Aims and Scope

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

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

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

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

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

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Trauma remains a significant healthcare burden, causing over five million yearly fatalities. Notably, the liver is a frequently injured solid organ in abdominal trauma, especially in patients under 40 years. It becomes even more critical given that uncontrolled hemorrhage linked to liver trauma can have mortality rates ranging from 10% to 50%. Liver injuries, mainly resulting from blunt trauma such as motor vehicle accidents, are traditionally classified using the American Association for the Surgery of Trauma grading scale. However, recent developments have introduced the World Society of Emergency Surgery classification, which considers the patient’s physiological status. The diagnostic approach often involves multiphase computed tomography (CT). Still, newer methods like split-bolus single-pass CT and contrast-enhanced ultrasound (CEUS) aim to reduce radiation exposure. Concerning management, nonoperative strategies have emerged as the gold standard, especially for hemodynamically stable patients. Incorporating angiography with embolization has also been beneficial, with success rates reported between 80% and 97%. However, it is essential to identify the specific source of bleeding for effective embolization. Given the severity of liver trauma and its potential complications, innovations in diagnostic and therapeutic approaches have been pivotal. While CT remains a primary diagnostic tool, methods like CEUS offer safer alternatives. Moreover, nonoperative management, especially when combined with angiography and embolization, has demonstrated notable success. Still, the healthcare community must remain vigilant to complications and continuously seek improvements in trauma care.

Keywords: Wounds and injuries; Liver; Therapeutic embolization

INTRODUCTION

Incidence
Trauma is a major burden on the healthcare system, with over five million fatalities per year worldwide [1]. A significant percentage of the patients involved in trauma are under the age of 40 years. The liver is a commonly injured solid organ in blunt and penetrating abdominal trauma [2,3], with an increased prevalence in recent decades [1,4–7]. Since uncontrolled bleeding can cause significant morbidity and has a mortality rate of 10% to 50% [8,9], it is important to control the hemorrhaging associated with liver trauma.

A database analysis of trauma centers in the United States showed that patients with liver injuries had a mean age of 31.3
years and a mean Injury Severity Score of 23, and that 64% were male and 79% had sustained blunt injuries [2]. A retrospective analysis at a Norwegian trauma center showed that the median age of patients presenting with abdominal trauma was 31 years and that 70.4% were male. Adult patients comprised 83.3% of the patient population with 91.1% of the injuries due to blunt trauma [6].

**Causative factors**

Most liver injuries in the setting of trauma are due to blunt injuries. Blunt trauma most frequently results from motor vehicle crashes, followed by falls from a height and pedestrian versus automobile accidents [7,10].

**Classification**

Liver injuries have traditionally been classified according to the American Association for the Surgery of Trauma (AAST) organ injury grading scale (Table 1) [11]. A criticism of the AAST grading scale is the lack of correlation to the patient’s physiological status. A more recently devised classification system presented by the World Society of Emergency Surgery (WSES) does consider the patient’s physiological status (Table 2) [12].

The WSES classifies liver injury according to three levels of severity. WSES grade I and AAST grades I–II include minor injuries, WSES grade II and AAST grade III include moderate injuries, and WSES grades III–IV and AAST grades IV–V include severe injuries. All AAST grades with hemodynamic instability are classified as severe [12].

**CLINICAL EVALUATION**

Patients presenting to the trauma bay are evaluated for clinical stability by monitoring vital signs, assessing laboratory values, and performing a physical examination, after which a determina-

---

**Table 1. AAST liver injury scale (2018 revision)**

<table>
<thead>
<tr>
<th>AAST grade</th>
<th>Imaging criteria</th>
<th>Operative criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Subcapsular hematoma &lt;10% surface area</td>
<td>Subcapsular hematoma &lt;10% surface area</td>
</tr>
<tr>
<td></td>
<td>Parenchymal laceration &lt;1 cm in depth</td>
<td>Parenchymal laceration &lt;1 cm in depth</td>
</tr>
<tr>
<td>II</td>
<td>Subcapsular hematoma 10%–50% surface area; intraparenchymal hematoma &lt;10 cm in diameter</td>
<td>Subcapsular hematoma 10%–50% surface area; intraparenchymal hematoma &lt;10 cm in diameter</td>
</tr>
<tr>
<td></td>
<td>Laceration 1–3 cm in depth and ≤10 cm in length</td>
<td>Laceration 1–3 cm in depth and ≤10 cm in length</td>
</tr>
<tr>
<td>III</td>
<td>Subcapsular hematoma &gt;50% surface area; ruptured subcapsular or parenchymal hematoma</td>
<td>Subcapsular hematoma &gt;50% surface area; ruptured subcapsular or parenchymal hematoma</td>
</tr>
<tr>
<td></td>
<td>Intraparenchymal hematoma &gt;10 cm</td>
<td>Intraparenchymal hematoma &gt;10 cm</td>
</tr>
<tr>
<td></td>
<td>Laceration &gt;3 cm in depth</td>
<td>Laceration &gt;3 cm in depth</td>
</tr>
<tr>
<td></td>
<td>Any injury in the presence of a liver vascular injury or active bleeding contained within liver parenchyma</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Parenchymal disruption involving 25%–75% of a hepatic lobe</td>
<td>Parenchymal disruption involving 25%–75% of a hepatic lobe</td>
</tr>
<tr>
<td></td>
<td>Active bleeding extending beyond the liver parenchyma into the peritoneum</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Parenchymal disruption &gt;75% of a hepatic lobe</td>
<td>Parenchymal disruption &gt;75% of a hepatic lobe</td>
</tr>
<tr>
<td></td>
<td>Juxtahepatic venous injury to include retrohepatic vena cava and central major hepatic veins</td>
<td>Juxtahepatic venous injury to include retrohepatic vena cava and central major hepatic veins</td>
</tr>
</tbody>
</table>

AAST, American Association for the Surgery of Trauma.
Adapted from Kozar et al. [11], with permission from Wolters Kluwer Health Inc.

**Table 2. WSES liver trauma classification**

<table>
<thead>
<tr>
<th>Classification</th>
<th>WSES grade</th>
<th>AAST grade</th>
<th>Hemodynamics</th>
<th>First-line treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor</td>
<td>I</td>
<td>I–II</td>
<td>Stable</td>
<td>Nonoperative</td>
</tr>
<tr>
<td>Moderate</td>
<td>II</td>
<td>III</td>
<td>Stable</td>
<td>Nonoperative</td>
</tr>
<tr>
<td>Severe</td>
<td>III</td>
<td>IV–V</td>
<td>Stable</td>
<td>Nonoperative</td>
</tr>
<tr>
<td>Severe</td>
<td>IV</td>
<td>I–V</td>
<td>Unstable</td>
<td>Operative management</td>
</tr>
</tbody>
</table>

WSES, World Society of Emergency Surgery; AAST, American Association for the Surgery of Trauma.
Adapted from Coccolini et al. [12], available under the Creative Commons License.
tion of hemodynamic stability can be made. The frequency of lab draws for hemoglobin assessment, the frequency of abdominal examinations, and the duration of monitoring vary depending on institutional protocols, and there are no official recommendations in terms of frequency and duration of monitoring [13]. Factors such as hemodynamic stability, the amount of acute blood loss, and the level of injury severity help determine whether patients can be managed nonoperatively [14].

**DIAGNOSTIC EVALUATION**

Patients typically undergo multiphase computed tomography (CT) during the initial evaluation for liver injury as it can clearly show complications resulting from the trauma [15]. A significant number of traumatic injuries occur in young patients, and efforts to decrease radiation exposure during CT are important. Performing split-bolus single-pass CT during the evaluation for trauma has been shown to decrease radiation exposure for patients while maintaining or increasing image quality as compared to traditional multiphase CT [16]. Split-bolus single-pass CT also has the potential to decrease the turnaround time for CT reporting given the decreased number of images compared to multiphase CT.

Contrast-enhanced ultrasound (CEUS) can also be useful in the evaluation of patients with liver injuries. CEUS has a higher sensitivity for detecting liver parenchymal lacerations than standard ultrasound [17]. The lack of ionizing radiation in CEUS exams also helps minimize patient exposure to radiation.

In a comparison of patients with intraperitoneal and retroperitoneal hemorrhage, patients with retroperitoneal hemorrhage had greater injury severity. Liver injury was more common among patients with intraperitoneal hemorrhage than those with retroperitoneal bleeding [18].

**NONOPERATIVE MANAGEMENT**

Nonoperative management of liver trauma has become the gold standard [2,19] when treating patients who are hemodynamically stable, show low-grade liver injuries on imaging, have an absence of peritoneal signs, and require transfusion of less than 2 units of blood [20,21]. Temporary endovascular occlusion of the aorta for the control of severe intra-abdominal bleeding in trauma settings has been reported. Although no reports have described its use specifically in liver trauma [22], the traumatologist can consider its use in carefully selected cases.

According to the algorithm proposed by WSES, hemodynamically stable patients with grades I–III liver injuries can be managed nonoperatively. Patients that are hemodynamically unstable (WSES grade IV) or with imaging evidence of intraperitoneal free air and peritonitis are not candidates for nonoperative management. Patients that are treated nonoperatively and have imaging that shows signs of active contrast extravasation are candidates for angiography with embolization. Patients who undergo successful embolization can continue to be monitored nonoperatively, while those who do not need operative management [12,23].

As stated in the WSES liver trauma management guidelines [23], there is growing evidence that nonoperative management is an option for patients with more severe liver injuries including AAST grades IV–V [21]. Inukai et al. [24] reported successful nonoperative management of patients with severe liver injuries (AAST grades IV–V) and found no significant difference in the development of biliary complications or abdominal compartment syndrome between hemodynamically stable and unstable patients.

Although debate continues over which patients with liver injury should undergo angiography with embolization, Xu et al. [10] concluded that selective angiography in patients with AAST grades III–IV hepatic trauma resulted in a significant decrease in the failure of nonoperative management. Boonsinsukh and Maroongroge [25] demonstrated that patients with shock and hemodynamic instability following abdominopelvic trauma were successfully managed with arterial embolization. Tamura et al. [26] reported that patients with AAST grades III–V liver injuries and hemodynamic instability that responded to initial resuscitative efforts could be managed with embolotherapy without a significant difference in mortality or clinical failure compared to operative management. CT showing active contrast extravasation was shown to be an indication for hepatic arteriography with embolization regardless of the grade of liver injury [5]. Because the incorporation of angioembolization in the management of hepatic trauma patients varies, it is the traumatologist who must identify which patients will benefit from endovascular therapy.

A study by Hwang et al. [27] found that, while most patients treated with embolization were treated nonoperatively, patients that underwent surgical management for trauma and developed persistent bleeding following surgery also had good outcomes with embolization. Hemodynamically unstable patients who respond to an initial fluid bolus are favorable candidates for nonoperative management or angiography with embolization [5,28]. Nonoperative management has shown a > 90% success rate with decreased overall mortality, complications, and transfusion re-
requirements compared to operative management [5]. A flow chart for the management of patients with liver trauma is presented in Fig. 1.

**HYBRID ROOM**

With the increased involvement of interventional radiology in the management of patients with liver trauma, more hybrid rooms are being incorporated that combine an interventional radiology (IR) suite with a traditional operating room (OR) or emergency room (ER). One goal of a hybrid room is to facilitate interventions in patients requiring angiography for hepatic bleeding. The benefits of the hybrid room include reduced transport times and reduced mortality due to blood loss in patients with liver hemorrhage [29]. A hybrid room consisting of an emergency trauma bay and an IR suite was described by Ahn et al. [30] in the successful treatment of two renal trauma patients with severe injuries. This concept can also be applied to liver trauma settings without significant modification. A study showing the benefits of a hybrid OR demonstrated the ability to effectively control severe hemorrhage by combining the skillsets of IR and surgery [31]. Although that study also identified a prolonged time for transporting patients from the ER to the hybrid OR, the delay may have been partly due to the lack of a well-developed protocol for use of the hybrid OR.

**EMBOLIZATION TECHNIQUES**

**Selection of embolic material**

A wide variety of embolic materials exist for use in hepatic arteriography for trauma [32]. Embolic agents can be broadly classified into three categories: mechanical occlusion devices, particulates, and liquids and gels. Particulates can be further subclassified as permanent or temporary, and calibrated or noncalibrated. Liquids and gels can be further subclassified as sclerosing agents or gels, based on their properties (physical vs. chemical crosslinking) [32,33].

Coils are the most widely used agents in hepatic trauma embolization [34]. Coils are composed of stainless steel, platinum, or nitinol and can be coated with fibers, proteins, or other bioactive materials to facilitate thrombus formation at the site of deployment. Coils can be deployed through catheters in a pushed, injected, or detached fashion, with the latter offering increased control at the site of embolization [35].

Gelfoam is another embolic agent commonly utilized in hepatic trauma [34]. It is a temporary occlusive embolic agent composed of absorbable gelatin powder and falls into the category of noncalibrated particles [36]. The temporary nature aids in occlusion of hepatic arteries in the acute phase and allows recanalization of the occluded arteries once the patient has stabilized and no further bleeding is expected. Gelfoam has been associated with an increased risk for infection, which may hinder patient recovery postembolization [37].

Polyvinyl alcohol (PVA) has also been used in liver trauma embolization [5]. PVA is categorized as a permanent particulate embolic agent. Although noncalibrated PVA exists, most PVA particles are used in the calibrated form with sizes varying from 100–300 µm to 900–1,200 µm [36]. PVA causes a mechanical occlusion of vessels and stimulates blood clot formation. Recanalization of the blood clot as well as particle migration may occur months after embolization [32].

While liquid, gel, and particulate embolic agents are not typically used in the management of hepatic trauma embolization, N-butyl cyanoacrylate has been used in the management of trauma patients with arterioportal shunting or coagulopathy [26].

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**Fig. 1.** Proposed management of liver trauma patients. CT, computed tomography; CEUS, contrast-enhanced ultrasound; AAST, American Association for the Surgery of Trauma.
Liquid embolic agents can cause inadvertent distal embolization if reflux occurs. Particulate embolic agents can be considered in small distal arteries where there is minimal chance for reflux [38].

**Hepatic arterial selection**

Various types of base catheters can be used in selecting the celiac axis, including Sos, Cobra, or shepherd hook type catheters, depending on operator preference and the angle of celiac axis take-off in relation to the aorta [39]. A review of preoperative CT scans may help to identify variant hepatic arterial branching anatomy. Microcatheters are advanced through the base catheter and used to selectively cannulate the right or left hepatic arteries, or further distally if needed. Virtual fluoroscopy combined with preoperative CT can aid in the selection of vessels [40].

**Selectivity of embolization**

Selective embolization of the hepatic arteries is important to minimize nontarget embolization and the consequences that can result from infarction of normal liver tissue [41]. Intraprocedural cone beam CT, which is frequently utilized in interventional oncology, may prove to be a useful tool in selecting hepatic arteries that may not be clearly visualized on standard digital subtraction angiography [42]. It is important to be as selective as possible in hepatic arterial embolization to minimize complications and to increase success rates for nonoperative management [5].

Once the proper hepatic artery has been identified, expedited embolization of the artery is paramount in preventing blood loss. In coil embolization, oversizing of the coil by 20% to 30% is recommended to prevent migration [43]. The scaffold and anchoring techniques are also important to prevent migration and to provide efficient packing of the coils. The scaffold technique involves the initial placement of an oversized high radial force coil followed by a softer coil to maximize packing of the coils. The anchoring technique involves placing the initial coil into a branch vessel, which increases the stability of the initially placed coil, followed by an additional coil placement for complete embolization of the vessel [35].

**POSTEMBOLIZATION OUTCOMES**

**Success rates**

Embolization of hepatic injuries has been reported to be 80% to 97% successful [26]. The hepatic artery, portal vein, and hepatic vein are potential sources of bleeding in liver trauma. Identifying the exact source of bleeding can be difficult, especially when multiple vessels are injured, and can result in incomplete embolization with the need for further nonoperative or operative intervention [37]. Despite the potential limitations of embolization in patients with high-grade liver injuries (both operative and nonoperative), patients who underwent embolization had higher survival rates than those that did not [44].

**Complications**

Major complications arising after embolization for liver trauma included hepatic necrosis, hepatic ischemia, abscess, biloma, bile leak, gallbladder necrosis, pseudoaneurysm formation, and cholecystitis [5,9,10,26,28,45,46]. Sivrikoz et al. [44] reported a higher incidence of systemic complications following embolization including acute respiratory distress syndrome, sepsis, pneumonia, and renal failure.

The liver receives its blood supply from the hepatic artery and portal vein. Disruption of both hepatic arterial and portal venous vasculature will result in hepatic ischemia and necrosis. Hepatic necrosis occurring after arterial embolization likely means there was concurrent portal vein disruption. Although one study showed hepatic necrosis rates up to 44% [46], most studies did not show rates nearly as high [9]. The low rates of hepatic necrosis after severe liver injury may be due to a compensatory increase in microcirculation that maintains liver perfusion despite the reduction in arterial and portal venous perfusion [47].

**CONCLUSIONS**

Routine use of CT during the follow-up of liver trauma patients is not recommended, given the low rate of complications, especially in low-grade liver injuries [45]. CEUS may be useful in the follow-up of hemodynamically stable patients and also minimizes the use of ionizing radiation and iodinated intravenous contrast [17,48].

**ARTICLE INFORMATION**

**Conflicts of interest**

The author has no conflicts of interest to declare.

**Funding**

The author did not receive any financial support for this study.

**Data availability**

Data of this study are available from the author upon reasonable request.
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27. Hwang MJ, Lee HK, Choi SJ, Chung SY. Clinical experiences


No frequency change of prehospital treatments by emergency medical services providers for traumatic cardiac arrest patients before and after the COVID-19 pandemic in Korea: an observational study

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Purpose: Out-of-hospital traumatic cardiac arrest (TCA) often has a poor prognosis despite rescue efforts. Although the incidence and mortality of out-of-hospital cardiac arrest have increased, bystander cardiopulmonary resuscitation (CPR) has decreased in some countries during the COVID-19 pandemic. In the prehospital setting, immediate treatment of cardiac arrest is required without knowing the patient’s COVID-19 status. Because COVID-19 is usually transmitted through the respiratory tract, airway management can put medical personnel at risk for infection. This study explored whether on-scene treatments involving CPR for TCA patients changed during the COVID-19 pandemic in Korea.

Methods: This retrospective study used data from emergency medical services (EMS) run sheets in Gangwon Province from January 2019 to December 2021. Patients whose initial problem was cardiac arrest and who received CPR were included. Data in 2019 were classified as pre–COVID-19 and all subsequent data (from 2020 and 2021) as post–COVID-19. Age, sex, possible cause of cardiac arrest, and treatments including airway maneuvers, oropharyngeal airway (OPA) or i-gel insertion, endotracheal intubation (ETI), bag-valve mask (BVM) ventilation, intravenous (IV) line establishment, neck collar application, and wound dressing with hemostasis were investigated.

Results: During the study period, 2,007 patients received CPR, of whom 596 patients had TCA and 367 had disease-origin cardiac arrest (DCA). Among the patients with TCA, 192 (32.2%) were pre–COVID-19 and 404 (67.8%) were post–COVID-19. In the TCA group, prehospital treatments did not decrease. The average frequencies were 59.7% for airway maneuvers, 47.5% for OPA, 57.4% for BVM, and 51.3% for neck collar application. The rates of ETI, i-gel insertion, and IV-line establishment increased. The treatment rate for TCA was significantly higher than that for DCA.

Conclusions: Prehospital treatments by EMS workers for patients with TCA did not decrease during the COVID-19 pandemic. Instead, the rates of ETI, i-gel insertion, and IV-line establishment increased.

Keywords: Cardiopulmonary resuscitation; Out-of-hospital cardiac arrest; Emergency medical services; COVID-19; Pandemics
INTRODUCTION

Background

Advances in emergency care such as the establishment of trauma centers, helicopter transport of patients, and trauma education for doctors and emergency medical technicians (EMTs) have improved the survival of patients with severe trauma. Nonetheless, traumatic cardiac arrest (TCA) has a poor prognosis, and its survival is reported to be lower than that of non-TCA [1–3]. Since the rapid transfer of patients with major trauma is critical, the Korean emergency medical services (EMS) recommend < 10 minutes of on-scene stay time after rescue, and transfer to an appropriate trauma center while performing essential treatments to maintain airway, breathing, and circulation [4].

The spread of COVID-19 around the world created medical crises and led to many changes in public health systems. In Korea, the first COVID-19 case was reported in January 2020, and as of February 2023, 30 million people have been diagnosed and 33,000 have died [5,6]. Since COVID-19 is highly contagious, the National Fire Agency of Korea established nationwide guidelines in February 2020, calling for all EMTs to wear personal protective equipment (PPE) to reduce the spread of secondary infection to other patients and to keep EMTs safe. Because COVID-19 is usually transmitted through the respiratory tract, management of a patient’s airway can expose medical personnel to infection. However, it is difficult to know a patient’s precise condition at the scene where immediate treatment is required. While the patient’s condition is unstable in the prehospital or emergency department setting, there may be minimal information available, including COVID-19 status. This is particularly true when responding to a patient in cardiac arrest, where cardiopulmonary resuscitation (CPR) and accompanying airway management should be performed without delay, exposing medical personnel to respiratory infectious diseases.

Objectives

This study investigated whether on-scene treatments involving CPR for patients with TCA changed during the COVID-19 pandemic in Korea.

METHODS

Ethics statement

Approval of the Institutional Review Board was not required because this was a retrospective study and did not include personal information except for patients’ sex and age.

Study design

This is a case series. This retrospective study analyzed the data from EMS run sheets.

Study period and participants

The EMS of Korea is organized by the National Fire Agency, and there are 17 fire headquarters located in metropolitan cities and provinces. When an emergency call is received and EMS personnel are dispatched, an EMS run sheet (recording sheet) is created each time a patient is treated and transferred. This retrospective study analyzed the data from these EMS run sheets.

