractures were checked on fluoroscopy. The hip joints appeared stable, and fluoroscopy pictures confirmed no fractures. Postoperatively, an X-ray examination verified concentric reduction of both hip joints with no fracture. The patient was given skin traction for 2 weeks and then ambulated with partial weight-bearing [5]. The abduction and external rotation of the limbs were maintained with an A-shaped pillow between the thighs. Full weight-bearing was allowed after 6 weeks.

The patient had no difficulties walking or carrying out other daily activities. X-ray examinations performed at 6-month intervals for 2 years revealed no avascular necrosis or osteoarthritis changes (Fig. 3). The patient can squat and sit cross-legged, just as before the accident. The patient provided informed consent for publication of the research details and clinical images.

**DISCUSSION**

Anterior dislocation of the native hip is the least prevalent type of dislocation and accounts for approximately 8% to 15% of total

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**Fig. 1.** Preoperative X-ray of bilateral anterior hip dislocation.

**Fig. 2.** Inability to do computed tomography scan because of limb position. Informed consent for publication of the clinical image was obtained from the patient.

**Fig. 3.** Postoperative after 2-year follow-up.
Bilateral anterior dislocations comprise fewer than 1% of all hip dislocations. Anterior dislocations are more uncommon than posterior dislocations because the anterior capsule of the hip joint is thicker than the posterior capsule, and the insertion of the iliofemoral ligament reinforces the anterior capsule.[7]

Most hip dislocations occur due to high-impact injuries, particularly in unrestrained passengers. The patient presented herein was riding a bike in the rear seat. The direction of the applied force and the local anatomy of the femur and acetabulum dictate the type of dislocation. If the applied force drives the hip into abduction and flexion, anterior femoral head dislocation occurs.[2]

These forces may act from the knee up or along the inner thigh. The location of the hip dictates the femoral head’s eventual position outside the pelvis. If the hip is in its resting flexion and extension postures before deforming stress, obturator and pubic anterior dislocations will occur, respectively.

The Epstein system categorizes anterior dislocations as superior or inferior. Dislocations have been subdivided depending on whether or not a fracture is present.[8]. Because there was no concomitant fracture and the femoral head was below the obturator foramen, we diagnosed our patient with a type 2A Epstein dislocation. The timing of reduction is critical. Delay in reduction causes an increased risk of avascular necrosis of the femur head.

Our patient arrived 6 hours after the accident. The patient’s initial visit to a primary health care center and subsequent referral to us caused the delay. We promptly took the patient to be reduced under propofol anesthesia. Patients with a dislocated hip and concomitant fracture are at elevated risk for avascular necrosis. Numerous factors play roles in the development of avascular necrosis in the aftermath of anterior dislocation. The primary explanation is that the femur head’s blood supply is compromised due to mechanical injury to the vasculature caused by the head itself.[8]. Another cause is spasms of the major blood vessels in the absence of pathology.[8]

Complications following anterior dislocation have been divided into early or late. Acetabular fractures, femoral head fractures, femoral nerve or artery damage, sciatic nerve damage, and ipsilateral knee injuries such as meniscal tears are early sequelae. Late-term complications include avascular necrosis (2%–10% of cases), posttraumatic osteoarthritis (20% of cases), and heterotopic ossification (10% of cases).[1]

Anterior hip dislocation is infrequent, and bilateral anterior hip dislocations are particularly rare; nonetheless, they are a medical emergency. Dislocations should be promptly detected clinically, verified radiologically, and reduced immediately. Anterior dislocations should be reduced within 6 hours to prevent complications. If closed reduction is unsuccessful, the head should be reduced by open reduction. Before attempting an open procedure, a computed tomography scan should be performed to rule out intraarticular or impacted fragments. Follow-up X-ray examinations should be performed every 6 months for 2 ensuing years after reduction to screen for late complications.

NOTES

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

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

Funding
None.

Author contributions
Conceptualization: all authors; Data curation: DM; Project administration: RS; Visualization: RS; Writing–original draft: DM; Writing–review & editing: DM. All authors read and approved the final manuscript.

REFERENCES

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☐ Authors have written the manuscript in compliance with Instructions for Authors and Recommendations for the Conduct, Reporting, Editing, and Publication of Scholarly Work in Medical Journals (http://www.icmje.org) from the International Committee of Medical Journal Editors, and the Guideline of Committee on Publication Ethics (https://publicationethics.org).

☐ Authors have omitted names and organizations in the manuscript submitted for review.

☐ The title page should include the title, author(s) full name(s), written as First Name then Last Name, and academic degree(s), the name(s) of the affiliation(s), contact information of the corresponding author(s), ORCID, and notes.

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☐ Three to five keywords should be included (those recommended in MeSH; http://www.ncbi.nlm.nih.gov/mesh).

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