Data sources and measurement

We analyzed data from January 2019 to December 2021 on patients in Gangwon Province who required EMS services for cardiac arrest and received CPR. Because the first COVID-19 patient was reported in January 2020 in Korea, data in 2019 were classified as pre–COVID-19 and data in 2020 and 2021 were classified as post–COVID-19. The inclusion criteria were limited to patients who received CPR by EMS personnel in response to an initial call of cardiac arrest. Cases in which help was requested for other initial symptoms such as dyspnea without cardiac arrest, but then developed cardiac arrest during transport were excluded. Patients who were not given CPR (e.g., do-not-resuscitate [DNR] status), were transported by helicopter, or had incomplete records were also excluded. Non-TCA cases included all patients who experienced arrest due to non-cardiac origins; for example, disease, hanging, or drowning. Gangwon Province has an area of 20,569 km² with a population of approximately 1.54 million. As of 2021, there were 246 level I EMTs (24.3%), 390 level II EMTs (38.5%), 114 nurses (11.2%), and 264 other designations (26.0%), for a total of 1,014 emergency rescue workers in Gangwon Province. In addition, for approximately 80% of calls, EMTs were dispatched in teams of three. The patients’ age, sex, possible cause of cardiac arrest (identified at the scene), and treatments performed during CPR (airway maneuvers, oropharyngeal airway [OPA], or i-gel [Intersurgical] insertion, endotracheal intubation [ETI], bag-valve mask [BVM] ventilation, intravenous [IV] line establishment, neck collar application, and wound dressing with heamostasis) were analyzed.

Statistical analysis

Categorical data were expressed as frequency and percentage. Continuous data were expressed as averages and standard deviations. Comparisons were calculated using the chi-square test. IBM SPSS ver. 26.0 (IBM Corp) was used for analysis, and statis-
tical significance was set at a P-value < 0.05.

RESULTS

During the 3-year study period, 321,156 emergency request calls were received, encompassing 107,185 patients who were not transferred, 205,959 cases without initial cardiac arrest, and 2,007 patients with initial cardiac arrest who received CPR (Fig. 1). Among the 2,007 patients who met our study criteria, help was dispatched for 616 in the pre–COVID-19 stage and 1,391 in the post–COVID-19 stage. The average age of the study patients was 56.9 years, and 69.6% were male. There were 596 patients with TCA, of whom 192 (32.2%) were in the pre–COVID-19 stage and 404 (67.8%) were in the post–COVID-19 stage. There were 367 patients with disease-origin cardiac arrest (DCA), of whom 70 (19.1%) and 297 (80.9%) were in the pre– and post–COVID-19 stages, respectively. There were 1,411 non-TCA patients, with 424 (30.0%) and 987 patients (70.0%) in the pre– and post–COVID-19 stages, respectively. Cardiac arrest due to disease and hanging in the post–COVID-19 stage increased compared to the pre–COVID-19 stage. No other statistically significant differences were found (Table 1).

The prehospital treatments performed during CPR by year are shown in Table 2 and Figs. 2 and 3. In cases of TCA, airway maneuvers were performed in 111 cases (57.8%) in 2019, 104 cases (58.1%) in 2020, and 141 cases (62.7%) in 2021. Whereas, in DCA, airway maneuvers were performed in five cases (7.1%) in 2019, five cases (3.7%) in 2020, and two cases (1.2%) in 2021. An OPA was inserted in 80 TCA cases (41.7%) in 2019, 89 TCA cases (49.7%) in 2020, and 114 TCA cases (50.7%) in 2021, while an OPA was inserted in one DCA case (1.4%) in 2019, two DCA cases (1.5%) in 2020, and two DCA cases (1.2%) in 2021. While ETI was performed in three cases (1.6%) in 2019, 10 cases (5.6%) in 2020, and 16 cases (7.1%) in 2021 in the TCA group; in the DCA group it was performed in 0 cases (0%) in 2019, two cases (1.5%) in 2020, and one case (0.6%) in 2021. I-gel insertion and IV-line establishment increased by year in the TCA group: I-gel insertion was performed in 61 cases (31.8%) in 2019, 73 cases (40.8%) in 2020, and 101 cases (44.9%) in 2021 (P = 0.022); and an IV line was established in 19 cases (9.9%) in 2019, 45 cases

Table 1. The patient characteristics and etiologies of cardiac arrest in Gangwon Province, Korea from January 2019 to December 2021

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n=2,007)</th>
<th>Pre–COVID-19 (n=616)</th>
<th>Post–COVID-19 (n=1,391)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>56.9±19.7</td>
<td>56.7±18.9</td>
<td>57.1±20.0</td>
<td>0.651</td>
</tr>
<tr>
<td>Male sex</td>
<td>1,396 (69.6)</td>
<td>445 (72.2)</td>
<td>951 (68.4)</td>
<td>0.194</td>
</tr>
<tr>
<td>Etiology of cardiac arrest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trauma</td>
<td>596 (29.7)</td>
<td>192 (31.2)</td>
<td>404 (29.0)</td>
<td>0.337</td>
</tr>
<tr>
<td>Disease origin</td>
<td>367 (18.3)</td>
<td>70 (11.4)</td>
<td>297 (21.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Electrical burn</td>
<td>3 (0.1)</td>
<td>1 (0.2)</td>
<td>2 (0.1)</td>
<td>0.667</td>
</tr>
<tr>
<td>Anaphylaxis</td>
<td>2 (0.1)</td>
<td>1 (0.2)</td>
<td>1 (0.1)</td>
<td>0.520</td>
</tr>
<tr>
<td>Hanging</td>
<td>515 (25.7)</td>
<td>183 (29.7)</td>
<td>332 (23.9)</td>
<td>0.006</td>
</tr>
<tr>
<td>Airway obstruction</td>
<td>43 (2.1)</td>
<td>16 (2.6)</td>
<td>27 (1.9)</td>
<td>0.349</td>
</tr>
<tr>
<td>Drowning</td>
<td>220 (11.0)</td>
<td>72 (11.7)</td>
<td>148 (10.6)</td>
<td>0.488</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>120 (6.0)</td>
<td>35 (5.7)</td>
<td>85 (6.1)</td>
<td>0.709</td>
</tr>
<tr>
<td>Hypothermia</td>
<td>3 (0.1)</td>
<td>2 (0.3)</td>
<td>1 (0.1)</td>
<td>0.225</td>
</tr>
<tr>
<td>Poisoning</td>
<td>58 (2.9)</td>
<td>19 (3.1)</td>
<td>39 (2.8)</td>
<td>0.729</td>
</tr>
<tr>
<td>Fire</td>
<td>27 (1.3)</td>
<td>6 (1.0)</td>
<td>21 (1.5)</td>
<td>0.337</td>
</tr>
<tr>
<td>Chemical injury</td>
<td>1 (0.1)</td>
<td>0</td>
<td>1 (0.1)</td>
<td>0.693</td>
</tr>
<tr>
<td>Unknown</td>
<td>52 (2.6)</td>
<td>19 (3.1)</td>
<td>33 (2.4)</td>
<td>0.354</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation or number (%). Pre–COVID-19 includes data from 2019 and post–COVID-19 includes data from 2020 and 2021.
In 2020, and 59 cases (26.2%) in 2021 (P < 0.001). The average rates of prehospital BVM ventilation, neck collar application, and wound dressings did not show statistically significant increases by year.

DISCUSSION

Coronavirus spreads through the respiratory tract and is highly contagious. Three years into the COVID-19 pandemic, vaccines and drugs have been developed, and concerns for the severity of COVID-19 have been relatively alleviated by recent data. However, because COVID-19 was a novel infectious disease and we lacked understanding in the early stages of the pandemic, there was a need for caution and careful preparedness. Moreover, it has been reported that the incidence and mortality of out-of-hospital cardiac arrest increased in other countries since the COVID-19 outbreak, and that bystander CPR decreased [7,8]. Because new infectious disease outbreaks are still possible, we will periodically face similar situations. In the hospital, PPE must be worn meticulously when treating patients with infectious diseases, and infection transmission should be minimized with thorough disinfection after treatments. When possible, it is also important to deter-

Table 2. The frequency of emergency treatments for cardiac arrest provided by emergency medical technicians in the prehospital setting in Gangwon Province, Korea (2019–2021).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total (n=2,007)</th>
<th></th>
<th>Year</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Airway maneuver</td>
<td></td>
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<tr>
<td>TCA</td>
<td>356 (59.7)</td>
<td>111 (57.8)</td>
<td>104 (58.1)</td>
<td>141 (62.7)</td>
<td></td>
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</tr>
<tr>
<td>DCA</td>
<td>12 (3.3)</td>
<td>5 (7.1)</td>
<td>5 (3.7)</td>
<td>2 (1.2)</td>
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</tr>
<tr>
<td>Non-TCA</td>
<td>332 (23.5)</td>
<td>124 (29.2)</td>
<td>107 (22.2)</td>
<td>101 (20)</td>
<td></td>
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<tr>
<td>OPA insertion</td>
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</tr>
<tr>
<td>TCA</td>
<td>283 (47.5)</td>
<td>80 (41.7)</td>
<td>89 (49.7)</td>
<td>114 (50.7)</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>DCA</td>
<td>5 (1.4)</td>
<td>1 (1.4)</td>
<td>2 (1.5)</td>
<td>2 (1.2)</td>
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</tr>
<tr>
<td>Non-TCA</td>
<td>257 (18.2)</td>
<td>88 (20.8)</td>
<td>88 (18.3)</td>
<td>81 (16)</td>
<td></td>
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<tr>
<td>Endotracheal intubation</td>
<td></td>
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<tr>
<td>TCA</td>
<td>29 (4.9)</td>
<td>3 (1.6)</td>
<td>10 (5.6)</td>
<td>16 (7.1)</td>
<td></td>
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</tr>
<tr>
<td>DCA</td>
<td>3 (0.8)</td>
<td>0</td>
<td>2 (1.5)</td>
<td>1 (0.6)</td>
<td></td>
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</tr>
<tr>
<td>Non-TCA</td>
<td>36 (2.6)</td>
<td>6 (1.4)</td>
<td>16 (3.3)</td>
<td>14 (2.8)</td>
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<tr>
<td>I-gel insertion</td>
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<tr>
<td>TCA</td>
<td>235 (39.4)</td>
<td>61 (31.8)</td>
<td>73 (40.8)</td>
<td>101 (44.9)</td>
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<tr>
<td>DCA</td>
<td>7 (1.9)</td>
<td>3 (4.3)</td>
<td>1 (0.7)</td>
<td>3 (1.9)</td>
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</tr>
<tr>
<td>Non-TCA</td>
<td>240 (17)</td>
<td>78 (18.4)</td>
<td>74 (15.4)</td>
<td>88 (17.4)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>BVM ventilation</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>TCA</td>
<td>342 (57.4)</td>
<td>102 (53.1)</td>
<td>104 (58.1)</td>
<td>136 (60.4)</td>
<td></td>
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<tr>
<td>DCA</td>
<td>8 (2.2)</td>
<td>3 (4.3)</td>
<td>3 (2.2)</td>
<td>2 (1.2)</td>
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<tr>
<td>Non-TCA</td>
<td>313 (22.2)</td>
<td>114 (26.9)</td>
<td>99 (20.5)</td>
<td>100 (19.8)</td>
<td></td>
<td></td>
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<tr>
<td>IV-line establishment</td>
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<tr>
<td>TCA</td>
<td>123 (20.6)</td>
<td>19 (9.9)</td>
<td>45 (25.1)</td>
<td>59 (26.2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DCA</td>
<td>6 (1.6)</td>
<td>2 (2.9)</td>
<td>2 (1.5)</td>
<td>2 (1.2)</td>
<td></td>
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<tr>
<td>Non-TCA</td>
<td>128 (9.1)</td>
<td>37 (8.7)</td>
<td>42 (8.7)</td>
<td>49 (9.7)</td>
<td></td>
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<tr>
<td>Neck collar application</td>
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</tr>
<tr>
<td>TCA</td>
<td>306 (51.3)</td>
<td>94 (47.4)</td>
<td>94 (52.5)</td>
<td>121 (53.8)</td>
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<td></td>
</tr>
<tr>
<td>DCA</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Non-TCA</td>
<td>83 (5.9)</td>
<td>28 (6.6)</td>
<td>31 (6.4)</td>
<td>24 (4.8)</td>
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<tr>
<td>Wound dressing</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>TCA</td>
<td>80 (13.4)</td>
<td>26 (13.5)</td>
<td>26 (14.5)</td>
<td>28 (12.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCA</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-TCA</td>
<td>1 (0.1)</td>
<td>0</td>
<td>1 (0.2)</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as number (%).
TCA, traumatic cardiac arrest; DCA, disease-origin cardiac arrest; OPA, oropharyngeal airway; BVM, bag-valve mask; IV, intravenous; NA, not applicable

(25.1%) in 2020, and 59 cases (26.2%) in 2021 (P < 0.001). The average rates of prehospital BVM ventilation, neck collar application, and wound dressings did not show statistically significant increases by year.
Fig. 2. The frequencies of emergency treatments provided by emergency medical technicians in the prehospital setting. (A) Airway maneuver. (B) Oropharyngeal airway insertion. (C) Endotracheal intubation. Only traumatic cardiac arrest (TCA) numbers are represented. (D) I-gel insertion. DCA, disease-origin cardiac arrest.

We excluded patients who experienced cardiac arrest during transport for the following reasons. Usually, a team of two to three EMTs was dispatched to the scene in Gangwon Province, but once transfer was started, one EMT drove the ambulance and the other one or two EMTs were left in the patient care compartment. Optimal treatment in alignment with the guidelines can be difficult due to this decrease in manpower and the confined space. Additional information may also be obtained at this point (e.g., DNR requests from guardians) that changes the characteristics of the initial dispatch for cardiac arrest and influences treatment decisions. Therefore, to confirm that any changes in the initial treatment were related to infection concerns, this study was limited to cases where rescue personnel were dispatched for cardiac arrest from the beginning.

During the study period, the emergency treatments remained unchanged or increased, including airway procedures during CPR for TCA. In addition, almost all treatments were performed at higher rates in the TCA group than in the DCA group. However, ETI was performed in only 4.9% of cases. ETI is highly dependent on the individual rescuer’s capabilities and training, and it was not often performed in the field due to lack of experience. Instead, an extraglottic airway device such as i-gel was preferred. Although ETI is the recommended airway procedure for patients with a Glasgow Coma Scale < 8 in major trauma [11], it has been performed at a significantly low rate. However, there have been...
reports that advanced airway treatment in the prehospital setting is neither beneficial nor harmful, so it remains inconclusive whether advanced airway treatments should be performed more frequently in the field [12–14]. Other studies have also demonstrated that prehospital airway management using extraglottic airways was not inferior to endotracheal intubation and should therefore be considered [15–18].

Only wound dressings for hemostasis showed a decreasing pattern. This should not be interpreted as a decrease in treatment, however, because the need for hemostasis is determined by external bleeding or wounds. Moreover, because the management of hemostasis is less likely to contribute to the transmission of respiratory tract infections than airway treatments, it was not considered significant in this study.

Interestingly, all treatments differed significantly between the DCA group and the TCA group. In fact, EMTs are advised to minimize on-scene time and to transfer patients with major trauma quickly, preferably within 10 minutes after rescue. However, in non-TCA events, where EMTs may be allowed to stay on-scene for longer periods and provide advanced life support under medical oversight, we found that on-scene treatment was lower than in the TCA group.

In light of studies reporting that several cases of severe acute respiratory syndrome (SARS) and severe fever with thrombocytopenia syndrome had spread to medical personnel during CPR [19,20], it was suspected that CPR and airway treatments would decrease in the field after the COVID-19 outbreak. However, statistically significant decreases were found only with airway maneuvers and BVM in the non-TCA group, and no differences and/or increases were found in other treatments in the trauma group. For TCA at least, it was confirmed that on-scene treatments did not decrease due to the influence of COVID-19.

There are possible reasons for this finding. First, EMTs may have been less likely to consider the possibility of COVID-19 infection in the trauma group since the signs and symptoms of COVID-19 (e.g., dyspnea or pneumonia) were more likely in the disease group. After the COVID-19 outbreak, ETI and i-gel insertion had statistically significant increases in the TCA group and appeared unaffected by COVID-19. Another possible reason was that the patients with TCA were somewhat younger than those

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Fig. 3. The frequencies of emergency treatments provided by emergency medical technicians in the prehospital setting. (A) Bag-valve mask ventilation. (B) Intravenous line establishment. Only traumatic cardiac arrest (TCA) numbers are represented. (C) Neck collar application. Only TCA and non-TCA numbers are represented. (D) Wound dressing. Only TCA numbers are represented. DCA, disease-origin cardiac arrest.
with DCA (55.9 ± 18.4 years vs. 68.5 ± 18.3 years, P < 0.001), and that more effort was made to revive younger patients with relatively fewer underlying diseases. Furthermore, this may have been due to the emphasis in EMS education on the importance of treatment in major trauma and might have reflected the hiring of new EMTs with recent hospital-based clinical experiences.

Limitations
This study had some limitations. First, because this work was based on the EMS run sheets, in some cases the cause of cardiac arrest was not clear. The recorded cause of the cardiac arrest was based on descriptions by witnesses at the scene, and by the patient’s condition and situation at the time of discovery. Therefore, the true etiology was not always clear. However, since EMTs often provide treatment based on the limited information available to them at the scene, it is appropriate to assume that the responses of the EMTs in this study were typical. Second, the data were collected from only one province and may not be generalizable to the entire country. Regional differences may exist, as exemplified by the fact that Gangwon Province is a large area that accounts for 20.5% of the country but has the lowest proportion (35.5%) of level I EMTs and nurses in the country (Seoul, 50.2%; Busan, 60.2%; Gwangju, 90.7%; Gyeonggi Province, 91.2%; national average, 65.7%). Certain skills are limited to level I EMTs and nurses in rescue situations, and a study of national data may show different results. Further study is needed to clarify the exact reasons for any changes in the treatment of TCA.

Conclusions
Our comparison of the prehospital EMS treatments provided to patients with TCA before the COVID-19 outbreak, to those provided during the COVID-19 outbreak showed that treatments did not decrease. In fact, endotracheal intubation, I-Gel insertion, and IV-line establishment increased.

ARTICLE INFORMATION

Author contributions
Conceptualization: HIK; Data curation: HIK; Formal analysis: all authors; Methodology: HIK; Writing–original draft: all authors; Writing–review and editing: HIK. All authors read and approved the final manuscript.

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

Funding
The authors did not receive any financial support for this study.

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

REFERENCES


Purpose: The purpose of this study was to report the treatment results of patients with traumatic cardiac tamponade after the opening of Jeju Regional Trauma Center.

Methods: We analyzed the treatment outcomes of patients with traumatic cardiac tamponade who were treated at Jeju Regional Trauma Center from January 2018 to August 2022.

Results: Seven patients with traumatic cardiac tamponade were treated. The male to female ratio was 1.33:1 (four male and three female patients) and the average age was 60.3±7.2 years. The mechanism of injury was blunt trauma in six cases and penetrating injury in one case. Upon arrival at the emergency department, pericardiostomy was performed in four cases, and an emergency operation was performed in six cases. Pericardiostomy alone was performed in one patient, who had cardiac tamponade due to extrapericardial suprahepatic inferior vena cava rupture. The causes of cardiac tamponade were right atrium appendage rupture in one case, right ventricle rupture in one case, inferior vena cava rupture in two cases, right atrium and left atrium rupture in one case, both atria and left ventricle rupture in one case, and intercostal artery rupture in one case. In three cases, intraoperative cardiopulmonary bypass was required. Two of the seven patients died (mortality rate, 28.5%).

Conclusions: Relatively favorable treatment results were observed for traumatic cardiac tamponade patients after Jeju Regional Trauma Center was established.

Keywords: Thoracic injury; Cardiac tamponade; Trauma center

INTRODUCTION

Background

The treatment of traumatic cardiac tamponade remains a difficult problem when treating severe trauma patients [1]. In all trauma patients, the incidence of traumatic cardiac tamponade due to thoracic injury is very low (0.16%–2%), but the mortality rate is relatively high (postoperative mortality, 24%) [2]. For the successful treatment of traumatic cardiac tamponade patients, it is important to promptly transport them from the scene of the accident to an emergency center where a prompt diagnosis and surgical treatment are possible. For this, there must be appropriate medical equipment for diagnosis and treatment, and close cooperation between skilled medical team members is required [3,4].
Objectives
This study analyzed the electronic medical records of patients with traumatic cardiac tamponade who were treated after the establishment of Jeju Regional Trauma Center to determine their treatment results and factors affecting the treatment outcomes.

METHODS

Ethics statement
The study was approved by the Institutional Review Board of Cheju General Hospital (No. 2022-L04-01). The requirement for informed consent was waived due to the retrospective nature of the study.

Study design and patients
From January 2018 to August 2022, seven patients with traumatic cardiac tamponade were treated at Jeju Regional Trauma Center. We conducted a retrospective study based on a review of the patients’ medical records. The subjects were patients in whom cardiac tamponade was confirmed by a physical examination and imaging studies, including ultrasonography, at the time of arrival at the emergency department. Patients with confirmed cardiac tamponade who could not be resuscitated due to cardiac arrest before arriving at the emergency department were excluded from the study.

Data collection
We reviewed patients’ medical records and collected data related to their general characteristics. Sex, age, transport time, injury mechanism, vital signs, Glasgow Coma Scale, the Injury Severity Score (ISS), and the Trauma and Injury Severity Score (TRISS) were collected. Emergency medical records, operative records, and the outcomes of the intervention were reviewed to obtain data related to the operative procedure and findings, the results of treatment, and postoperative complications.

Statistical analysis
Statistical analyses were performed using IBM SPSS ver. 20 (IBM Corp). Descriptive statistics of the basic characteristics of patients were calculated. We examined whether there were differences in the mean scores of basic characteristics and the trauma score of patients according to whether they survived or died. The independent samples t-test was used to determine whether any variables showed significant differences between the survival and death groups.

RESULTS

From January 2018 to August 2022, nine patients were diagnosed with traumatic cardiac tamponade at Jeju Regional Trauma Center. Among them, two patients presented to the hospital in cardiac arrest although resuscitation was performed; since they did not recover, they were excluded from the analysis. Therefore, seven patients were included in the study (Table 1).

The average age of the patients was 60.3 ± 7.2 years, and the male to female ratio was 1.33:1. The average transport time to the emergency department after the accident was 48 ± 26.6 minutes, and the causes of the accidents were blunt chest injury due to traffic accidents in six cases (85.7%) and a thoracic penetrating injury due to a stab wound in one case (14.3%).

The diagnosis of traumatic cardiac tamponade in the emergency department was made on the basis of a physical examination and emergency ultrasonography (extended focused assessment with sonography for trauma [eFAST]). When the vital signs were stable, a whole-body computed tomography (CT) was performed immediately to make an accurate diagnosis. eFAST is a diagnostic test that plays an important role in the diagnosis and treatment of cardiac tamponade. If necessary, pericardiostomy can be performed under ultrasound guidance, and accompanying thoracic and abdominal injuries can also be screened. All seven patients treated at this center were diagnosed with cardiac tamponade by ultrasound examinations, and two patients underwent surgery immediately after the ultrasound examination without additional imaging tests.

Six patients had bony thorax injuries (sternum or rib fractures), and five patients had lung injuries, including lung laceration, hemothorax, and pneumothorax. Associated injuries other than those to the chest were observed in three cases: abdominal injuries in two cases and pelvic bone fractures in one case (Table 2).

An emergency operation was performed in six of the seven patients. Median sternotomy was performed in all operations. During surgery, extracorporeal circulation support was required in three cases, and the other cases could be sutured directly without extracorporeal circulation support (Fig. 1). In one patient, venoarterial extracorporeal membrane oxygenation (VA-ECMO; i.e., extracorporeal cardiopulmonary resuscitation [ECPR]) was applied because the blood pressure was not maintained in the emergency department before the operation. After transfer to the operation department, surgery was performed with the patient switched from VA-ECMO to extracorporeal circulation using a cardiopulmonary bypass machine.

The cardiac and vascular injury sites identified during surgery
<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Injury type</th>
<th>Diagnosis</th>
<th>Arrival (min)</th>
<th>BP (mmHg)</th>
<th>PR (beats/ min)</th>
<th>RR (breaths/ min)</th>
<th>GCS</th>
<th>ISS</th>
<th>RTS</th>
<th>TRISS (%)</th>
<th>Treatment</th>
<th>Operation finding</th>
<th>ICU</th>
<th>Adm</th>
<th>Result</th>
<th>Cx</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>69</td>
<td>Female</td>
<td>TA</td>
<td>Blunt</td>
<td>Cardiac tamponade Right hemotorax Right MRF</td>
<td>60</td>
<td>86/53</td>
<td>91</td>
<td>21</td>
<td>15</td>
<td>25</td>
<td>7.11</td>
<td>RA repair</td>
<td>RAA rupture</td>
<td>3</td>
<td>14</td>
<td>Alive</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>61</td>
<td>Male</td>
<td>TA</td>
<td>Blunt</td>
<td>Cardiac tamponade</td>
<td>59</td>
<td>158/97</td>
<td>82</td>
<td>32</td>
<td>6</td>
<td>37</td>
<td>5.68</td>
<td>5.0</td>
<td>Pericardiostomy Repair of IVC, RA A, LV VA-ECMO</td>
<td>IVC rupture RA appendage LV</td>
<td>0</td>
<td>1</td>
<td>Death</td>
</tr>
<tr>
<td>3</td>
<td>68</td>
<td>Female</td>
<td>TA</td>
<td>Blunt</td>
<td>Cardiac tamponade Right hemothorax Left MRF Sternum fracture Spleen rupture</td>
<td>29</td>
<td>78/39</td>
<td>93</td>
<td>28</td>
<td>13</td>
<td>52</td>
<td>7.11</td>
<td>Repair of atrium rupture (both) Partial CPB</td>
<td>RA rupture LA rupture</td>
<td>2</td>
<td>2</td>
<td>Death</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
<td>Male</td>
<td>Stab penetrate</td>
<td>Cardiac tamponade Right hemothorax Lung laceration</td>
<td>23</td>
<td>78/54</td>
<td>134</td>
<td>20</td>
<td>10</td>
<td>26</td>
<td>6.17</td>
<td>85.1</td>
<td>Ligation of intercostal a. Pericardial drainage No CPB</td>
<td>Right intercostal a. cut Pericardium laceration Noncardiac injury</td>
<td>3</td>
<td>119</td>
<td>Alive (discharge)</td>
<td>Left MCA infarction</td>
</tr>
<tr>
<td>5</td>
<td>62</td>
<td>Female</td>
<td>TA</td>
<td>Blunt</td>
<td>Cardiac tamponade Both MRF Liver laceration</td>
<td>60</td>
<td>67/47</td>
<td>101</td>
<td>20</td>
<td>15</td>
<td>29</td>
<td>6.38</td>
<td>75.7</td>
<td>Pericardiostomy Delayed tamponade</td>
<td>IVC (diaphragmatic) rupture</td>
<td>16</td>
<td>42</td>
<td>Alive (discharge)</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>Male</td>
<td>TA</td>
<td>Blunt</td>
<td>Cardiac tamponade Both MRF Both hemothorax Pelvis fracture</td>
<td>15</td>
<td>112/86</td>
<td>172</td>
<td>32</td>
<td>13</td>
<td>29</td>
<td>7.55</td>
<td>97.3</td>
<td>Pericardiostomy Repair of IVC Partial CPB</td>
<td>IVC (RA junction) rupture</td>
<td>28</td>
<td>95</td>
<td>Alive (discharge)</td>
</tr>
<tr>
<td>7</td>
<td>52</td>
<td>Male</td>
<td>TA</td>
<td>Blunt</td>
<td>Cardiac tamponade Flail chest Left hemothorax Left pneumothorax</td>
<td>90</td>
<td>80/50</td>
<td>75</td>
<td>23</td>
<td>14</td>
<td>27</td>
<td>7.10</td>
<td>95.4</td>
<td>Repair of RV No CPB</td>
<td>Epicardial laceration of apex RV rupture &lt;5mm</td>
<td>6</td>
<td>21</td>
<td>Alive</td>
</tr>
</tbody>
</table>

Arrival, transport time; BP, blood pressure; PR, pulse rate; RR, respiratory rate; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; RTS, Revised Trauma Score; TRISS, Trauma and Injury Severity Score; ICU, intensive care unit stay time; Adm, admission day; Cx, complication; TA, traffic accident; MRF, multiple rib fracture; RA, right atrium; CPB, cardiopulmonary bypass; RAA, right atrium appendage; IVC, inferior vena cava; LV, left ventricle; VA-ECMO, venoarterial extracorporeal membrane oxygenation; LA, left atrium; MCA, middle cerebral artery; RV, right ventricle.
Table 2. Associated injury

<table>
<thead>
<tr>
<th>Associated injury</th>
<th>No. of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture of bony thorax (rib or sternum)</td>
<td>6</td>
</tr>
<tr>
<td>Hemothorax or hemopneumothorax</td>
<td>5</td>
</tr>
<tr>
<td>Lung contusion or laceration</td>
<td>1</td>
</tr>
<tr>
<td>Spleen rupture</td>
<td>1</td>
</tr>
<tr>
<td>Liver laceration</td>
<td>1</td>
</tr>
<tr>
<td>Pelvic bone fracture</td>
<td>1</td>
</tr>
</tbody>
</table>

Results in a mortality rate of 28.5%. Although there was a small number of treated patients, we did perform a statistical analysis between the survival and death groups. As a result, the ISS was significantly higher in patients who died (P=0.09) and the TRISS was significantly higher in patients who survived (P<0.001) (Table 4).

One patient who presented to the hospital with a chest penetrating injury caused by a right anterior chest stab wound underwent surgery. At the time of arrival, the patient’s blood pressure was 78/54 mmHg and cardiac tamponade was diagnosed on eFAST. According to the operative findings, the right third rib and intercostal artery were cut, and an open wound of 1 cm was observed on the right side of the pericardium. This was a very rare case where intercostal artery bleeding flowed into the pericardium and caused cardiac tamponade (Fig. 2).

In one patient with suprahepatic IVC rupture, treatment was possible by pericardiostomy alone without open thoracic surgery. The patient was a 60-year-old female presented to the emergency room with a penetrating injury caused by a stab wound under the right anterior chest. At the time of arrival, the patient’s blood pressure was 78/54 mmHg and cardiac tamponade was diagnosed on eFAST. According to the operative findings, the right third rib and intercostal artery were cut, and an open wound of 1 cm was observed on the right side of the pericardium. This was a very rare case where intercostal artery bleeding flowed into the pericardium and caused cardiac tamponade (Fig. 2).

Table 3. Comparison of injury site of cardiac chamber between survival and death group

<table>
<thead>
<tr>
<th>Cardiac injury</th>
<th>Survival group (n=5)</th>
<th>Death group (n=2)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IVC</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>RA+LA</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>RV</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>IVC+RA+LV</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Extrapericardial vascular injury</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

RA, right atrium; IVC, inferior vena cava; LA, left atrium; RV, right ventricle; LV, left ventricle.

Table 4. Comparison of parameter between the survival group and the death group

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Survival group (n=5)</th>
<th>Death group (n=2)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>58.6±7.7</td>
<td>64.5±5.0</td>
<td>0.846</td>
</tr>
<tr>
<td>Male to female ratio</td>
<td>1.5</td>
<td>1.0</td>
<td>0.376</td>
</tr>
<tr>
<td>Arrival time (min)</td>
<td>49.6±30.6</td>
<td>44.0±21.2</td>
<td>0.827</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>84.6±16.8</td>
<td>118.0±56.6</td>
<td>0.233</td>
</tr>
<tr>
<td>Pulse rate (beats/min)</td>
<td>114.6±38.7</td>
<td>87.5±7.8</td>
<td>0.394</td>
</tr>
<tr>
<td>Respiration rate (breaths/min)</td>
<td>23.2±5.1</td>
<td>30.0±2.8</td>
<td>0.145</td>
</tr>
<tr>
<td>Glasgow Coma Scale</td>
<td>13.4±2.1</td>
<td>9.5±4.9</td>
<td>0.167</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>27.2±1.8</td>
<td>44.5±10.1</td>
<td>0.009</td>
</tr>
<tr>
<td>Revised Trauma Score</td>
<td>6.9±0.5</td>
<td>6.4±1.0</td>
<td>0.387</td>
</tr>
<tr>
<td>Trauma and Injury Severity Score (%)</td>
<td>89.3±8.9</td>
<td>32.3±1.47</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation unless otherwise indicated.
department with a blunt chest injury due to a traffic accident. At that time, her blood pressure was 67/47 mmHg, cardiac tamponade was confirmed on eFAST, and pericardiostomy was performed immediately. Enhanced chest CT showed a suprahepatic IVC rupture near the diaphragm, and a difficult operation was expected. No additional bleeding was observed after the first 300 mL of blood was drained following pericardiostomy. Then, the vital signs remained stable without any bleeding, and the pericardiostomy tube could be removed 7 days after the procedure. On the 14th day after admission, delayed cardiac tamponade (perhaps related to novel oral anticoagulant rivaroxaban use) occurred, but this was also treated with pericardiostomy, and she was discharged without any problems (Figs. 3, 4).

**DISCUSSION**

From January 2018 to August 2022, seven traumatic cardiac tamponade patients were treated at Jeju Regional Trauma Center. Five patients survived and two patients died, resulting in a mortality rate of 28.5%. This result is similar to a 26.6% rate reported at a trauma center in Korea and a 28.6% rate reported at trauma centers abroad [5,6].

Although the difference was not statistically significant, higher ISS and lower TRISS were found in the patients who died. These results are similar to those of previous studies [5,7].

When comparing the anatomical locations of the damaged heart and great vessels in the surviving and deceased cases based on the surgical findings, single atrium and single ventricle ruptures were observed in the surviving cases, and multichamber damage was observed in the deceased cases. This result also aligns with those of previous studies [5,7].

Most patients with traumatic pericardial tamponade require surgical treatment [7–10]. Among the treatment cases at Jeju Regional Trauma Center, one case of IVC rupture at the diaphragm level was treated with pericardiostomy alone without open thoracic surgery. In this case, the rupture of the IVC was at a site where compression hemostasis was possible due to the diaphragm structure and the connective tissue around the liver, and natural healing was possible. If an IVC rupture does not extend into the pericardium, the bleeding volume after pericardiostomy is less than 100 mL/hr, and if the blood pressure is stably maintained, natural healing without open thoracic surgery can be expected.

For the effective treatment of traumatic cardiac tamponade, a
rapid prediction based on clinical findings, prompt diagnosis, and surgical treatment are important [11,12]. Emergency ultrasonography can be performed immediately after the patient arrives at the hospital to diagnose cardiac tamponade, and it can also predict accompanying major abdominal and chest injuries. Pericardiostomy to relieve cardiac tamponade before open thoracic surgery can also be performed under ultrasonography. In blunt chest trauma, patients have severe soft tissue edema, subcutaneous emphysema, and a distended abdomen and pneumothorax [13,14]. These conditions reduce the accuracy of ultrasonography in blunt cardiac injury. However, repeated ultrasonography examinations can overcome these problems.

In one case, VA-ECMO (ECPR) was applied before open thoracic surgery because the blood pressure was not maintained even after pericardiostomy. Multichamber rupture was observed, and this patient died from multiorgan dysfunction syndrome caused by massive intraoperative bleeding and postoperative low cardiac output syndrome. If a patient is hemodynamically very unstable, switching to extracorporeal circulation in the operating department after VA-ECMO (ECPR) in the emergency department may be considered [15].

Limitations
This study had some limitations. First, few cases of traumatic cardiac tamponade were analyzed in this study; therefore, a meaningful statistical analysis was not possible. Also, this was a retrospective study conducted at a single trauma center. To obtain meaningful statistical data, we need to obtain data related to the treatment of cardiac tamponade from multiple centers over a longer period.

Conclusions
Over the past 4 years, after establishing Jeju Regional Trauma Center, seven patients were treated for traumatic pericardial tamponade. Five patients survived, showing a relatively favorable survival rate of 71.5%.

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

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

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

REFERENCES
Factors associated with the injury severity of falls from a similar height and features of the injury site in Korea: a retrospective study

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Purpose: This study aimed to determine the risk factors associated with the severity of fall-related injuries among patients who suffered a fall from similar heights and analyze differences in injury sites according to intentionality and injury severity.

Methods: The Emergency Department-based Injury In-depth Surveillance (EDIIS) data collected between 2019 and 2020 were used in this retrospective study. Patients with fall-related injuries who fell from a height of ≥6 and <9 m were included. Patients were categorized into the severe and mild/moderate groups according to their excessive mortality ratio-adjusted Injury Severity Score (EMR-ISS) and the intention and non-intention groups. Injury-related and outcome-related factors were compared between the groups.

Results: In total, 33,046 patients sustained fall-related injuries. Among them, 543 were enrolled for analysis. A total of 256 and 287 patients were included in the severe and mild/moderate groups, respectively, and 93 and 450 patients were included in the intention and non-intention groups, respectively. The median age was 50 years (range, 39–60 years) and 45 years (range, 27–56 years) in the severe and mild/moderate groups, respectively (P<0.001). In multivariable analysis, higher height (odds ratio [OR] 1.638; 95% confidence interval [CI], 1.279–2.098) and accompanying foot injury (OR, 0.466; 95% CI, 0.263–0.828) were independently associated with injury severity (EMR-ISS ≥25) and intentionality of fall (OR, 0.722; 95% CI, 0.418–1.248) was not associated with injury severity. The incidence of forearm injuries was four (4.3%) and 58 cases (12.9%, P=0.018) and that of foot injuries was 20 (21.5%) and 54 cases (12.0%, P=0.015) in the intention versus non-intention groups, respectively.

Conclusions: Among patients who fell from a similar height, age, and fall height were associated with severe fall-related injuries. Intentionality was not related to injury severity, and patients with foot injury were less likely to experience serious injuries. Injuries in the lower and upper extremities were more common in intentional and unintentional falls, respectively.

Keywords: Accidental falls; Risk factors; Injuries; Intention

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INTRODUCTION

Background
In Korea, slips and falls are the most common causes of injuries among patients presenting to the emergency department (ED). In 2020, 68,904 patients suffered from slips and falls, representing 33.3% of patients presenting to the ED. Among patients with injuries due to slips and falls, approximately 21% suffer fall-related injuries and present to the ED [1]. Hospitalization and mortality rates are higher among the patients who suffer a fall than among patients with other injuries. Additionally, several patients who suffer a fall also suffer from disability after discharge, which leads to difficulties in returning to daily life and work. Clinicians in EDs or trauma centers also experience difficulties in treating patients who suffer a fall, as they often present with severe injuries and multiple traumas.

Several studies have investigated the risk factors associated with the severity of fall-related injuries. Known risk factors include the fall height and the age and body mass index of the patient [2–5]. Additionally, intentional falls are associated with more severe injuries than unintentional falls [6,7]. However, the aforementioned studies reported that the mean fall height was greater in intentional falls than in unintentional falls; as such, differences in the severity of injuries between intentional and unintentional falls may be attributed to the simple difference in fall height. Furthermore, studies have reported differences in the injury site. Intentional falls tend to result in a higher frequency of injuries in the lower extremity, whereas unintentional falls are more commonly associated with head injuries [7]. Several studies have also reported the differences in injury site depending on the fall height [8,9]. At present, it is unclear whether the differences in injury site between intentional and unintentional falls are due to the intention of the patients.

Fall height has a significant effect on the clinical outcome of patients with fall-related injuries [10,11]. Therefore, the independent effects of other risk factors may be masked by the effects of fall height. To elucidate the effects of other risk factors, it may be helpful to compare the clinical features of the patients who suffer fall-related injuries after falling from similar heights.

Objectives
This retrospective study aimed to investigate the patients with fall-related injuries from a similar fall height, who were divided into severe and nonsevere cases to identify risk factors related to the severity of injury, and examine the differences in patient characteristics and injury site between intentional and unintentional falls from a similar fall height.

METHODS

Ethics statement
This study was approved by the Institutional Review Board of Gachon University Gil Medical Center (No. GCIRB2022-187). The Institutional Review Board waived the need for informed consent.

Study design and data collection
We analyzed patients who were admitted to the ED for fall-related injuries using the Emergency Department-based Injury Depth Surveillance (EDIIS) data. EDIIS is an injury investigation and monitoring project under the Korea Disease Control and Prevention Agency (KDCA). The project started in 2006, and as of 2020, 23 large hospitals in Korea are currently participating in the project. EDIIS data provide information on all injured patients who are admitted to the ED, including their demographic information, injury mechanism, and treatment outcomes. Data are collected in a standardized manner by trained investigators in each participating hospital and are then entered into the KDCA disease and health management system (https://is.kdca.go.kr/). The data undergo a quality check by third party personnel who review the appropriateness of the data.

Inclusion and exclusion criteria
EDIIS data from January 2019 to December 2020 were used in this study. To select fall patients, the injury mechanism (MECH) variables of the data were checked. We selected patients who satisfied the criteria of fall-related injury: patients who corresponded to C12.4 (fell, jumped, or pushed from a height < 1 m), C12.5 (fell, jumped, or pushed from a height ≥ 1 m and < 4 m), C12.6 (fell, jumped, or pushed from a height ≥ 4 m), or C12.7 (fell, jumped, or pushed from an unknown height). Detailed descriptions of the circumstances of injury were reviewed using the NARRATIVE variable. MECH variables that were improperly classified were also corrected based on the NARRATIVE variable. According to the Center for Disease Control and Prevention (CDC) guidelines for patients with injuries, the standard minimum height presumed to be associated with severe trauma is 20 ft (6 m), and the standard height of each floor is 10 ft (3 m). Therefore, we set the height of the third floor as ≥ 6 m and < 9 m. Accordingly, patients who fell from a height of ≥ 6 m and < 9 m (third floor) were included in the final analysis of this study.
The injury intention (INTENT) variable was checked to exclude those whose intention could not be evaluated as well as those who had unknown intentions, were admitted to the ED due to violence or homicide, had dementia, or took drugs (such as methamphetamine). Additionally, patients with missing excessive mortality ratio-adjusted Injury Severity Score (EMR-ISS) were also excluded.

**Collected variables and definitions of terms**

The demographic information of patients (such as age and sex) was recorded. In addition, data related to the characteristics of the injury, including time of fall, season, location (indoor vs. outdoor), and the public emergency medical transport service used were analyzed. Information related to the injury outcome, such as vital signs at the ED visit, Glasgow Coma Scale scores, the severity of injury (EMR-ISS), ED outcome, admission outcome, and diagnosis (International Classification of Diseases 10th Revision [ICD-10]) were analyzed.

Fall height was assessed as follows: if both the number of floors and fall height were recorded, the height (m) was prioritized; if only the number of floors was available, the fall height was calculated assuming a 3 m height for each floor [12]. The injury period was divided into four seasons: spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). Injury time was divided into four categories: morning (06:00–11:59), afternoon (12:00–17:59), evening (18:00–23:59), and late night (00:00–05:59).

The EMR-ISS is a scale used to assess the severity of an injury based on ICD-10 [13,14]. Excess mortality ratio is calculated as the percentage of deaths among patients diagnosed with each ICD-10 code against the expected mortality in the general population. The EMR-ISS is calculated using the summation of squares of the three highest EMR grades from all the ICD-10 codes for a particular patient: EMR-ISS = (first highest EMR grade)$^2$ + (second highest EMR grade)$^2$ + (third highest EMR grade)$^2$. The severity of an injury can be classified into four groups depending on the EMR-ISS: mild (1 < EMR-ISS ≤ 8), moderate (9 ≤ EMR-ISS ≤ 24), severe (25 ≤ EMR-ISS ≤ 74), and critical (EMR-ISS ≥ 75 or death). In this study, we categorized patients into the following groups based on the severity of their injury, as assessed using the EMR-ISS: mild/moderate group (< 25) and severe group (≥ 25).

The injury site was classified according to the ICD-10 code. In the EDIIS data, the major diagnosis for each patient was entered across 10 different variables: head (S00–S09); neck (S10–S19); chest (S20–S29); abdomen, waist, and pelvis (S30–S39); shoulder and upper arm (S40–S49); elbow and forearm (S50–S59); wrist, hand, and finger (S60–S69); hip and thigh (S70–S79); knee and lower extremity (S80–S89); and ankle and foot (S90–S99).

**Primary outcome**

Primary outcomes were to evaluate the risk factors associated with the severity of fall-related injuries from similar fall heights and assess differences in the injury site between the severe and mild/moderate groups and between the intention and non-intention groups.

**Statistical analysis**

Data were analyzed using PASW SPSS ver. 18.0 (SPSS Inc). Continuous variables are reported as medians and interquartile ranges or means and standard deviations, as appropriate. Data were compared using the Mann-Whitney U-test or Student t-test. Categorical variables are expressed as frequencies and percentages and were compared using the chi-square test or Fisher exact test. Multivariable binary logistic regression analysis was used to assess the independent predictors of the severity of the injury. All variables with a significance level of $< 0.10$ in the univariate analysis were included in the multivariable logistic regression analysis. The backward stepwise method was used to select the final model. The Hosmer-Lemeshow test was used to assess the goodness of fit. All statistical tests were two-sided, and a P-value of $< 0.05$ was considered significant.

**RESULTS**

**Study population**

The injury mechanism of 33,046 patients was recorded as a fall in the EDIIS database from January 1, 2019 to December 31, 2020. Of these, 563 patients who had a fall height ≥ 6 m and < 9 m were selected initially (Fig. 1). Nine patients with unknown intention, two patients who had dementia or used methamphetamine, four patients who were victims of violence, and five patients with missing EMR-ISS were excluded, and a total of 543 patients were included in the final analysis. The severity of injury was divided according to the EMR-ISS values. A total of 256 (47%) and 287 patients (53%) were categorized in the severe and mild/moderate groups, respectively. The patients were also divided into groups according to their recorded intention. A total of 93 (17%) and 450 patients (83%) were included in the intention and non-intention groups, respectively.
Comparison of severe and mild/moderate groups

Table 1 lists the characteristics of the severe and mild/moderate groups. There was no difference in the percentage of male patients between the two groups (79.3% vs. 78.4%, P = 0.798), and the median age of the severe and mild/moderate groups was 50 years (range, 39–60 years) and 45 years (range, 27–56 years), respectively (P < 0.001). The number of patients over the age of 65 years was 45 (17.6%) in the severe group and 32 (11.1%) in the mild/moderate group (P = 0.032). The mean fall height was 6.0 m (range, 6.0–7.5 m) in the severe group and 6.0 m (range, 6.0–7.0 m) in the mild/moderate group (P < 0.001). The systolic blood pressure was 117.5 mmHg (range, 99.5–140 mmHg) in the severe group and 130.0 mmHg (range, 113.0–150.0 mmHg) in the mild/moderate group (P < 0.001). ED death and overall deaths occurred in 16 (6.3%) and 37 patients (14.5%), respectively, in the severe group and nine (3.1%) and 16 patients (5.6%), respectively, in the mild/moderate group; the differences were statistically significant (P = 0.084 and P = 0.001, respectively).

Multivariable logistic regression analysis for independent factors associated with severe injuries

Factors related to the severity of fall injuries included fall height (odds ratio [OR], 1.638; 95% confidence interval [CI], 1.279–2.098), foot injury (OR, 0.466; 95% CI, 0.263–0.828), and systolic blood pressure < 90 mmHg (OR, 2.358; 95% CI, 1.231–4.520) (Table 2). When age was divided into quartiles and the first quartile (1Q; < 31.5 years) was set as the reference, the ORs of 2Q, 3Q, and 4Q were 1.747 (95% CI, 1.028–2.971), 1.545 (95% CI, 0.898–2.657), and 2.421 (95% CI, 1.405–4.171), respectively.

Comparison of intention and non-intention groups

Table 3 lists the characteristics of the intention and non-intention groups. The number of male patients in the intention and non-intention groups was 44 (47.3%) and 384 (85.3%), respectively (P < 0.001). The median age was 33 years (range, 20–46 years) and 50 years (range, 37–60 years) in the intention and non-intention groups, respectively (P < 0.001). The number of patients over the age of 65 years was six (6.5%) in the intention group and 71 (15.8%) in the non-intention group (P = 0.019). A total of 28 patients (33.7%) in the intention group and 51 patients (11.6%) in the non-intention group were under the influence of alcohol when they fell (P < 0.001). ED death and overall deaths occurred in seven (7.5%) and 14 patients (15.1%), respectively, in the intention group and 18 (4.0%) and 39 patients (8.7%), respectively, in the non-intention group; the differences were not statistically significant (P = 0.169 and P = 0.059, respectively).

Comparison of injury site

In the severe and mild/moderate groups, the injury sites were as follows: head and neck (171 [66.8%] vs. 58 [20.2%], P < 0.001), torso (183 [71.5%] vs. 104 [36.2%], P < 0.001), upper extremity (96 [37.5%] vs. 34 [11.8%], P < 0.001), and lower extremity (82 [32.0%] vs. 93 [32.4%], P = 0.926) (Table 1). In the intention and non-intention groups, the injury sites were upper extremity (10 [10.8%] vs. 120 [26.7%], P = 0.001) and lower extremity (30 [32.3%] vs. 145 [32.2%], P = 0.995) (Table 3). Figs. 2 and 3 show the difference in the injury site between the severe and mild/moderate groups and the intention and non-intention groups, respectively. The incidence of forearm injuries was four (4.3%) and 58 cases (12.9%, P = 0.018) and that of foot injuries was 20 (21.5%) and 54 cases (12.0%, P = 0.015) in the intention and non-intention groups, respectively.

DISCUSSION

In this study, we compared the general characteristics of patients who fell from a height of ≥ 6 m and < 9 m. Although the patients fell from almost similar height, fall height was associated with injury severity. Consistent with the findings of previous studies, age was also associated with injury severity. Contrary to the findings of previous studies, intentionality was not associated with injury.
**Table 1. Comparison between severe and mild/moderate groups**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Severe (n=256)</th>
<th>Mild/moderate (n=287)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex</td>
<td>203 (79.3)</td>
<td>225 (78.4)</td>
<td>0.798</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>50 (39–60)</td>
<td>45 (27–56)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age group (yr)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First quartile (&lt;31.5)</td>
<td>46 (18.0)</td>
<td>90 (31.4)</td>
<td>0.001</td>
</tr>
<tr>
<td>Second quartile (&lt;31.5 and &lt;47.0)</td>
<td>66 (25.8)</td>
<td>70 (24.4)</td>
<td></td>
</tr>
<tr>
<td>Third quartile (≥47.0 and &lt;58.5)</td>
<td>66 (25.8)</td>
<td>69 (24.0)</td>
<td></td>
</tr>
<tr>
<td>Fourth quartile (≥58.5)</td>
<td>78 (30.5)</td>
<td>58 (20.2)</td>
<td></td>
</tr>
<tr>
<td>Height (m)</td>
<td>6.0 (6.0–7.5)</td>
<td>6.0 (6.0–7.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
<td>0.053</td>
</tr>
<tr>
<td>06:00–11:59</td>
<td>80 (31.3)</td>
<td>62 (21.7)</td>
<td></td>
</tr>
<tr>
<td>12:00–17:59</td>
<td>105 (41.0)</td>
<td>123 (43.0)</td>
<td></td>
</tr>
<tr>
<td>18:00–23:59</td>
<td>38 (14.8)</td>
<td>49 (17.1)</td>
<td></td>
</tr>
<tr>
<td>00:00–05:59</td>
<td>33 (12.9)</td>
<td>52 (18.2)</td>
<td></td>
</tr>
<tr>
<td>Season</td>
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<td></td>
<td>0.826</td>
</tr>
<tr>
<td>Spring</td>
<td>72 (28.1)</td>
<td>71 (24.7)</td>
<td></td>
</tr>
<tr>
<td>Summer</td>
<td>72 (28.1)</td>
<td>84 (29.3)</td>
<td></td>
</tr>
<tr>
<td>Autumn</td>
<td>64 (25.0)</td>
<td>78 (27.2)</td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>48 (18.8)</td>
<td>54 (18.8)</td>
<td></td>
</tr>
<tr>
<td>Injury location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residence</td>
<td>79 (30.9)</td>
<td>86 (30.0)</td>
<td>0.926</td>
</tr>
<tr>
<td>Outdoor</td>
<td>205 (80.1)</td>
<td>229 (79.8)</td>
<td>1.000</td>
</tr>
<tr>
<td>Alcohol</td>
<td>39 (16.0)</td>
<td>40 (14.3)</td>
<td>0.600</td>
</tr>
<tr>
<td>Working</td>
<td>138 (54.5)</td>
<td>139 (48.8)</td>
<td>0.181</td>
</tr>
<tr>
<td>Transport by ambulance</td>
<td>186 (72.7)</td>
<td>186 (64.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>117.5 (99.5–140.0)</td>
<td>130.0 (113.0–150.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>74 (60–85)</td>
<td>80 (70–91)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pulse rate (beats/min)</td>
<td>88 (14–104)</td>
<td>86 (73–100)</td>
<td>0.142</td>
</tr>
<tr>
<td>Respiration rate (breaths/min)</td>
<td>20 (18–23)</td>
<td>20 (18–21)</td>
<td>0.460</td>
</tr>
<tr>
<td>Glasgow Coma Scale (score)</td>
<td>15 (10–15)</td>
<td>15 (15–15)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Body temperature (°C)</td>
<td>36.3 (36.0–36.7)</td>
<td>36.6 (36.2–37.1)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mental status</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Alert</td>
<td>170 (66.4)</td>
<td>233 (81.2)</td>
<td></td>
</tr>
<tr>
<td>Voice</td>
<td>20 (7.8)</td>
<td>28 (9.8)</td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>40 (15.6)</td>
<td>13 (4.5)</td>
<td></td>
</tr>
<tr>
<td>Unresponsive</td>
<td>26 (10.2)</td>
<td>13 (4.5)</td>
<td></td>
</tr>
<tr>
<td>Injury site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head and neck</td>
<td>171 (66.8)</td>
<td>58 (20.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Torso</td>
<td>183 (71.5)</td>
<td>104 (36.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Upper extremity</td>
<td>96 (37.5)</td>
<td>34 (11.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lower extremity</td>
<td>82 (32.0)</td>
<td>93 (32.4)</td>
<td>0.926</td>
</tr>
<tr>
<td>Death</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In the emergency department</td>
<td>16 (6.3)</td>
<td>9 (3.1)</td>
<td>0.084</td>
</tr>
<tr>
<td>Overall</td>
<td>37 (14.5)</td>
<td>16 (5.6)</td>
<td>0.001</td>
</tr>
</tbody>
</table>

Values are expressed as number (%) or median (interquartile range).
Odds ratios are calculated using a backward stepwise logistic regression analysis. The covariates included in this analysis are sex, age group, mental status, occurrence of abnormal heart rate, intentional fall, foot injuries, occurrence of low body temperature, SBP <90 mmHg, and fall height. CI, confidence interval; SBP, systolic blood pressure.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fallen height (m)</td>
<td>1.638</td>
<td>1.279–2.098</td>
</tr>
<tr>
<td>Intentional fall (yes)</td>
<td>0.722</td>
<td>0.418–1.248</td>
</tr>
<tr>
<td>Foot injury (yes)</td>
<td>0.466</td>
<td>0.263–0.828</td>
</tr>
<tr>
<td>Mental status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alert</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Verbal response</td>
<td>0.688</td>
<td>0.354–1.334</td>
</tr>
<tr>
<td>Painful response</td>
<td>3.835</td>
<td>1.913–7.688</td>
</tr>
<tr>
<td>Unresponsive</td>
<td>1.298</td>
<td>0.531–3.171</td>
</tr>
<tr>
<td>SBP &lt;90 mmHg (yes)</td>
<td>2.358</td>
<td>1.231–4.520</td>
</tr>
<tr>
<td>Abnormal heart rate (yes)</td>
<td>1.233</td>
<td>0.813–1.870</td>
</tr>
<tr>
<td>Age group (yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First quartile (&lt;31.5)</td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td>Second quartile (≥31.5 and &lt;47.0)</td>
<td>1.747</td>
<td>1.028–2.971</td>
</tr>
<tr>
<td>Third quartile (≥47.0 and &lt;58.5)</td>
<td>1.545</td>
<td>0.898–2.657</td>
</tr>
<tr>
<td>Fourth quartile (≥58.5)</td>
<td>2.421</td>
<td>1.405–4.171</td>
</tr>
</tbody>
</table>

Odds ratios are calculated using a backward stepwise logistic regression analysis. The covariates included in this analysis are sex, age group, mental status, occurrence of abnormal heart rate, intentional fall, foot injuries, occurrence of low body temperature, SBP <90 mmHg, and fall height.

severity [6,7]. Here, we found that patients with foot injuries were less likely to suffer from severe injuries. Those who suffered intentional falls had a higher frequency of injuries in the lower extremity, whereas the non-intention group showed a higher frequency of injuries in the upper extremity.

The fall height is one of the key risk factors for serious fall-related injuries [2,10]. As demonstrated in previous studies, the force of impact increases with fall height, which increases the risk of injury. In this study, we used a relatively large amount of data, which enabled comparisons between patients who fell from specific heights (≥6 m and <9 m). Although patients who fell from a similar height were compared, injury severity differed even with small differences in fall height. This suggests that fall height was the most powerful factor related to injury severity in fall-related injuries. Therefore, even if we compared patients who fell from a similar height, this study was limited because the effect of fall height could not be completely excluded. Future large-scale studies can help elucidate the effects of other risk factors by comparing patient groups with specific fall heights.

Age is known to affect responses to stimuli, cognition, and motor skills [3]. Injury severity generally increases with the age of trauma patients [3,4]. Consistent with this, we found that age was associated with injury severity in this study. This may be because fall injuries often result from loss of balance or consciousness. When the patients were divided into four different age groups, multivariable logistic regression analysis showed that severe injuries were associated with a patient age of 31.5 to 47.0 years. A previous study showed that suicide attempts were higher in a similar age group than in other age groups [15], suggesting that a higher incidence of intentional falls might have led to more severe injuries. Previous studies have also reported that injuries were more severe in intention groups than in non-intention groups [6,7]. Contrary to these findings, we observed that intention was not associated with injury severity. This may be because in the present study, factors predicting injury severity were investigated in patients who suffered from both intentional and unintentional falls. As a result, age and intentionality may have acted as confounding factors. In previous studies where injuries were reported to be more severe in intentional falls than in unintentional falls [6,7], the mean fall height was higher in the intention group than in the non-intention group. This suggests that intentionality and fall height may have acted as confounding factors in other studies as well. Thus, further studies must be conducted to determine whether intentionality and injury severity interact with each other at similar fall heights for patients in the age group of 31.5 to 47.0 years.

Injury sites were compared according to the injury severity. In the severe group, injuries were more frequent in the head and neck, torso, shoulder, forearm, and thigh. In contrast, the mild/moderate group showed a high frequency of foot injury. Multivariable logistic regression analysis revealed a small OR for foot injury, suggesting a low risk of severe injury in patients with foot injuries. This could mean that landing on one’s feet may help absorb the shock and reduce damage to the vital organs. Therefore, predicting injury severity in fall patients may require the evaluation of not only vital organs, but also foot injuries.

Foot injury also has another implication for clinicians who treat unconscious fall patients. In this study, the frequency of injuries in the shoulder, upper arm, and forearm was higher in the non-intention group than in the intention group. The frequency of upper extremity injuries in the non-intention group may be related to the patients’ unconscious acts to protect their body. In contrast, the frequency of foot injury was higher in the intention group than in the non-intention group. Consistent with our findings, injury sites have been shown to differ among fall patients depending on their intentionality [7]. Injuries in the lower extremity and abdomen were more common in intentional falls than in unintentional falls. Based on these findings, previous studies have suggested the "land feet first" theory [7,16]. Patients
Table 3. Comparison between the intention and non-intention groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intention (n=93)</th>
<th>Non-intention (n=450)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex</td>
<td>44 (47.3)</td>
<td>384 (85.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>33.0 (20.5–46.0)</td>
<td>50.0 (37.0–60.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age group (yr)</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>First quartile (&lt;31.5)</td>
<td>43 (46.2)</td>
<td>93 (20.7)</td>
<td></td>
</tr>
<tr>
<td>Second quartile (≥31.5 and &lt;47.0)</td>
<td>29 (31.2)</td>
<td>107 (23.8)</td>
<td></td>
</tr>
<tr>
<td>Third quartile (≥47.0 and &lt;58.5)</td>
<td>11 (11.8)</td>
<td>124 (27.6)</td>
<td></td>
</tr>
<tr>
<td>Fourth quartile (≥58.5)</td>
<td>10 (10.8)</td>
<td>126 (28.0)</td>
<td></td>
</tr>
<tr>
<td>Height (m)</td>
<td>6.0 (6.0–7.5)</td>
<td>6.0 (6.0–7.0)</td>
<td>0.720</td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>06:00–11:59</td>
<td>8 (8.6)</td>
<td>134 (29.8)</td>
<td></td>
</tr>
<tr>
<td>12:00–17:59</td>
<td>22 (23.7)</td>
<td>206 (45.9)</td>
<td></td>
</tr>
<tr>
<td>18:00–23:59</td>
<td>26 (28.0)</td>
<td>61 (13.6)</td>
<td></td>
</tr>
<tr>
<td>00:00–05:59</td>
<td>37 (39.8)</td>
<td>48 (10.7)</td>
<td></td>
</tr>
<tr>
<td>Season</td>
<td></td>
<td></td>
<td>0.360</td>
</tr>
<tr>
<td>Spring</td>
<td>24 (25.8)</td>
<td>119 (26.4)</td>
<td></td>
</tr>
<tr>
<td>Summer</td>
<td>33 (35.5)</td>
<td>123 (27.3)</td>
<td></td>
</tr>
<tr>
<td>Autumn</td>
<td>19 (20.4)</td>
<td>123 (27.3)</td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>17 (18.3)</td>
<td>85 (18.9)</td>
<td></td>
</tr>
<tr>
<td>Injury location</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Residence</td>
<td>61 (65.6)</td>
<td>104 (23.1)</td>
<td></td>
</tr>
<tr>
<td>Outdoor</td>
<td>66 (71.0)</td>
<td>368 (81.8)</td>
<td>0.056</td>
</tr>
<tr>
<td>Alcohol</td>
<td>28 (33.7)</td>
<td>51 (11.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Working</td>
<td>0</td>
<td>277 (62.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Transport by ambulance</td>
<td>89 (95.7)</td>
<td>394 (87.6)</td>
<td>0.023</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>113 (90–126)</td>
<td>128 (110–150)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>70 (49–83)</td>
<td>80 (66–90)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pulse rate (beats/min)</td>
<td>94 (80–109)</td>
<td>85 (73–100)</td>
<td>0.001</td>
</tr>
<tr>
<td>Respiration rate (breaths/min)</td>
<td>20 (17–22)</td>
<td>20 (18–22)</td>
<td>0.240</td>
</tr>
<tr>
<td>Glasgow Coma Scale (score)</td>
<td>15 (12–15)</td>
<td>15 (14–15)</td>
<td>0.056</td>
</tr>
<tr>
<td>Body temperature (°C)</td>
<td>36.4 (36.0–37.0)</td>
<td>36.5 (36.0–36.8)</td>
<td>0.973</td>
</tr>
<tr>
<td>Mental status</td>
<td></td>
<td></td>
<td>0.015</td>
</tr>
<tr>
<td>Alert</td>
<td>58 (62.4)</td>
<td>345 (76.7)</td>
<td></td>
</tr>
<tr>
<td>Voice</td>
<td>14 (15.1)</td>
<td>34 (7.6)</td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>10 (10.8)</td>
<td>43 (9.6)</td>
<td></td>
</tr>
<tr>
<td>Unresponsive</td>
<td>11 (11.8)</td>
<td>28 (6.2)</td>
<td></td>
</tr>
<tr>
<td>Injury site</td>
<td></td>
<td></td>
<td>0.330</td>
</tr>
<tr>
<td>Head and neck</td>
<td>35 (37.6)</td>
<td>194 (43.1)</td>
<td></td>
</tr>
<tr>
<td>Torso</td>
<td>51 (54.8)</td>
<td>236 (52.4)</td>
<td>0.674</td>
</tr>
<tr>
<td>Upper extremity</td>
<td>10 (10.8)</td>
<td>120 (26.7)</td>
<td>0.001</td>
</tr>
<tr>
<td>Lower extremity</td>
<td>30 (32.3)</td>
<td>145 (32.2)</td>
<td>0.995</td>
</tr>
<tr>
<td>Death</td>
<td></td>
<td></td>
<td>0.169</td>
</tr>
<tr>
<td>In the emergency department</td>
<td>7 (7.5)</td>
<td>18 (4.0)</td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>14 (15.1)</td>
<td>39 (8.7)</td>
<td>0.059</td>
</tr>
</tbody>
</table>

Values are expressed as number (%) or median (interquartile range).
who suffer an unintentional fall have a higher risk of arm and hand injuries owing to the human body’s instinctive urge to defend themselves with their upper extremity, whereas patients who suffer an intentional fall may have a higher risk of landing on the feet, thus increasing their risk of foot injury. Thus, it would be necessary to further assess whether patients with foot injuries have intentionally fallen after alcohol or drug use.

Limitations
Several limitations must be considered in the interpretation of this study’s findings. First, this study retrospectively analyzed prospectively collected data. Second, the fall height analyzed in this study might be distorted. We compared patients with a similar fall height to reduce the effects of fall height and evaluate other risk factors. However, the fall heights analyzed in this study were subjective height estimates provided by the patient and other personnel who reported the patient’s injury status. Therefore, the values may not be accurate. Third, this study analyzed patients who fell from a height of third floors. The units to compare the fall height were meter and floor. However, as previously described, meter is a subjective numerical unit measured by witnesses. Therefore, floor was considered more objective than meter, and patients who fell from a height of third floors were analyzed. Fourth, we used diagnostic codes to identify the injury sites of patients. Therefore, the injury site variable was omitted if a diagnostic code related to the injury site was not entered after death, or if the diagnostic code entered did not specify the injury site (e.g., T148, other injury of body). Fifth, as the analyzed data were collected from large hospitals and institutions, patients with mild symptoms or those who died at the scene may not have been included. Sixth, the medical history of the patients and the material of the surface that the patients landed on after falling could not be identified or analyzed in this study. Seventh, among the various injury severity assessment tools used to assess patients in the EDIIS database, EMR-ISS had the least missing data. Thus, EMR-ISS was used in this study to analyze disease severity.

Conclusions
Our results showed that fall height and age were associated with severe fall-related injuries in patients with a similar fall height. Intentionality was not related to injury severity, and patients with foot injuries were less likely to suffer from serious injuries. Lower and upper extremity injuries were more common in intentional and unintentional falls, respectively.
ARTICLE INFORMATION

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

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

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Data availability
The 2019 data of this study are openly available on the KDCA website at https://www.kdca.go.kr/injury/biz/injury/recsroom/rawDta/rawDtaDwldMain.do. Restrictions apply to the availability of the 2020 data. The 2020 data of this study are available from KDCA with their permission.

REFERENCES

Clinical characteristics of patients with the hardware failure after surgical stabilization of rib fractures in Korea: a case series

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Purpose: Surgical stabilization of rib fractures (SSRF) is widely used in patients with flail chests, and several studies have reported the efficacy of SSRF even in multiple rib fractures. However, few reports have discussed the hardware failure (HF) of implanted plates. We aimed to evaluate the clinical characteristics of patients with HF after SSRF and further investigate the related factors.

Methods: We retrospectively reviewed the electronic medical records of patients who underwent SSRF for multiple rib fractures at a level I trauma center in Korea between January 2014 and January 2021. We defined HF as the unintentional loosening of screws, dislocation, or breakage of the implanted plates. The baseline characteristics, surgical outcomes, and types of HF were assessed.

Results: During the study period, 728 patients underwent SSRF, of whom 80 (10.9%) were diagnosed with HF. The mean age of HF patients was 56.5 ± 13.6 years, and 66 (82.5%) were men. There were 59 cases (73.8%) of screw loosening, 21 (26.3%) of plate breakage, 17 (21.3%) of screw migration, and seven (8.8%) of plate dislocation. Nine patients (11.3%) experienced wound infection, and 35 patients (43.8%) experienced chronic pain. A total of 21 patients (26.3%) underwent reoperation for plate removal. The patients in the reoperation group were significantly younger, had fewer fractures and plates, underwent costal fixation, and had a longer follow-up. There were no significant differences in subjective chest symptoms or lung capacity.

Conclusions: HF after SSRF occurred in 10.9% of the cases, and screw loosening was the most common. Further longitudinal studies are needed to identify risk factors for SSRF failure.

Keywords: Bone fractures; Bone screws; Flail chest; Reoperation; Ribs

INTRODUCTION

Background
Multiple rib fractures are the most common injuries observed after blunt chest trauma and account for approximately 10% of all trauma cases [1]. As rib fractures are frequently accompanied by major intrathoracic and extrathoracic injuries, they are inevitably associated with severe damage, pain, and long-term sequelae [2–
Furthermore, more fractured ribs and older age were associated with poorer outcomes [5,6]. Insufficient ventilation and impaired pulmonary hygiene due to pain can lead to critical respiratory complications in these patients. Pain control, respiratory support, and pulmonary rehabilitation are the standard therapies for rib fractures, conventionally [1]. However, over the past few decades, there has been emerging interest in the surgical stabilization of rib fractures (SSRF) with technological advancements in surgical instruments. Previous randomized studies have demonstrated that SSRF reduces the duration of hospital stay, ventilator days, the occurrence of pneumonia, and mortality in patients with flail chest [7–9]. Recent trials on chest wall injuries have shown favorable outcomes in terms of pain and disability-related quality of life among patients with a nonflail chest [10]. Throughout the literature supporting the advantages of SSRF, the indications for SSRF have expanded, and SSRF is now becoming an established technique at regional trauma centers [11–13].

As the use of SSRF increases, concerns regarding surgical complications have inevitably been raised. To stabilize a fractured rib, SSRF usually involves nonabsorbable metallic implants. Unlike other bones, the ribs continue to move while breathing after orthopedic surgery, which can contribute to long-term complications. Recent studies have reported an incidence of up to 10% for complications, including bleeding, infection, inadequate bone healing, implant-related irritation, and implant failure [14]. Despite the assumption of relative safety, little is known about the long-term complications of SSRF, particularly those associated with hardware failure (HF) of the implanted plates. HF is defined as the unintentional loosening of screws, dislocation, or breakage of implanted plates and can occur for various reasons, such as improper placement, insufficient screw fixation, or a lack of plate length [15]. Previous studies have investigated the efficacy of SSRF and its associated risks; however, few have explored the clinical characteristics and factors related to HF after SSRF [14–18]. Understanding the clinical characteristics and risk factors of HF can help improve patient selection, surgical techniques, and postoperative care, which may reduce the incidence of complications and improve patient outcomes.

**Objectives**

In this study, we aimed to retrospectively analyze the electronic medical records of patients who underwent SSRF for multiple rib fractures at a level I trauma center in Korea to assess the clinical characteristics of patients with HF and further investigate the factors related to reoperation. We hypothesized that HF after SSRF is not prevalent and typically has insignificant clinical consequences.

**METHODS**

**Ethics statement**

This study was approved by the Ethics Committee of Pusan National University Hospital (No. H-2205-007-114). The requirement for informed consent was waived due to the retrospective nature of the study. The study was conducted in accordance with the Declaration of Helsinki for experiments involving humans.

**Study setting and populations**

This retrospective cohort study was performed at a regional trauma center between January 1, 2014 and January 1, 2021. Using the hospital inpatient inquiry system, 5,792 patients with chest injuries admitted to the level I trauma center were identified. We selected patients who had undergone surgical fixation of the chest wall. A total of 728 patients who underwent SSRF were included in the study. The exclusion criteria were as follows: no HF, age < 16 years, death within 48 hours after surgery, and follow-up duration < 30 days. The final study population comprised 80 patients with HF after SSRF (Fig. 1).

**Data collection**

Patient demographics, mechanisms of injury, and SSRF and HF characteristics were recorded. The available data included age, sex, mechanism of injury, Injury Severity Score (ISS), anatomical
features of the chest wall injuries (flail chest, bilateral fracture, sternal fracture, number of rib fractures, costal fractures), HF location, failed plating system, failure mode, time to detection of HF, surgical details (such as fixation site, number of plates implanted, fixed rib number, and time to SSRF), any postoperative complication, reoperation, hospital stay, laboratory values of pulmonary function, follow-up duration, and survival status. In addition, a subgroup analysis was performed by dividing the patients into two groups according to whether metal removal was performed.

Definition of anatomic location chest wall injury
The consensus of the Chest Wall Injury Society (CWIS) was used to describe the location of rib fractures [19]. The chest wall was defined as having three sectors: the anterior, lateral, or posterior sector. These were divided by the anterior and posterior axillary lines, where the anterior axillary line defined the border between the anterior and lateral fractures and the posterior axillary line defined the border between the lateral and posterior fractures. In addition to these three sectors, the costal cartilage sector was recorded. A flail segment was defined as three or more consecutive ribs that fractured in more than one location, producing a free-floating segment of the chest wall.

Type of chest wall plating system
During the study period, four thoracic surgeons performed SSRF using at least one of four commercially available plating systems, all of which were anterior bicortical screw locking systems: SternaLock Blu Plate (Zimmer Biomet Inc), ARIX Sternal & Rib System (Jeil Medical Corp), APIS Rib Locking Plate System (TDM Corp), and MatrixRIB Fixation System (Depuy Synthes) (Fig. 2). All the systems included straight or precontoured titanium plates and self-drilling and self-tapping screws, except for the MatrixRIB Plate. The choice of plating system was at the discretion of the surgeon.

Definition of HF mode
HF was defined as follows: (1) screw loosening, defined as a screw that protrudes from the screw hole but does not pull out completely; (2) screw migration, defined as a screw being pulled out of a screw hole and moved to a completely different position; (3) plate fracture, defined as breakage of implanted plates; and (4) plate dislocation, defined as the displacement of a plate superiorly or inferiorly (Fig. 3).

HF detection
All patients visited the hospital regularly at 3, 6, and 12 months.

Fig. 2. Type of chest wall plating system. (A) SternaLock Blu Plate (Zimmer Biomet Inc). (B) ARIX Sternal & Rib System (Jeil Medical Corp). (C) APIS Rib Locking Plate System (TDM Corp). (D) MatrixRIB Plate (Depuy Synthes).
after surgery. Three-dimensional chest computed tomography (CT), pulmonary function tests, and chest radiography were routinely performed. HF was confirmed using routine imaging after surgery.

**Outcome measure**

The primary objective of this study was to report the incidence, characteristics, and clinical impact of HFs. The secondary objective was to determine the differences between patients who underwent reoperation (the plate removal surgery group) and those who did not.

**Statistical analysis**

Summary statistics are reported as median and interquartile range (IQR) or mean ± standard deviation, where appropriate. Categorical variables are expressed as numbers and percentages. Chi-square and Fisher exact tests were used to compare the frequencies of categorical variables between the groups. The Mann-Whitney U-test and Wilcoxon rank-sum test were used to compare the mean values of continuous variables. We used the receiver operating characteristic (ROC) curve and area under the curve (AUC) to evaluate predictive factors for plate removal. A P-value of < 0.05 was considered statistically significant. Statistical analysis was performed using IBM SPSS ver. 22 (IBM Corp).

**RESULTS**

**Characteristics of the patients with HF**

The demographic characteristics of patients with HF are summarized in Table 1. The overall incidence of HF after SSRF was 10.9% (80 of 728). The mean age of HF patients was 56.5 ± 13.6 years, with the most common mechanism being motor vehicle accidents (57.5%). The median number of fractured ribs per patient was 9 (IQR, 4–24) and 73.8% of the patients had a flail segment. The median ISS was 22 (IQR, 4–45), indicating a severe injury. In terms of comorbidities, the majority of patients (68.6%) had no underlying disease, whereas those with diabetes mellitus (2.5%) had ischemic heart disease.

SSRF was performed within 7.5 days by four thoracic surgeons with SSRF experience ranging from 1 to more than 10 years. At least one of the four commercially available plating systems was chosen for the SSRF, with the most commonly used system being ARIX (62.5%), followed by the SternaLock (41.3%), APIS (22.5%), and MatrixRIB (3.8%). An average of four ribs (IQR, 1–13) were fixed, and six plates (IQR, 1–29) were implanted. SSRF was mainly performed anterolaterally (anterior, 52.5%; lateral, 72.5%; and posterior, 43.8%). This is consistent with the most common location of HF.

Although no deaths were reported during hospitalization, perioperative complications such as pneumonia (51.2%), acute...
kidney injury (16.3%), and wound infection (11.3%) occurred. Thirty-five patients (43.8%) experienced chronic pain during follow-up. Thirty-two patients (40.0%) presented with normal lung capacity at the last follow-up. A total of 21 patients (26.3%) underwent reoperation for plate removal.

Clinical features of HF in total cohort
The clinical features of patients with HF are shown in Table 2. The mean time from implantation to HF was approximately 3 months. HF was detected in the anterolateral region of the chest (78.8%), and screw loosening (73.8%) was the most common mode of failure. The ARIX plating system was used more frequently, resulting in HF. By location, 42.4% lateral screw loosening, 52.9% anterior screw migration, 47.6% posterolateral plate fractures, and 57.1% anterior plate dislocations were recorded. In addition, the ARIX system in the anterolateral sector and the SternaLock system in the posterior sector failed. Screw loosening, screw migration, and plate fractures were more common in the ARIX system (Table 3). However, there was no statistically significant correlation between the failure location, failed plate, and failure mode. Although up to 80% of the HF cases occurred in the ARIX and SternaLock systems, the correlation was not statistically significant (P = 0.12 and P = 0.29, respectively). There was no definitive relationship between anterolateral location and HF (P = 0.70 and P = 0.80, respectively) (Table 4). Furthermore, screw failure occurred in 12 of the 14 patients (85.7%) who underwent costal fixation; however, the difference was not statistically significant (P = 0.33).

Table 1. Clinical characteristics of the patients included in the study

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value (n=80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>56.5±13.6</td>
</tr>
<tr>
<td>Male sex</td>
<td>66 (82.5)</td>
</tr>
<tr>
<td>Mechanism of injury</td>
<td></td>
</tr>
<tr>
<td>Motor vehicle accident</td>
<td>46 (57.5)</td>
</tr>
<tr>
<td>Fall</td>
<td>24 (30.0)</td>
</tr>
<tr>
<td>Crush injury</td>
<td>9 (11.3)</td>
</tr>
<tr>
<td>Penetrating injury</td>
<td>1 (1.3)</td>
</tr>
<tr>
<td>Injury severity</td>
<td></td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>22 (4–45)</td>
</tr>
<tr>
<td>Flail segment</td>
<td>59 (73.8)</td>
</tr>
<tr>
<td>Bilateral rib fracture</td>
<td>31 (38.8)</td>
</tr>
<tr>
<td>Sternal fracture</td>
<td>14 (17.5)</td>
</tr>
<tr>
<td>No. of rib fractures</td>
<td>9.3±4.8</td>
</tr>
<tr>
<td>Surgical procedure</td>
<td></td>
</tr>
<tr>
<td>Time from admission to SRF (day)</td>
<td>7.5±6.4</td>
</tr>
<tr>
<td>No. of fixed ribs</td>
<td>4.4±2.0</td>
</tr>
<tr>
<td>No. of implanted plates</td>
<td>6.6±4.2</td>
</tr>
<tr>
<td>Fixation of costal cartilage</td>
<td>14 (17.5)</td>
</tr>
<tr>
<td>Fixation sector of chest wall</td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>42 (52.5)</td>
</tr>
<tr>
<td>Lateral</td>
<td>58 (72.5)</td>
</tr>
<tr>
<td>Posterior</td>
<td>35 (43.8)</td>
</tr>
<tr>
<td>Sternum</td>
<td>12 (15.0)</td>
</tr>
<tr>
<td>Complication</td>
<td></td>
</tr>
<tr>
<td>Wound infection</td>
<td>9 (11.3)</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>41 (51.2)</td>
</tr>
<tr>
<td>Acute kidney injury</td>
<td>13 (16.3)</td>
</tr>
<tr>
<td>Tracheostomy</td>
<td>29 (36.3)</td>
</tr>
<tr>
<td>Hospital stay (day)</td>
<td>52.0±66.1</td>
</tr>
<tr>
<td>Patients’ follow-up</td>
<td></td>
</tr>
<tr>
<td>Follow-up duration (day)</td>
<td>358.6±291.3</td>
</tr>
<tr>
<td>Subjective chest symptom</td>
<td>41 (51.2)</td>
</tr>
<tr>
<td>FVC ≥80% predicted</td>
<td>32 (40.0)</td>
</tr>
<tr>
<td>Plate removal operation</td>
<td>21 (26.3)</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation, number (%), or median (interquartile range). SRF, surgical rib fixation; FVC, functional vital capacity.

Table 2. Clinical features of hardware failure

<table>
<thead>
<tr>
<th>Clinical feature</th>
<th>Value (n=80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to detection of hardware failure (day)</td>
<td>84.0±131.2</td>
</tr>
<tr>
<td>Failure location</td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>28 (35.0)</td>
</tr>
<tr>
<td>Lateral</td>
<td>35 (43.8)</td>
</tr>
<tr>
<td>Posterior</td>
<td>18 (22.5)</td>
</tr>
<tr>
<td>Sternum</td>
<td>7 (8.8)</td>
</tr>
<tr>
<td>Failed plating system</td>
<td></td>
</tr>
<tr>
<td>SternaLock</td>
<td>27 (33.8)</td>
</tr>
<tr>
<td>ARIX</td>
<td>45 (56.3)</td>
</tr>
<tr>
<td>APIS</td>
<td>10 (12.5)</td>
</tr>
<tr>
<td>MatrixRIB</td>
<td>1 (1.3)</td>
</tr>
<tr>
<td>Failure mode</td>
<td></td>
</tr>
<tr>
<td>Screw loosening</td>
<td>59 (73.8)</td>
</tr>
<tr>
<td>Screw migration</td>
<td>17 (21.3)</td>
</tr>
<tr>
<td>Plate fracture</td>
<td>21 (26.3)</td>
</tr>
<tr>
<td>Plate dislocation</td>
<td>7 (8.8)</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation or number (%). *SternaLock Blu Plate (Zimmer Biomet Inc), ARIX Sternal & Rib System (Jeil Medical Corp), APIS Rib Locking Plate System (TDM Corp), and MatrixRIB Plate (DePU Synthes).

Comparison of patients’ characteristics according to plate removal surgery
Table 5 demonstrates the differences between patients with HF who underwent reoperation (the plate removal surgery group) and those who did not undergo reoperation. The reoperation group was statistically significantly younger (59.1 ± 12.8 years vs.
49.1 ± 13.3 years, P = 0.03), had fewer fractures (10.0 ± 4.6 vs. 7.2 ± 5.0, P = 0.01), and had more costal fixation (11.8% vs. 8.0%, P = 0.04). SSRF performed at another location on the chest wall was more common in patients who did not undergo reoperation (67.8% vs. 47.6%, P = 0.03). Although there was no difference in the failure mode or plating system between the two groups, the failure location, especially in the anterior sternum, was frequent in the reoperation group (P = 0.007). The time to detect HF was not different, but the follow-up duration was longer in the reoperation group (312.8 ± 244.7 vs. 487.3 ± 371.4, P = 0.01).

There were no significant differences in wound infection, subjective chest symptoms, or lung capacity at the last follow-up. A total of 52.4% of patients with plate removal surgery experienced chronic chest pain; however, no statistically significant difference was noted between the groups (P = 0.13) (Fig. 4).

**DISCUSSION**

This is the first study to describe the incidence and clinical features of HF after SSRF in a contemporary cohort of level I regional trauma centers in Korea. We found that the overall incidence of HF after SSRF was 10.9% (80 of 728) over the 7 years. Screw failure was the most common type of HF, followed by plate fractures and plate dislocations. HF frequently occurs in the anterolateral region, including the costal cartilage. Half of these patients experienced subjective symptoms, and only 26.3% underwent plate removal surgery. Plate removal was associated with a younger age, fewer fixed ribs, failure location in the anterior region, especially in the costal cartilage portion, and a longer follow-up duration. There was no relationship among the failure mode, failure location, and plating system.

SSRF has become increasingly popular in recent years as multiple studies have demonstrated its benefits, even in nonfrail rib fractures [7–10,20]. As the indications for SSRF have expanded, it has become essential to identify and analyze the long-term surgical complications associated with this procedure. Since its inception in the early 21st century, there have been only a few case reports or single-center studies of implant-related complications [21–27]. In 2019, the CWIS published a multicenter retrospective study reporting a 3% (38 of 1,224) HF rate after SSRF, mainly due to screw loosening.

### Table 3. Detailed frequency of hardware failures according to location, plating system, and mode

<table>
<thead>
<tr>
<th>Variable</th>
<th>Failure location</th>
<th>Failed plating system</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anterior</td>
<td>Lateral</td>
</tr>
<tr>
<td>Screw mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Screw loosening</td>
<td>22 (37.3)</td>
<td>25 (42.4)</td>
</tr>
<tr>
<td>Screw migration</td>
<td>9 (52.9)</td>
<td>6 (35.3)</td>
</tr>
<tr>
<td>Plate fracture</td>
<td>5 (23.8)</td>
<td>10 (47.6)</td>
</tr>
<tr>
<td>Plate dislocation</td>
<td>4 (57.1)</td>
<td>2 (28.6)</td>
</tr>
<tr>
<td>Failure location</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lateral</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Posterior</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sternum</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Values are presented as number (%).

*SternaLock Blu Plate (Zimmer Biomet Inc), ARIX Sternal & Rib System (Jeil Medical Corp), APIS Rib Locking Plate System (TDM Corp), and MatrixRIB Plate (Depuy Synthes).

### Table 4. Relationship between the location of hardware failure, failed plating system, and mode

<table>
<thead>
<tr>
<th>Variable</th>
<th>SternaLock and ARIX</th>
<th>P-value</th>
<th>APIS and MatrixRIB</th>
<th>P-value</th>
<th>Anterolateral</th>
<th>P-value</th>
<th>Posterior</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screw failure (n=59)</td>
<td>54 (91.5)</td>
<td>0.12</td>
<td>7 (8.8)</td>
<td>0.46</td>
<td>45 (76.3)</td>
<td>0.70</td>
<td>14 (23.7)</td>
<td>0.10</td>
</tr>
<tr>
<td>Plate failure (n=27)</td>
<td>22 (81.5)</td>
<td>0.29</td>
<td>6 (7.5)</td>
<td>0.16</td>
<td>20 (74.1)</td>
<td>0.80</td>
<td>10 (37.0)</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Values are presented as numbers (%). Failed plating systems are SternaLock Blu Plate (Zimmer Biomet Inc), ARIX Sternal & Rib System (Jeil Medical Corp), APIS Rib Locking Plate System (TDM Corp), and MatrixRIB Plate (Depuy Synthes).
Table 5. Comparison of patients according to plate removal

<table>
<thead>
<tr>
<th>Variable</th>
<th>No (n=59)</th>
<th>Yes (n=21)</th>
<th>P-value</th>
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<tbody>
<tr>
<td><strong>Age (yr)</strong></td>
<td>59.1±12.8</td>
<td>49.1±13.3</td>
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<tr>
<td><strong>Male sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>49 (83.1)</td>
<td>17 (80.9)</td>
<td>-</td>
</tr>
<tr>
<td><strong>Motor vehicle accident</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>34 (57.6)</td>
<td>12 (57.1)</td>
<td>-</td>
</tr>
<tr>
<td><strong>Injury severity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>23.5±9.0</td>
<td>21.5±12.7</td>
<td>-</td>
</tr>
<tr>
<td>Flail segment</td>
<td>50 (84.7)</td>
<td>9 (42.8)</td>
<td>0.010</td>
</tr>
<tr>
<td>Bilateral rib fracture</td>
<td>25 (42.4)</td>
<td>6 (28.6)</td>
<td>-</td>
</tr>
<tr>
<td>Sternal fracture</td>
<td>9 (15.3)</td>
<td>5 (23.8)</td>
<td>-</td>
</tr>
<tr>
<td>No. of rib fractures</td>
<td>10.0±4.6</td>
<td>7.2±5.0</td>
<td>0.010</td>
</tr>
<tr>
<td><strong>Surgical procedure</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time from admission to SRF (day)</td>
<td>8.0±7.0</td>
<td>6.1±4.4</td>
<td>-</td>
</tr>
<tr>
<td>No. of fixed ribs</td>
<td>4.5±1.7</td>
<td>4.1±2.8</td>
<td>-</td>
</tr>
<tr>
<td>No. of implanted plates</td>
<td>6.8±3.4</td>
<td>5.9±5.9</td>
<td>0.050</td>
</tr>
<tr>
<td>Fixation of costal cartilage</td>
<td>7 (11.8)</td>
<td>17 (80.9)</td>
<td>0.040</td>
</tr>
<tr>
<td>Fixation sector of chest wall</td>
<td></td>
<td></td>
<td>0.030</td>
</tr>
<tr>
<td>Anterior</td>
<td>6 (10.2)</td>
<td>4 (19.0)</td>
<td></td>
</tr>
<tr>
<td>Lateral</td>
<td>7 (11.8)</td>
<td>2 (9.5)</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>6 (10.2)</td>
<td>2 (9.5)</td>
<td></td>
</tr>
<tr>
<td>Combined</td>
<td>40 (67.8)</td>
<td>10 (47.6)</td>
<td></td>
</tr>
<tr>
<td>Sternum (isolated)</td>
<td>0</td>
<td>3 (14.3)</td>
<td></td>
</tr>
<tr>
<td><strong>HF</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure mode</td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Screw loosening</td>
<td>42 (71.2)</td>
<td>17 (80.9)</td>
<td></td>
</tr>
<tr>
<td>Screw migration</td>
<td>7 (11.8)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Plate fracture</td>
<td>13 (22.0)</td>
<td>8 (38.1)</td>
<td></td>
</tr>
<tr>
<td>Plate dislocation</td>
<td>12 (20.3)</td>
<td>5 (23.8)</td>
<td></td>
</tr>
<tr>
<td>Failed plating system</td>
<td></td>
<td></td>
<td>0.060</td>
</tr>
<tr>
<td>SternaLock</td>
<td>19 (32.2)</td>
<td>8 (38.1)</td>
<td></td>
</tr>
<tr>
<td>ARIX</td>
<td>33 (55.9)</td>
<td>12 (57.1)</td>
<td></td>
</tr>
<tr>
<td>APIS</td>
<td>8 (13.6)</td>
<td>2 (9.5)</td>
<td></td>
</tr>
<tr>
<td>MatrixRIB</td>
<td>0</td>
<td>1 (4.8)</td>
<td></td>
</tr>
<tr>
<td>Failure location</td>
<td></td>
<td></td>
<td>0.007</td>
</tr>
<tr>
<td>Anterior</td>
<td>18 (30.5)</td>
<td>10 (47.6)</td>
<td></td>
</tr>
<tr>
<td>Lateral</td>
<td>31 (52.5)</td>
<td>4 (19.0)</td>
<td></td>
</tr>
<tr>
<td>Posterior</td>
<td>11 (18.6)</td>
<td>7 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Sternum</td>
<td>2 (3.4)</td>
<td>5 (23.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Complication</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wound infection</td>
<td>6 (10.2)</td>
<td>14 (66.7)</td>
<td>-</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>34 (57.6)</td>
<td>7 (33.3)</td>
<td>-</td>
</tr>
<tr>
<td>Acute kidney injury</td>
<td>11 (18.6)</td>
<td>2 (9.5)</td>
<td>-</td>
</tr>
<tr>
<td>Tracheostomy</td>
<td>26 (44.1)</td>
<td>3 (14.3)</td>
<td>0.018</td>
</tr>
<tr>
<td>Hospital stay (day)</td>
<td>53.2±61.3</td>
<td>49.2±79.6</td>
<td>-</td>
</tr>
<tr>
<td>Patients’ follow-up</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to detection HF</td>
<td>62.8±96.8</td>
<td>143.9±189.0</td>
<td>-</td>
</tr>
<tr>
<td>Follow-up duration (day)</td>
<td>312.8±244.7</td>
<td>487.3±371.4</td>
<td>0.010</td>
</tr>
<tr>
<td>Subjective chest symptoms</td>
<td>27 (45.8)</td>
<td>14 (66.7)</td>
<td>-</td>
</tr>
<tr>
<td>FVC ≥80% predicted</td>
<td>19 (32.2)</td>
<td>15 (71.4)</td>
<td>-</td>
</tr>
</tbody>
</table>

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

SRF, surgical rib fixation; HF, hardware failure; FVC, functional vital capacity.

*a* SternaLock Blu Plate (Zimmer Biomet Inc), ARIX Sternal & Rib System (Jeil Medical Corp), APIS Rib Locking Plate System (TDM Corp), and MatrixRIB Plate (Depuy Synthes).
Subjective symptom after SRF

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>32 (54.2%)</td>
</tr>
<tr>
<td>Chronic pain</td>
<td>24 (41%)</td>
</tr>
<tr>
<td>Clicking</td>
<td>11 (52.4%)</td>
</tr>
<tr>
<td>Others</td>
<td>3 (5.1%)</td>
</tr>
</tbody>
</table>

Fig. 4. Subjective chest symptoms in patients with hardware failure. No statistically significant differences were noted between the groups. SRF, surgical rib fixation.

Plate removal surgery

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>32 (54.2%)</td>
<td>2 (9.5%)</td>
</tr>
<tr>
<td>Subjective symptom after SRF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>7 (30%)</td>
<td>0</td>
</tr>
<tr>
<td>Chronic pain</td>
<td>24 (41%)</td>
<td>0</td>
</tr>
<tr>
<td>Clicking</td>
<td>11 (52.4%)</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>3 (5.1%)</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 5. Receiver operating characteristics curve analysis for the prediction of plate removal surgery in patients with hardware failure. The area under the curve for follow-up duration was 0.65 (0.5≤95% confidence interval≤0.79), but not statistically significant. FVC, functional vital capacity; SRF, surgical rib fixation.

Among the patients who experienced HF, only 23% underwent screw migration (n = 17, 44.7%) and plate fracture (n = 18, 47.4%) in the posterolateral region. Forty percent of these patients were asymptomatic, and 55% required explantation of the hardware [15]. The authors concluded that HF after SSRF rarely occurs and is clinically insignificant. A systematic review published in 2020 also reported a low HF risk [14]. Through a review of 1952 SSRF patients, the study reported 173 surgery- and implant-related complications (10.3%). Implant irritation was the most common (n = 65, 6.9%) implant-related complication, and only one patient (0.1%) presented with a plate fracture. The most recent meta-analysis showed similar results, with 4% (range, 3%--7%) of HF cases reported, including mechanical failure, infection, pain or discomfort, and nonunion [28]. Broken plates were the most common cause of HF, and insufficient patient data precluded the characterization of the failure location and reasons for failure.

The incidence of HF in our study was slightly higher (10.3%) than that reported previously. This difference can be attributed to two factors. First, the detection rate may have increased due to regular follow-up after surgery. Previous multicenter study lacked follow-up imaging protocols, which may have led to underreporting [15]. However, in our center, we followed a specific imaging protocol, including an x-ray check-up 2 weeks after postdischarge and three-dimensional CT imaging at 3, 6, and 12 months after surgery, which could have contributed to the higher detection rate. Second, the surgeon might have played a role, as the four surgeons involved may have differed in ability, experience, and technical selection, such as the number of screws and plate length, based on the fracture pattern. Although the plate locking screw system theoretically leads to more plate fractures or dislocations, the higher screw failure rate in our study could be attributed to technical errors. To minimize technical errors, it is essential to be meticulous during surgery, focusing on details such as bicortical screwing, proper plate fitting on the rib surface, adequate plate length, and reduction in bone defects.

Compared to other orthopedic surgeries, SSRF poses unique technical challenges because immobilization after surgery is not possible. The posterolateral region is known to experience the most stress during respiration, and plate fatigue in this area can result in the fracture or dislocation of the plate [15,29]. We found that plate fracture or dislocation occurred more frequently in the posterolateral region of the chest. However, to better understand the correlation between the location and mode of metal failure, further research on the biomechanics of metal respiration is necessary. In terms of plating systems, we used four distinct locking screw plate systems that varied in terms of metal thickness, shape, and minor deviations. Despite these variations, no correlation between the plating system and the failure modes was observed in this study. Although ARIX occurred more frequently in HF cases, it was deemed insignificant because it was the most commonly used metal.

Among the patients who experienced HF, only 23% under-
went metal removal surgery. Of these patients, only two underwent removal due to infection, while the rest underwent surgery due to irritation symptoms, such as pain, tightness, or sensitivity to touch, or during surgery to remove metal from other areas, particularly in cases of orthopedic surgery. Metal removal surgery was more common in younger patients, those with fewer rib plates, and in the anterior region, particularly the costal cartilage, than in the nonsurgical group. Elderly patients with multiple areas requiring metal removal surgery may be hesitant to undergo this procedure because of the potential increased surgical risks and associated complications. Given the relatively infrequent occurrence of HF and the low likelihood of subsequent reoperations, the clinical implications of HF are not particularly substantial. However, this is a technical shortcoming; it is essential to follow proper surgical techniques and carefully monitor patients after surgery to minimize the risk of mechanical complications.

Limitations
This study had several limitations. First, as this was a single-center study, it cannot be considered representative of other trauma centers in Korea. Second, the sample size was insufficient to yield statistically significant results. Although we observed a high frequency of screw failure in the anterior region, no significant correlation was found between the associated variables. Therefore, it is imperative to conduct further multicenter studies with a larger patient cohort to elucidate the underlying characteristics of HF in patients undergoing SSRF. Third, this study had several confounding factors. Differences in technical skills, such as the type of plates selected, the length of the plates used, and the number of screws used, may vary among surgeons. Because HF is a technical error, these factors may have influenced the results. Moreover, the frequency of the surgical sites or plating systems cannot be applied uniformly, leading to a selection bias that affects the results. Given the constrained sample size of the four plating systems, it was impractical to establish any discernible variance in HF outcomes attributed to the particular plating system employed. To conduct an investigation in this regard, it would be necessary to perform an analysis incorporating each plating system with a substantial sample size, carried out by a single surgeon.

Conclusions
HF occurred in 10.9% of cases following SSRF, with no observed correlation between the mode, location, or type of plate used. Patients with coastal fractures require special attention. Although not all patients require plate removal surgery, HF is a technical shortcoming requiring increased surgical vigilance. Furthermore, a deeper understanding of respiratory dynamics through additional research is needed to better understand the etiology of HF.

ARTICLE INFORMATION

Author contributions
Conceptualization: Seon Hee K, YK, HMC; Data curation: DYR, CIP, YK; Formal analysis: DYR, SBL, HK, GHK; Funding acquisition: Seon Hee K; Investigation: Sun Hyun K, NHL; Methodology: SBL, CIP, HK; Project administration: Seon Hee K; Writing—original draft: Sun Hyun K, NHL; Writing—review & editing: all authors. All authors read and approved the final manuscript.

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

Funding
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Data availability
Data of this study are available from the corresponding author upon reasonable request.

Additional information
This study was presented at the 9th Pan-Pacific Trauma Congress (PPTC) in July 2022 in Gyeongju, Korea.

REFERENCES


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Indications and findings of flexible bronchoscopy in trauma field in Korea: a case series

Dongsub Noh, MD

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2Department of Thoracic and Cardiovascular Surgery, Daejeon Eulji Medical Center, Eulji University School of Medicine, Daejeon, Korea

**Purpose:** Since its implementation, flexible fiberoptic bronchoscopy (FBS) has played an important role in the diagnosis and treatment of tracheobronchial tree and pulmonary disease. Although FBS is often performed by endoscopists, it has also been performed by surgeons, albeit rarely. This study investigated FBS from the surgeon's perspective.

**Methods:** This retrospective study included patients who underwent FBS performed by a single thoracic surgeon between March 2017 and December 2021. Accordingly, the epidemiology, purpose, results, and complications of FBS were analyzed.

**Results:** A total of 47 patients received FBS, whereas 13 patients underwent repeat FBS. Their mean age was 60.7 years. The main organs injured involved the chest (n=22), brain (n=9), abdominal organ (n=7), cervical spine (n=4), extremities (n=4), and face (n=1). The average Injury Severity Score was 22.5. Indications for FBS included atelectasis or haziness on chest x-ray (n=34), pneumonia (n=17), difficult ventilator management (n=7), percutaneous dilatory tracheostomy (n=3), blood aspiration (n=2), foreign body removal (n=2), and intubation due to a difficult airway (n=1). The findings of FBS were mucous plugs (n=36), blood and blood clots (n=16), percutaneous dilatory tracheostomy (n=3), foreign bodies (n=2), granulation tissue at the tracheostomy site (n=2), tracheostomy tube malposition (n=1), bronchus spasm (n=1), difficult airway intubation (n=1), and negative findings (n=5). None of the patients developed complications.

**Conclusions:** FBS is an important modality in the trauma field that allows for the possibility of diagnosis and therapy. With sufficient practice, surgeons may safely perform FBS at the bedside with relative ease.

**Keywords:** Bronchoscopy; Intratracheal intubation; Mechanical ventilators; Pulmonary atelectasis; Tracheostomy

**INTRODUCTION**

**Background**
Blunt trunk trauma has occasionally been associated with lung parenchymal and bronchial injuries. Intrabronchial bleeding or aspiration, as evidenced by blood-tinged sputum, can lead to bronchial occlusion and atelectasis [1]. In cases requiring long-term mechanical ventilator care or having severe neurologic inju-
ry involving the brain, pulmonary complications, such as pneumonia and atelectasis, could occur because of the inability to perform voluntary sputum expectoration. These pulmonary complications often lead to devastating results. As such, the early detection of lung parenchymal or bronchial injury is beneficial to patients as they allow for prompt treatment. Moreover, resolving atelectasis or detecting pneumonia-causing bacteria at an early stage is helpful for patients receiving long-term ventilation therapy.

Since its implementation by Ikeda et al. [2], flexible fiberoptic bronchoscopy (FBS) has played an important role in the diagnosis and treatment of tracheobronchial tree and pulmonary diseases, given that it is relatively easy to learn and use, can be used with topical anesthesia and minimal sedation, and rarely causes serious complications. Although FBS is often performed by an endoscopist, surgeons have also performed it, albeit rarely.

**Objectives**

This study investigated FBS from the surgeon’s perspective in the trauma field, in an attempt to identify the usefulness and complications of FBS in trauma patients.

**METHODS**

**Ethics statement**

This study was approved by the Ethics Committee of Dankook University Hospital (No. 2022-06-046-002). The requirement for informed consent was waived due the retrospective nature of the study.

**Study design and participants**

This is a case series by one surgeon in two institutes. From March 2017 to December 2021, patients who underwent FBS (BF-P260F Bronchoscope, Olympus Medical Systems Corp) by a single thoracic surgeon at Dankook University Hospital (Cheonan, Korea) and Daejeon Eulji Medical Center (Daejeon, Korea) for multiple trauma were enrolled in this retrospective study, and the epidemiology, purpose, results, and complications of FBS were analyzed. All medical records were reviewed.

**Study setting and procedures**

Indications for FBS included abnormal findings on chest x-rays or chest computed tomography, unexplained hypoxemia, and procedures for the trachea or bronchi. During FBS, oxygen saturation, electrocardiogram readings, and blood pressure were monitored. FBS was performed under a fraction of inspired oxygen of 100% and volume control (60 mL/kg), with a positive end-expiratory pressure of 10 mmHg in patients undergoing mechanical ventilation. Midazolam was administered intravenously for general anesthesia with spontaneous breathing or complete loss of consciousness. Intravenous atropine (0.01–0.02 mg/kg) was administered for bradycardia induced by vagal stimulation. Topical anesthesia was achieved by using lidocaine spray. Muscle relaxants were occasionally administered in patients undergoing mechanical ventilation.

**Statistical analysis**

Descriptive statistics are expressed as the mean ± standard deviation unless otherwise specified.

**RESULTS**

A total of 47 patients received FBS, whereas 13 patients underwent repeat FBS. The total number of FBS procedures was 68, and the number of repeat FBS was 33. The patients had a mean age of 60.7 years. The main organs injured were the chest (n = 22), brain (n = 9), abdominal organ (n = 7), cervical spine (n = 4), extremities (n = 4), and face (n = 1). The average Injury Severity Score was 22.5 (Table 1). All patients except one received endotracheal intubation and mechanical ventilator care.

The purpose of FBS was atelectasis or haziness on chest x-ray (n = 34), pneumonia (n = 17), difficult ventilator management (n = 7), percutaneous dilatory tracheostomy (n = 3), blood aspiration (n = 2), foreign body removal (n = 2), and intubation due to a difficult airway (n = 1) (Table 2). The patient who received intubation due to a difficult airway was the same patient who did not receive mechanical ventilator care. The findings of FBS were mucous plugs (n = 36), blood and blood clots (n = 16), percutaneous

| Table 1. Patient characteristics (n=47) |
|-------------------------------|-----------------|
| Characteristic               | Value           |
| Age (yr)                     | 60.7±17.4       |
| Sex                          |                 |
| Male                         | 38              |
| Female                       | 9               |
| Injured organ                |                 |
| Chest                        | 22              |
| Brain                        | 9               |
| Abdomen                      | 7               |
| Spine                        | 4               |
| Extremity                    | 4               |
| Face                         | 1               |
| Injury Severity Score        | 22.5±9.6        |

Values are presented as mean±standard deviation or number only.
dilatory tracheostomy (n = 3), foreign bodies (n = 2), granulation tissue at the tracheostomy site (n = 2), tracheostomy tube malposition (n = 1), bronchus spasm (n = 1), difficult airway intubation (n = 1), and negative findings (n = 5) (Table 3). The reasons for repeated FBS were pneumonia (n = 12), atelectasis (n = 4), and percutaneous dilatary tracheostomy (n = 1). None of the patients developed complications.

DISCUSSION

This study found that airway maintenance was an important purpose of FBS in the trauma field. In this study, FBS was performed mainly because a majority of the patients received ventilator care. The findings of FBS can be categorized into clearance and securing the airway. With regard to clearance, materials removed during FBS included mucous plugs, blood, and foreign bodies. With regard to securing the airway, percutaneous tracheostomy and difficult airway intubation were observed.

Blunt trunk trauma has been associated with lung parenchymal and bronchial injuries. In such cases, blood-tinged sputum was present, and intrabronchial bleeding and aspiration promoted bronchial occlusion and atelectasis [1]. The ultimate goal of FBS was the restoration of airway patency by removing phlegm or blood in the airway [3]. In study, the main reasons for FBS included atelectasis or haziness on chest x-ray and pneumonia. The primary findings of FBS were mucous plugs and blood aspiration. Furthermore, the reasons for repeated FBS were pneumonia and atelectasis. The main bronchoscopy findings in acute trauma to the chest and upper airway were distal hemorrhage/pulmonary contusion and mucous plugs/ thick secretions [4]. Most mucous plugging can be removed through FBS [3]. By removing blood, mucous plugs, and aspirated fluid, the medium for bacterial growth could be reduced [1]. Bronchoscopy after blunt thoracic trauma could help establish an early diagnosis of lung contusion and provide information on the respiratory prognosis of these patients [1].

FBS has a channel for irrigation and endoscopic forceps, which allows for the removal of foreign bodies in the airway. In this study, two cases required foreign body removal. One case involved the aspiration of a bone fragment from a fractured mandible after the patient fell on the face, whereas the other case involved the aspiration of dust and soil after being buried in the mud following a traffic accident. The best option for removing foreign bodies in the trachea and bronchus is rigid bronchoscopy [5]. In these two cases, the patients received mechanical ventilator care for acute respiratory failure. Given that rigid bronchoscopy was dangerous for these patients, foreign body removal was done through FBS, which was indeed completely successful.

Percutaneous tracheostomy using the dilation technique under FBS assistance would be effective and safe in preventing serious complications or deaths in critical care patients under mechanical ventilation [6]. In our study, three percutaneous tracheostomies were performed. Two surgeons were required for percutaneous tracheostomy under FBS. One thoracic surgeon performed tracheostomy using the dilator (Cook Blue Rhino single dilator kit, Cook Medical), whereas another thoracic surgeon observed the trachea through FBS. The safe placement of the needle and guidewire was achieved through FBS. None of the patients developed early complications, such as bleeding, transient hypoxia, or tracheostomy cannula displacement. Long-term monitoring was required to assess late complications, such as bronchomalacia, tracheoesophageal fistulas, or tracheoinnominate fistulas. Although studies have found no advantage of percutaneous tracheostomy under FBS [7], evidence has shown that it lowers the possibility of iatrogenic damage to surrounding tissues [8].

In our study, one patient had difficult airway intubation with FBS due to limitations in mouth opening related to facial bone fractures. FBS provides direct visualization of the airway structures. Indications for flexible bronchoscopic intubation include limited mouth opening; short thyromental distance; macrogos-
sia; obesity; airway compromised by infection, tumor, or edema; inability to extend the neck or cervical instability; fragile or protruding teeth; and patients with Mallampati class III to IV [9].

FBS is a safe procedure, with a mortality rate under 0.04% and a major complication rate between 0.08% and 0.3% [10]. Major complications include death, cardiopulmonary arrest, myocardial infarction, pneumonia, large-sized pneumothorax, severe airways obstruction, severe pulmonary hemorrhage, seizures, and stroke [10]. In our study, none of the patients developed such complications or died.

FBS offers some advantages over rigid bronchoscopy. Its flexibility allows for better examination of the distal airways and upper lobe segment and can be introduced through an endotracheal tube or tracheostomy, allowing for the evaluation of tube placement and bronchoscopic intubation [11]. FBS has been most useful in the evaluation of patients with atelectasis or a suspected foreign body for which there was insufficient evidence to warrant open-tube bronchoscopy and for those with tracheostomies [12]. FBS plays an essential role in the diagnosis and treatment of patients under ventilator care [13,14].

**Limitations**

This study had several limitations. First, this study included a heterogeneous group of patients. Second, the number of patients was only 47. Therefore, further studies with a larger population seem necessary. However, our data highlight the effectiveness of FBS performed by trauma surgeons in the trauma field.

**Conclusions**

FBS is an important procedure in the trauma field that allows for the possibility of diagnosis and therapy. With sufficient practice, FBS can be performed with relative ease and safety by surgeons at the bedside.

**ARTICLE INFORMATION**

**Conflicts of interest**

The author has no conflicts of interest to declare.

**Funding**

The author did not receive any financial support for this study.

**Data availability**

Data of this study are available from the author upon reasonable request.

**REFERENCES**

Relationship between sonorheometry parameters and laboratory values in a critical care setting in Italy: a retrospective cohort study

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¹Department of Anesthesia and Intensive Care Unit, Azienda Ospedaliero Universitaria San Giovanni di Dio Ruggi d’Aragona, Salerno, Italy
²Department of Anesthesia and Intensive Care, University of Naples Federico II, Naples, Italy

Purpose: This preliminary retrospective cohort study analyzed the relationship between the parameters provided by sonorheometry device Quantra and the coagulation values obtained from standard venous blood samples in patients admitted in intensive care unit (ICU).

Methods: We reviewed medical charts of 13 ICU adult patients in whom at least one coagulation study with Quantra was performed. The relationship between Quantra and laboratory data was analyzed with the Spearman rank correlation coefficient (rho). The 95% confidence interval (CI) was computed. A P-value <0.05 was considered statistically significant.

Results: We collected 28 data pairs. Statistically significant moderate correlations were found for the following parameters: clot time (CT) and activated partial thromboplastin time (rho=0.516; 95% CI, 0.123–0.904; P=0.009; clot stiffness (CS) and the international normalized ratio (INR; rho=0.418; 95% CI, 0.042–0.787; P=0.039); INR and platelet contribution to CS (rho=0.459; 95% CI, 0.077–0.836; P=0.022); platelet count and platelet contribution to CS (PCS; rho=0.498; 95% CI, 0.166–0.825; P=0.008); and fibrinogen and fibrinogen contribution to CS (FCS; rho=0.620; 95% CI, 0.081–0.881; P=0.001).

Conclusions: Quantra can provide useful information regarding coagulation status, showing modest correlations with the parameters obtained from laboratory tests. During diffuse bleeding, CT and FCS values can guide the proper administration of clotting factors and fibrinogens. However, the correlation of INR with CS and PCS can cause misinterpretation. Further studies are needed to clarify the relationship between Quantra parameters and laboratory tests in the critical care setting and the role of sonorheometry in guiding targeted therapies and improving outcomes.

Keywords: Blood coagulation; Point-of-care testing; Nonparametric statistics

INTRODUCTION

Background

Coagulation disorders are common in the intensive care unit (ICU) and are related to adverse clinical outcomes [1–3]. In the ICU, coagulation parameters are typically monitored using venous blood samples and the proper therapeutic strategy is adjusted according to the results. However, obtaining blood venous...
samples is a time-consuming procedure, and the results require several minutes before clinical availability.

The use of whole blood viscoelastic testing (VET) surmounts these limitations, allowing quick corrections with the adoption of the proper therapeutic strategy, especially in urgent cases or emergencies [4]. TEG (Haemonetics Corp) and ROTEM (Tem Instrumental GmbH) are the most common VET devices, consisting of a pin suspended in a cup of blood, one of which oscillates. When coagulation begins, the clot connects the pin and the cup, and the pin’s movement becomes coupled with that of the cup (or vice versa if it is the pin rotating). The displacement can be displayed graphically [5], and its magnitude is referred to as the "clot amplitude" or "clot firmness," representing the strength of the clot connecting the pin and cup. However, in these VET devices, the applied mechanical stress is strong enough to alter the clot formation [6], invalidating the exact variable value the devices are trying to measure.

Quantra (HemoSonics), a VET device based on sonic estimation of elasticity via resonance (SEER) or sonorheometry technology [7], uses high-frequency ultrasound pulses to quantify the shear modulus—a parameter that describes the elastic properties of solid material—of a blood sample during the process of coagulation, without interference with clot formation [8,9]. SEER has been studied in different surgical settings, such as cardiac and major surgery [10–16], with encouraging results and good correlations with common VET devices and laboratory tests. However, patients requiring ICU admission represent a heterogeneous population completely different from those requiring scheduled surgical interventions. Clinical data about the role of SEER technology in ICU patients, such as the correlation between SEER parameters and common coagulation laboratory values, still need to be thoroughly explored.

Objectives
This preliminary retrospective cohort study aimed to analyze the relationship between the SEER parameters provided by the Quantra device and the coagulation values obtained from standard venous blood samples in patients requiring ICU admission.

METHODS

Ethics statement
Due to the study's retrospective nature, we did not require approval from the local ethic committee. The requirement of informed consent was also waived due to the retrospective nature of the study. The study was conducted following the International Conference on Harmonization Good Clinical Practice Guideline and the provisions of the 2008 Declaration of Helsinki.

Patient enrollment
For this preliminary retrospective analysis, we reviewed medical charts of 13 adult patients admitted in our ICU (Azienda Ospedaliero Universitaria San Giovanni di Dio Ruggi d’Aragona, Salerno, Italy) in whom at least one VET coagulation study with Quantra was performed. Therapeutic interventions aimed to treat coagulation disorders were adopted only according to laboratory results.

Patients’ data were anonymously collected on an electronic sheet (Microsoft Excel, Microsoft Corp.). For every patient, we collected age, sex, body mass index, and the clinical reason for ICU admission. To stratify patients’ clinical conditions on admission, we calculated the Charlson Comorbidity Index, the Simplified Acute Physiology Score (SAPS) II [17], and the Glasgow Coma Scale (GCS) [18].

Blood samples
Whole blood samples were drawn from central or peripheral venous catheters. The catheters from which blood samples were drawn were not coated with anticoagulant, nor was heparin used in the flush system. To avoid contamination with the flush system, all venous samples were obtained after the withdrawal of 10 mL of blood, corresponding to roughly three times the dead space volume of the catheter.

The following parameters were noted: platelet count (PLT), international normalized ratio (INR), prothrombin activity (PT; expressed as a percentage), activated partial thromboplastin time (aPTT; expressed in seconds), and fibrinogen. Within 30 minutes after the routine venous blood samples were taken, another venous blood sample was performed and tested with the Quantra in combination with the QStat Cartridge (HemoSonics). The QStat Cartridge was designed to evaluate hemostatic function in trauma, liver transplantation, and other critical care settings, providing the following parameters [9]: (1) clot time (CT; normal range, 113 to 164 seconds) in citrated whole blood, measured with activation of the intrinsic pathway activated by kaolin; (2) clot stiffness (CS; normal range, 13.0 to 33.2 hPa) of the whole blood, measured with activation of the extrinsic pathway by thromboplastin and heparin inhibition by polybrene and expressed as hectopascals; fibrinogen contribution to CS (FCS; normal range, 1.0 to 3.7 hPa), measured with activation of the extrinsic pathway by thromboplastin, heparin inhibition by poly-
brene, and platelet inhibition by abciximab, representing the contribution of functional fibrinogen to overall CS; (3) platelet contribution to CS (PCS; normal range, 11.9 to 29.8 hPa), calculated as the difference between CS and FCS, representing the contribution of platelet activity to overall clot stiffness; and (4) clot stability to lysis within 15 minutes (normal range, 93% to 100%), calculated by normalizing the rate of stiffness reduction observed with thromboplastin activation to the corresponding change CS observed with thromboplastin activation and tranexamic acid, representing the reduction in clot stiffness related to fibrinolysis.

Statistical analysis
Statistical analysis was performed with RStudio Posit team 2022 (RStudio). Categorical variables were reported as absolute values and percentages, while continuous data were reported as median (first and third quartile) and minimum and maximum values. In case of missing data, statistics were computed with available values. The relationship between Quantra and laboratory results was analyzed with the Spearman rank correlation coefficient (rho), and the 95% confidence interval (CI) was computed.

In detail, we explored the following relationships: (1) coagulation intrinsic pathway (the relationship between CT and aPTT); (2) coagulation extrinsic pathway (the relationship of CS with INR and PT); (3) platelet (the relationship between PCS and PLT); (4) fibrinogen (the relationship between FCS and fibrinogen). The magnitude of the observed rho values was interpreted as follows: negligible (0 ≤ rho < 0.10), weak (0.10 ≤ rho ≤ 0.39), moderate (0.39 < rho ≤ 0.69), strong (0.69 < rho ≤ 0.89), and very strong (0.89 < rho ≤ 1.00) [19]. A P-value < 0.05 was considered statistically significant. Further analysis was performed according to the results. The results are reported in tables and scatterplots.

RESULTS
From the 13 ICU patients, we collected 28 laboratory and Quantra samples. Patients’ main characteristics, together with laboratory and Quantra results, are presented in Table 1. Regarding the reason for ICU admission, seven patients (53.8%) were admitted due to trauma, three (23.1%) required postsurgical monitoring, and three (23.1%) had experienced stroke.

Table 1. Main characteristics of the population (n=13)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
<th>Rangea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex</td>
<td>8 (61.5)</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>59.0 (36.0–69.0)</td>
<td>21.0–88.0</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>26.1 (24.2–29.4)</td>
<td>22.5–44.1</td>
</tr>
<tr>
<td>Charlson Comorbidity Index</td>
<td>3.0 (0–3.0)</td>
<td>0–5.0</td>
</tr>
<tr>
<td>Simplified Acute Physiology Score II</td>
<td>59.0 (49.0–75.0)</td>
<td>34.0–78.0</td>
</tr>
<tr>
<td>Glasgow Coma Scale</td>
<td>9.0 (6.0–13.0)</td>
<td>5.0–14.0</td>
</tr>
<tr>
<td>Reason for ICU admission</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trauma</td>
<td>7 (53.8)</td>
<td></td>
</tr>
<tr>
<td>Postsurgical monitoring</td>
<td>3 (23.1)</td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td>3 (23.1)</td>
<td></td>
</tr>
<tr>
<td>Coagulation parameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelets (10³)</td>
<td>145.5 (108.5–189.5)</td>
<td>58.0–490.0</td>
</tr>
<tr>
<td>International normalized ratiob</td>
<td>1.36 (1.24–1.46)</td>
<td>1.09–2.52</td>
</tr>
<tr>
<td>Prothrombin activity (%)b</td>
<td>67.0 (61.0–75.0)</td>
<td>33.0–90.0</td>
</tr>
<tr>
<td>Activated partial thromboplastin time (sec)b</td>
<td>26.5 (23.2–28.9)</td>
<td>18.1–58.5</td>
</tr>
<tr>
<td>Fibrinogen (mg/dL)b</td>
<td>303.0 (211.0–448.0)</td>
<td>59.0–703.0</td>
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<tr>
<td>Quantra parameter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clot time (sec)</td>
<td>131.5 (116.8–154.2)</td>
<td>93.0–177.0</td>
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<tr>
<td>Clot stiffness (hPa)</td>
<td>17.9 (13.7–23.9)</td>
<td>5.5–49.0</td>
</tr>
<tr>
<td>Fibrinogen contribution to clot stiffness (hPa)</td>
<td>2.7 (1.5–3.7)</td>
<td>0.7–10.8</td>
</tr>
<tr>
<td>Platelet contribution to clot stiffness (hPa)</td>
<td>14.9 (10.8–20.5)</td>
<td>4.8–38.2</td>
</tr>
<tr>
<td>Clot stability to lysis</td>
<td>0.99 (0.99–1.00)</td>
<td>0.96–1.00</td>
</tr>
</tbody>
</table>

Values are presented as number (%) or median (first and third quartile).

ICU, intensive care unit.

aMinimum to maximum values. bThree missing data
Coagulation intrinsic pathway
The intrinsic coagulation pathway was explored by examining the relationship between CT and aPTT (25 data pairs). The magnitude of the relationship was moderate, and the correlation was statistically significant, with a rho coefficient equal to 0.516 (95% CI, 0.123 to 0.904; P = 0.009) (Fig. 1).

Coagulation extrinsic pathway
The extrinsic coagulation pathway was explored by examining the relationship between CT and aPTT (25 data pairs). The magnitude of the relationship was moderate, and the correlation was statistically significant, with a rho coefficient equal to 0.516 (95% CI, 0.123 to 0.904; P = 0.009) (Fig. 1).

Because CS is used to compute PCS, we also explored the relationship of INR with PCS and FCS. The relationship between INR and PCS (25 data pairs) was not statistically significant (rho = 0.288; 95% CI, -0.154 to 0.724; P = 0.163).

Platelets
The relationship between platelet count and PCS (28 data pairs) was statistically significant (P = 0.008) with moderate magnitude (rho = 0.498; 95% CI, 0.166 to 0.825) (Fig. 3).

Fibrinogen
Fibrinogen showed a statistically significant, moderate relation-
ship with FCS (25 data pairs), with a rho coefficient of 0.620 (95% CI, 0.081 to 0.881; P = 0.001) (Fig. 4).

DISCUSSION

Quantra is based on SEER technology and has been designed and optimized for ease of use, automation, and rapid turnaround time to enable utilization at the point of care. Furthermore, SEER technology does not require moving mechanical components to be in direct contact with the whole blood sample being measured, thus overcoming the limitations of TEG and ROTEM technology [6]. Quantra has been studied in various surgical settings, with encouraging results and good correlations with standard VET devices and common laboratory test results [10–16].

However, patients requiring ICU admission, especially trauma patients, represent a different population than those requiring scheduled surgery. First, patients undergoing surgery discontinue drugs that alter platelet aggregation and coagulation before surgery. Second, during surgery, bleeding events are predictable, preventable, and can be promptly treated. Third, during surgery, parameters that can modify the coagulation cascade, such as body temperature, calcium levels, and the volume of liquids infused, are well monitored and correctable. On the contrary, patients requiring ICU admission may present numerous coagulation alterations due to the intake of anticoagulant and antiplatelet drugs, hypocalcemia, uncontrolled administration of fluids to reach adequate hemodynamic parameters, and hypothermia [2]. All these factors could invalidate the results obtained by Quantra in surgical settings.

In our preliminary study, performed in patients requiring ICU admission, we found that Quantra parameters moderately correlated with traditional laboratory tests, providing data about coagulation intrinsic and extrinsic pathways, platelet count, and fibrinogen concentration.

Even if data exploring the relationship between Quantra and common laboratory values in patients requiring critical care are still scarce, our results are in line with those obtained in surgical settings. We found that aPTT showed a statistically significant moderate correlation with CT, suggesting to clinicians when clotting factors should be administered during bleeding [9].

However, the findings in the literature about the relationship between aPTT and CT are discordant. A prospective cohort study in cardiac surgery (30 patients) performed by Baryshnikova et al. [10] found that the correlation between the CT provided by Quantra and the aPTT values was negligible, while Huffmyer et al. [16], in a prospective observational study performed on 55
patients undergoing elective cardiac surgery, found a better correlation. In noncardiac surgical settings, Idowu et al. [12], in a prospective nonrandomized observational study performed on 74 adults undergoing oncologic surgery with an anticipated blood loss of more than 500 mL, found that the correlation coefficients between conventional laboratory tests and Quantra ranged from 0.74 to 0.83, indicating moderate correlations (P < 0.001).

We found that Quantra was able to explore the extrinsic coagulation pathway, with a statistically significant relationship between CS and INR. Our study found that INR values can modify the CS parameter, generating misinterpretation. According to this finding, we also observed that INR showed a moderate correlation with PCS but not with FCS. To the best of our knowledge, no previous studies have explored these relationships.

Generally, an increase in INR is typical of hypocoagulable states with multiple coagulation factor deficiencies. Although our results should be interpreted cautiously, an increase in the INR value can be associated with an increase in the CS value, altering the PCS value. PCS represents the contribution of platelet activity to overall clot stiffness and is an indirect parameter calculated as the difference between CS and FCS. This phenomenon partly explains the moderate correlation between platelet count and PCS found in our and other studies [10,16]. Huffmyer et al. [16] concluded that a possible explanation for the moderate correlation with platelet count is that the PCS value considers not only the platelet number, but also the ability of platelets to contract and interact with the polymerized fibrin. In contrast, the laboratory platelet count considers only a single dimension, with no functional information. Although it was reported that the PCS parameter was independently associated with platelet count and adenosine diphosphate–dependent platelet function, as measured by multiple electrode aggregometry [10], this issue deserves to be analyzed in further studies that consider the value of the INR and its ability to alter the CS. Patients with high INR and low fibrinogen values can present normal or high PCS values even with a low platelet count, causing misinterpretation of the results and delaying the administration of the platelet pool in emergency conditions.

In our study, fibrinogen showed a statistically significant moderate relationship magnitude with FCS, suggesting a role to guide the prompt fibrinogen administration when required. The data in the literature are discordant regarding the role of Quantra in guiding the administration of blood products to correct acquired coagulopathies. Zghaibe et al. [14], in a prospective cohort study performed on 52 patients undergoing urgent cardiac surgery, found a high negative predictive value for Quantra parameters, suggesting that Quantra may be useful for demonstrating when coagulation is normal, and bleeding is probably related to surgical causes. Meanwhile, the low positive predictive value may not accurately indicate when blood component therapy is required and what components should be administered. Contrarily, Naik et al. [11], in a multicenter, prospective observational study (163 subjects undergoing cardiac bypass surgery, 79 subjects undergoing major orthopedic surgery, and five patients presenting with acute bleeding) showed that the FCS and PCS parameters reported by Quantra could reliably predict most critical levels of hypofibrinogenemia and thrombocytopenia.

We want to emphasize that the present preliminary study analyzed for the first time the relationship between laboratory data and those obtained by Quantra in patients requiring ICU admission. Furthermore, we provide findings regarding possible interference with Quantra parameters (especially CS and PCS) by INR values, which has not been previously reported in the literature.

Limitations
This study had some limitations. First, we could not perform further statistical elaborations due to its retrospective nature and the small sample size. Second, our study was heterogeneous regarding the reasons for ICU admission (only seven patients for trauma). Third, multiple samples were obtained from the same patients during their ICU stay, and we did not perform a trend analysis. Fourth, due to the small sample size, we did not explore the performance of Quantra for low coagulation parameter values. Fifth, the lack of data in the literature about the role of Quantra values in patients requiring ICU admission limits our discussion to the results obtained in surgical settings.

Conclusions
Quantra, a device based on SEER technology, can provide useful information regarding patients’ coagulation status with a modest correlation with the parameters obtained from laboratory tests. In detail, during diffuse bleeding, CT and FCS values can guide the proper administration of clotting factors and fibrinogens. However, it is still unclear if therapy guided by SEER technology can prompt correct coagulation factors in acute and critical illnesses, influencing clinical outcomes. Moreover, the correlation of INR with CS and PCS can cause misinterpretation of the results. Further studies are needed to clarify the relationship between Quantra parameters and laboratory tests in the critical care setting and the role of SEER technology in guiding targeted therapies and improving outcomes.
ARTICLE INFORMATION

Author contributions
Conceptualization: AR, RG, AC; Data curation: AR, AC, AS; Formal analysis: AR, RG, SP; Methodology: AR, AC, SP; Project administration: RG; Visualization: AC, SP, AS; Writing–original draft: AR, AC, SP, AS; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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

Funding
The authors did not receive any financial support for this study.

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

REFERENCES

Distally based lateral supramalleolar flap: for reconstructing distal foot defects in India: a prospective cohort study

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Department of Plastic Surgery, Osmania General Hospital, Osmania Medical College, Hyderabad, India

**Purpose:** Defects involving the ankle and foot are often the result of road traffic accidents. Many such defects are composite and require a flap for coverage, which is a significant challenge for reconstructive surgeons. Various locoregional options, such as reverse sural artery, reverse peroneal artery, peroneus brevis muscle, perforator-based, and fasciocutaneous flaps, have been used, but each flap type has limitations. In this study, we used the distally based lateral supramalleolar flap to reconstruct distal dorsal defects of the foot. The aim of this study was to analyze the efficacy of the flap in reconstructing distal dorsal defects of the foot. The specific objectives were to study the adequacy, reach, and utility of the lateral supramalleolar flap for distal defects of the dorsum of the foot; to observe various complications encountered with the flap; and to study the functional outcomes of reconstruction.

**Methods:** The distal dorsal foot defects of 10 patients were reconstructed with distal lateral supramalleolar flaps over a period of 6 months at a tertiary care center, and the results were analyzed.

**Results:** We were able to effectively cover distal foot defects in all 10 cases. Flap congestion was observed in two cases, and minor graft loss was seen in two cases.

**Conclusions:** The distally based lateral supramalleolar flap is a good pedicled locoregional flap for the coverage of distal dorsal foot and ankle defects of moderate size, with relatively few complications and little morbidity. It can be used as a lifeboat or even substitute for a free flap.

**Keywords:** Foot defects; Ankle defects; Lateral supramalleolar flap; Pedicled flap; Reconstruction

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step in deciding our treatment modality. Various options are available for the coverage of foot defects, such as grafts, local flaps, pedicled flaps, perforator-based flaps, and free flaps. Using a skin graft to cover mobile sites is not ideal because more damage may occur and function may be impaired. Therefore, the use of fasciocutaneous flaps for covering these defects encourages vascularity at the site, provides a stable cover to the exposed vital structures, and offers a good gliding surface for tendons. Locoregional flap options available for foot defects are the reverse sural artery (RSA) flap, reverse peroneal artery (RPA) flap, peroneus brevis muscle flap, perforator-based fasciocutaneous flaps, and lateral supramalleolar flap. Each flap has its own merits and demerits. In this study, we investigated the specific advantages of the distally based lateral supramalleolar flap over other pedicled options. A classical lateral supramalleolar flap can be used for reconstruction of defects in the distal third of the leg, the ankle, and the proximal foot, whereas a distally based lateral supramalleolar flap can cover moderately sized distal defects of the dorsum of the foot.

Objectives
The purpose of our study was to test the efficiency of the distally based lateral supramalleolar flap for reconstruction of defects of the distal dorsal foot and ankle. The specific objectives of our study were to study the adequacy, reach, and usefulness of a lateral supramalleolar flap for distal defects of the dorsum of the foot; to observe various complications encountered with the flap; and to study the functional outcomes of reconstruction.

METHODS

Ethics statement
We conducted this study in compliance with the principles of the Declaration of Helsinki. The study’s protocol was reviewed and approved by the Institutional Review Board of Osmania Medical College (No. ECR/300/Inst/AP/2013/RR-20). Written informed consent was obtained from the patients.

Study design
This prospective cohort study followed patients with distal defects of the dorsum of the foot for 6 months, after direct admission to a tertiary care center in Telangana or referral from an orthopedics department. Participants’ defects were reconstructed using a lateral supramalleolar flap. Patients with an injury to the intended flap area (lateral perimalleolar area), the anterior tibial artery, or in areas of communication between the anterior tibial and anterior lateral malleolar arteries were excluded from the study.

After an initial workup and hemodynamic stabilization, patients were taken for skeletal stabilization by orthopedic surgeons. Debridement of the wound and defect analysis were performed, and the defect was reconstructed with a distal lateral supramalleolar flap. The postoperative position was maintained with splint support or external fixation. The flap was clinically monitored postoperatively, and complications were analyzed.

Demographic parameters were recorded, including age, sex, etiology, time of presentation, defect site, defect size, defect extent, dimensions of the flap, the distance of the anterior perforating branch of peroneal artery from the tip of the lateral malleolus, distal communication with the anterior tibial artery, and postoperative complications.

Lateral supramalleolar flap design and planning
The anterolateral lower half of the leg is supplied by the superficial cutaneous branch of the anterior perforating branch of the peroneal artery (Figs. 1, 2). The proximally based lateral supramalleolar flap is based on the anterior perforating branch of the peroneal artery, with a pivot point 5-cm superomedial to the tip of the lateral malleolus in the tibia-fibular groove. In contrast, the distally based lateral supramalleolar flap is based on the distal communications of the peroneal artery with the anterior tibial artery, that is, the sinus tarsus branch and anterior lateral malleolar artery; blood flow comes from the anterior tibial artery by extending its reach to the most distal parts of the dorsal foot (Fig. 1). The upper border of the flap is the midpoint of the leg in a lateral neutral line, the anterior border is the shin or tibia, and the posterior border is the posterior side of the fibula. The perforating branch of the peroneal artery 5-cm supramedial and the distal communication with the anterior tibial artery were marked with a handheld Doppler ultrasound device. The defect was measured and transposed on the leg’s anterolateral surface in the lower half with a pivot point at the communicating vessels, and planning was done in reverse. The superficial peroneal nerve was included with the flap in order to increase the blood supply around the nerve (Fig. 3).

Description of participants
Ten patients ranging from 17 to 67 years of age (eight male and two female patients) were included in the study, of whom nine (90%) were young to middle-aged and one (10%) was geriatric. The right foot was more commonly affected (80%). All patients (100%) presented within the 1st week of injury. The defect loca-
tion was the distal dorsum of the foot in nine patients (90%) and the distal ankle in one patient (10%).

RESULTS

All cases (100%) were caused by RTAs. The average defect size was 5.8 × 4.7 cm, with a range from 4 to 8 cm. The average pedicle length was 8.6 cm. After passing through the interosseous membrane, the anterior perforating branch emerged an average of 5 cm superomedial to the tip of the lateral malleolus in the tibi-fibular groove. The first distal communication, namely the anterior lateral malleolar artery, was seen on average 3.8 cm distal to the lateral malleolus (range, 3–5 cm). The average pedicle width was 2.97 cm. The farthest extent of a flap was up to the base of the toes (Table 1, Fig. 4).

Islanded flaps were performed in all cases (100%). All flaps healed well and provided good coverage. Minor complications were seen in four cases. In two cases (20%) where congestion occurred in the distal few centimeters, one was relieved and healed well with conservative treatment, and the other developed partial necrosis of 2 cm, which required debridement and grafting. There was minimal graft loss in two cases over the donor area and pedicle, both of which were mended with skin grafts. The postoperative position was maintained with splint support.

Fig. 1. (A, B) Communications of the peroneal artery with anterior tibial artery branches.

Fig. 2. Cross-section of lower leg showing region of lateral supramalleolar skin flap. EDL, extensor digitorum longus; EHL, extensor hallucis longus.

Fig. 3. Preoperative reverse planning for a lateral supramalleolar (LSM) flap.

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Table 1. Demographic data of patients with details of the defects and distally based lateral supramalleolar flaps.

<table>
<thead>
<tr>
<th>Serial no.</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Etiology</th>
<th>Defect detail</th>
<th>Flap type</th>
<th>Flap size (cm)</th>
<th>Pedicle length (cm)</th>
<th>Distance between tip of lateral malleolus and later malleolar artery (cm)</th>
<th>Complication</th>
<th>Pedicle width (cm)</th>
<th>Patient satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28</td>
<td>Male</td>
<td>RTA</td>
<td>Right midfoot-forefoot</td>
<td>Islanded</td>
<td>6×5</td>
<td>7×6</td>
<td>8</td>
<td>None</td>
<td>3.2</td>
<td>Excellent</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>Male</td>
<td>RTA</td>
<td>Right hindfoot</td>
<td>Islanded</td>
<td>4×3</td>
<td>5×4</td>
<td>8</td>
<td>None</td>
<td>3</td>
<td>Excellent</td>
</tr>
<tr>
<td>3</td>
<td>27</td>
<td>Male</td>
<td>RTA</td>
<td>Left hindfoot</td>
<td>Islanded</td>
<td>8×7</td>
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<td>9</td>
<td>Flap congestion</td>
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<td>Female</td>
<td>RTA</td>
<td>Right ankle</td>
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<td>9</td>
<td>None</td>
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<td>5</td>
<td>67</td>
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<td>RTA</td>
<td>Left hindfoot</td>
<td>Islanded</td>
<td>6×5</td>
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<td>7</td>
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<td>26</td>
<td>Male</td>
<td>RTA</td>
<td>Right hindfoot</td>
<td>Islanded</td>
<td>7×4</td>
<td>8×5</td>
<td>9</td>
<td>None</td>
<td>3.9</td>
<td>Excellent</td>
</tr>
<tr>
<td>7</td>
<td>17</td>
<td>Male</td>
<td>RTA</td>
<td>Right hindfoot</td>
<td>Islanded</td>
<td>4×4</td>
<td>5×5</td>
<td>10</td>
<td>Patchy graft loss</td>
<td>2.7</td>
<td>Good</td>
</tr>
<tr>
<td>8</td>
<td>26</td>
<td>Female</td>
<td>RTA</td>
<td>Left midfoot-forefoot</td>
<td>Islanded</td>
<td>6×6</td>
<td>7×7</td>
<td>8</td>
<td>None</td>
<td>3.1</td>
<td>Excellent</td>
</tr>
<tr>
<td>9</td>
<td>29</td>
<td>Male</td>
<td>RTA</td>
<td>Right hindfoot</td>
<td>Islanded</td>
<td>7×5</td>
<td>8×6</td>
<td>9</td>
<td>None</td>
<td>3.1</td>
<td>Good</td>
</tr>
<tr>
<td>10</td>
<td>25</td>
<td>Male</td>
<td>RTA</td>
<td>Right hindfoot</td>
<td>Islanded</td>
<td>4×4</td>
<td>5×5</td>
<td>9</td>
<td>None</td>
<td>3</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

RTA, road traffic accident.

a) Excluding pedicle length.

DISCUSSION

The distal vasculature of the leg, ankle, and foot has been studied extensively, especially the septocutaneous perforators and communications between the peroneal artery and anterior tibial artery. Several studies have discussed the distal anterolateral vascular communications in the lower leg and ankle, which form the basis of the lateral supramalleolar flap [1–3]. The lateral supramalleolar flap was first described by Romana and Masquelet [4] in 1999 as part of a detailed discussion of both the classical and the disal based lateral supramalleolar flaps. The relevant vascular communications in the lower leg and ankle, which form the basis of the lateral supramalleolar flap [1–3]. The lateral supramalleolar flap was first described by Romana and Masquelet [4] in 1999 as part of a detailed discussion of both the classical and the disal based lateral supramalleolar flaps. The relevant vascular communications in the lower leg and ankle, which form the basis of the lateral supramalleolar flap [1–3].
foot defects with fewer complications than with other pedicled flaps. The overall flap survival rate was 100%. The main advantages of this flap are as follows. First, the length and therefore the reach of the pedicle can be significantly increased by basing it on distal communications with the anterior tibial artery, which allows its reach to extend as far as the base of the toes. Second, the islanded flap eliminates the need for a secondary procedure. Third, the muscular bed at the flap donor site and the subcutaneous pedicle offer a reliable graft uptake. Fourth, this flap can cover small as well as moderately sized defects of the distal dorsal foot. Fifth, when microsurgical facilities are not available, the surgeon can use it as a lifeboat for a free flap, or even as a substitute for a free flap.

The drawbacks of the flap we encountered were that it is suitable only for moderately sized defects of the ankle and dorsal foot, the flap donor site leaves a scar in a relatively exposed area, and it cannot be used in weight-bearing areas, such as sole defects. In a recent study conducted by Mehmood Hashmi et al. [14] concerning 26 cases of classical (proximally based) supramalleolar flaps, two cases each of flap tip necrosis and venous congestion were observed. In contrast, in our study, which used a distally based adipofasciocutaneous lateral supramalleolar flap instead of an adipofascial flap, we similarly found that venous congestion occurred in two cases and preferred to avoid a subcutaneous tunnel. Instead, we raised subnormal flaps at the normal intervening skin between the defect and the skin paddle for the passage of our subcutaneous pedicle, which allowed a single-stage procedure without much damage to the surrounding tissues. Aside from the studies cited above, few studies have been published regarding either the distally based adipofasciocutaneous lateral supramalleolar flap or the distally based adipofascial lateral supramalleolar flap.

After defect measurement and planning in reverse, the course of the anterior perforating branch of the peroneal artery and the distal communications with anterior tibial artery were identified using a handheld Doppler device (8 MHz), and the flap area was marked. The limb was elevated, and a tourniquet was applied without exsanguination.

First, subdermal flaps (via a lazy-S incision) were elevated over the pedicle at the anterior boundary. The pedicle was elevated on one side, and the cutaneous branch to the skin paddle was identified. Then the anterior compartment tendons at the tibiofibular groove were retracted to demonstrate the perforating branch of the peroneal artery at the tibiofibular groove, as it emerges from...
the interosseous membrane. After that, the superior border was incised, and the superficial peroneal nerve was dissected and tagged to the skin paddle and deep fascia. Further dissection of the flap was carried out, and the lateral intermuscular septum was dissected between the peroneus brevis and extensor digitorum longus and included in the flap. Distally, subperiosteal dissection was required to elevate the pedicle from the fibula. To check the adequacy of retrograde supply, the perforating branch was clamped proximal to the bifurcation of the superficial and deep branches at its exit from the interosseous membrane. Then, the perforating branch was ligated and severed just proximal to the bifurcation of the superficial cutaneous and deep descending branches. Further dissection of the islanded pedicle continued until the distal communication with the anterior tibial artery and the flap’s reach were checked. The flap was then transposed onto the defect and inset. A split-thickness skin graft cover was applied over the flap donor site and the pedicle.

Limitations
This study had some limitations. This study was conducted at a single institute with 10 patients with the follow-up showing good

Fig. 5. Operative steps. (A) A lazy-S incision (line) over the pedicle. The proximal star represents the perforator for classical lateral supramalleolar flap, which has limited reach. The distal star represents the perforator for the distally based lateral supramalleolar flap, which has extended reach. (B) Entry of superficial cutaneous branch into the skin paddle (arrow and circle). (C) Emergence of the anterior perforating branch of peroneal artery through the interosseous membrane (arrow and circle). (D) Incision of the superior border of the flap and identification, transection, and inclusion of superficial peroneal nerve in the flap (circle). (E) Dissection of the lateral intermuscular septum between the extensor digitorum longus and peroneus brevis muscles detached from the fibula. (F) After confirmation of retrograde supply from the anterior tibial artery, ligation of the anterior perforating branch of peroneal artery just proximal to the bifurcation (arrow and circle). (G, H) Further elevation of the skin paddle until the distal communication with anterior tibial artery, and confirmation of flap reach by transposition onto the defect. (I) Final inset and skin graft cover over flap donor site and pedicle.
functional as well as aesthetic recovery. While this surgical method is regarded as one of the best for treating patients with distal foot defects, a larger study population will be more helpful in determining whether this surgical procedure will be applicable in a diverse clinical scenario.

Conclusions
The distally based islanded lateral supramalleolar fasciocutaneous flap provides reliable cover for distal dorsal foot and ankle defects of moderate size. It can reach as far as the base of the toes with good wound healing and without major complications. It can be applied safely in all age groups and is safe following acute trauma. Islanding the flap makes it a single-stage procedure. It can be used as a lifeboat or even a substitute or alternative to free flaps.

ARTICLE INFORMATION

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

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

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

REFERENCES

Epidemiology and outcomes of patients with penetrating trauma in Incheon Metropolitan City, Korea based on National Emergency Department Information System data: a retrospective cohort study

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1Department of Trauma Surgery, Gachon University Gil Medical Center, Incheon, Korea
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Purpose: Patients with penetrating injuries are at a high risk of mortality, and many of them require emergency surgery. Proper triage and transfer of the patient to the emergency department (ED), where immediate definitive treatment is available, is key to improving survival. This study aimed to evaluate the epidemiology and outcomes of patients with penetrating torso injuries in Incheon Metropolitan City.

Methods: Data from trauma patients between 2014 and 2018 (5 years) were extracted from the National Emergency Department Information System. In this study, patients with penetrating injuries to the torso (chest and abdomen) were selected, while those with superficial injuries were excluded.

Results: Of 66,285 patients with penetrating trauma, 752 with injuries to the torso were enrolled in this study. In the study population, 345 patients (45.9%) were admitted to the ward or intensive care unit (ICU), 20 (2.7%) were transferred to other hospitals, and 10 (1.3%) died in the ED. Among the admitted patients, 173 (50.1%) underwent nonoperative management and 172 (49.9%) underwent operative management. There were no deaths in the nonoperative management group, but 10 patients (5.8%) died after operative management. The transferred patients showed a significantly longer time from injury to ED arrival, percentage of ICU admissions, and mortality. There were also significant differences in the percentage of operative management, ICU admissions, ED stay time, and mortality between hospitals.

Conclusions: Proper triage guidelines need to be implemented so that patients with torso penetrating trauma in Incheon can be transferred directly to the regional trauma center for definitive treatment.

Keywords: Abdominal injuries; Thoracic injuries; Penetrating wounds; Trauma centers
INTRODUCTION

Background
Trauma is the most common cause of death among young people in Korea, and the preventable death rate ranges from 32.6% to 50.4% [1–3]. Therefore, the Korean government and medical societies agreed to develop a trauma system, including the establishment of regional trauma centers (RTCs) in 2012. In 2014, the first RTC opened, with plans to establish 17 RTCs in Korea by 2021. However, several aspects of the regional trauma system, including governance, low-level trauma centers, and authorized guidelines for injured patient care, have yet to be established.

The management of penetrating torso injuries is challenging because it requires rapid and accurate assessment and surgical intervention. The rapid prehospital transportation of patients with penetrating injuries to the appropriate facility (i.e., a trauma center) is crucial [4,5]. Rapid transportation and management by experienced trauma surgeons at trauma centers have been shown to improve the survival of patients with major penetrating injuries [6,7]. A study also showed that patients from rural areas had a higher prehospital mortality risk than those from urban areas [8]. Worse outcomes were related to the response time, distance of transport, and limitations in specialized care in rural areas.

Objectives
This study aimed to describe the demographics and outcomes of patients with penetrating torso injuries in Incheon Metropolitan City after 2014, when the first RTC opened in Incheon.

METHODS

Ethics statement
This study was approved by the Institutional Review Board of Gachon University Gil Medical Center (No. GCIRB2020-375). The requirement for informed consent from patients was waived due to the retrospective nature of the study.

Study design and setting
This retrospective cohort study used data obtained from the National Emergency Department Information System (NEDIS), which is a database operated by the Ministry of Health and Welfare that collects data from all patients visiting 434 emergency departments (EDs) in Korea. The data included patients’ demographics, clinical characteristics, and diagnosis codes at admission. This study did not receive any funding from external sources.

We extracted the data of all trauma patients who visited EDs in Incheon Metropolitan City from NEDIS between January 2014 and December 2018. Patients with trauma were identified using International Classification of Diseases (ICD) codes. Superficial injuries, drowning, or intoxication cases were not included in the dataset. In this study, we included patients with penetrating injuries to the torso (chest and abdomen) based on ICD codes (Fig. 1).

Population and trauma care system of Incheon Metropolitan City
Three million people live in Incheon Metropolitan City, which is surrounded by Seoul and Gyeonggi Province. This region has a population of approximately 20 million. There is one hospital—hereinafter referred to hospital B—in Incheon that has both a regional emergency center (REC) and an RTC. In addition, one REC without an RTC, nine local emergency centers (LECs), and nine local emergency institutions exist in the city. Before the RTC opened in 2014, trauma patients were triaged based on the shortest transport time and distance, such that severely injured patients could be brought to the nearest REC or LEC. After the RTC opened in 2014, trauma patients were triaged based on the shortest transport time and distance, such that severely injured patients could be brought to the nearest REC or LEC; however, this has not been well orchestrated by the trauma governance system.

Statistical analysis
The basic demographic variables, types of ED, mechanism of injury, ED presentation route, and other clinical information were analyzed. Age was categorized into the following groups: 0–19, 20–29, 30–39, 40–49, 50–59, 60–69, and ≥ 70 years. The presentation routes were categorized as either direct or transferred.

Fig. 1. Flowchart of the study enrollment. NEDIS, National Emergency Department Information System.
Medical information included vital signs, mental status at the time of ED arrival, patient’s disposition after ED management, diagnosis on admission, and outcome at the time of discharge. The time variables included estimated injury time, ED arrival time, and discharge time from the ED or admission. Using the time variables, we calculated the time from injury to ED arrival, the ED stay time, and the time from injury to ED disposition.

All data were analyzed using IBM SPSS ver. 22 (IBM Corp., Armonk, NY, USA). Numerical data are presented as mean ± standard deviation or median (interquartile range), and categorical data are presented as percentages. The chi-square test was used to compare proportions for categorical variables, and the Student t-test or Mann-Whitney U-test was used to compare means or medians for continuous variables, as appropriate. Statistical significance was defined as P < 0.05.

RESULTS

Of the 768,703 trauma patients who visited EDs in Incheon during the 5-year study period, 752 patients with penetrating torso injuries were included in this study (Fig. 1). Among them, 377 (50.1%) were discharged from the ED, 345 (45.9%) were admitted, 20 (2.7%) were transferred to another hospital, and 10 (1.3%) died in the ED. The most common age group was 40 to 49 years (22.5% of total patients, 24.3% of admitted patients), and more than 70% of the patients were male (Table 1). Approximately half

### Table 1. The basic demographic and clinical characteristics of the study population

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n=752)</th>
<th>Admitted (n=345)</th>
<th>Non-admitted (n=407)</th>
<th>P-value</th>
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<td>Age (yr)</td>
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<td></td>
<td></td>
<td>&lt;0.001²</td>
</tr>
<tr>
<td>0–19</td>
<td>92 (12.2)</td>
<td>21 (6.1)</td>
<td>71 (17.4)</td>
<td></td>
</tr>
<tr>
<td>20–29</td>
<td>115 (15.3)</td>
<td>55 (15.9)</td>
<td>60 (14.7)</td>
<td></td>
</tr>
<tr>
<td>30–39</td>
<td>133 (17.7)</td>
<td>63 (18.3)</td>
<td>70 (17.2)</td>
<td></td>
</tr>
<tr>
<td>40–49</td>
<td>169 (22.5)</td>
<td>84 (24.3)</td>
<td>85 (20.9)</td>
<td></td>
</tr>
<tr>
<td>50–59</td>
<td>143 (19.0)</td>
<td>63 (18.3)</td>
<td>80 (19.7)</td>
<td></td>
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<tr>
<td>60–69</td>
<td>62 (8.2)</td>
<td>30 (8.7)</td>
<td>32 (7.9)</td>
<td></td>
</tr>
<tr>
<td>≥70</td>
<td>38 (5.1)</td>
<td>29 (8.4)</td>
<td>9 (2.2)</td>
<td></td>
</tr>
<tr>
<td>Male sex</td>
<td>537 (71.4)</td>
<td>255 (73.9)</td>
<td>282 (69.3)</td>
<td>0.162</td>
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<tr>
<td>Classification of emergency center</td>
<td></td>
<td></td>
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<td>Regional emergency center</td>
<td>321 (42.7)</td>
<td>185 (53.6)</td>
<td>136 (33.4)</td>
<td></td>
</tr>
<tr>
<td>Local emergency center</td>
<td>413 (54.9)</td>
<td>151 (43.8)</td>
<td>262 (64.4)</td>
<td></td>
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<tr>
<td>Direct transportation</td>
<td>687 (91.4)</td>
<td>293 (84.9)</td>
<td>394 (96.8)</td>
<td>&lt;0.001²</td>
</tr>
<tr>
<td>KTAS⁵ score</td>
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<td></td>
<td></td>
<td>&lt;0.001²</td>
</tr>
<tr>
<td>1</td>
<td>9 (1.2)</td>
<td>2 (0.6)</td>
<td>7 (1.7)</td>
<td></td>
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<tr>
<td>2</td>
<td>161 (21.4)</td>
<td>119 (34.5)</td>
<td>42 (10.3)</td>
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<tr>
<td>3</td>
<td>104 (13.8)</td>
<td>59 (17.1)</td>
<td>45 (11.1)</td>
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<tr>
<td>4</td>
<td>159 (21.1)</td>
<td>23 (6.7)</td>
<td>136 (33.4)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>22 (2.9)</td>
<td>1 (0.3)</td>
<td>21 (5.2)</td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>118.2±43.8</td>
<td>124.7±34.5</td>
<td>112.6±49.7</td>
<td>&lt;0.001²</td>
</tr>
<tr>
<td>Pulse rate (beats/min)</td>
<td>82.2±27.5</td>
<td>89.4±22.4</td>
<td>76.1±29.9</td>
<td>0.020²</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>18.7±6.2</td>
<td>20.0±4.1</td>
<td>17.7±7.4</td>
<td>&lt;0.001²</td>
</tr>
<tr>
<td>ED disposition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discharge</td>
<td>377 (50.1)</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Transfer out</td>
<td>20 (2.7)</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Admission to ward or ICU</td>
<td>345 (45.9)</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Death in ED</td>
<td>10 (1.3)</td>
<td>NA</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Time from injury to ED (min)</td>
<td>48 (30–60)</td>
<td>54 (30–65)</td>
<td>39 (27–60)</td>
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</tr>
<tr>
<td>ED stay time (min)</td>
<td>79 (36–138)</td>
<td>108 (68–167)</td>
<td>52 (24–104)</td>
<td>&lt;0.001⁴</td>
</tr>
<tr>
<td>Time from injury to ED disposition (min)</td>
<td>143 (85–248)</td>
<td>175 (120–274)</td>
<td>115 (65–208)</td>
<td>&lt;0.001⁴</td>
</tr>
</tbody>
</table>

Values are presented as number (%), mean±standard deviation, or median (interquartile range).
KTAS, Korean Triage and Acuity Scale; ED, emergency department; NA, not applicable; ICU, intensive care unit.
⁵Statistically significant differences between groups. ⁶Available from 2016.
of the patients (42.7%) were transported to RECs, and 90% of patients presented directly to the ED. The admission group showed a significantly lower percentage of patients who presented directly to the ED and had higher Korean Triage and Acuity Scale (KTAS) scores than the nonadmission group. The ED stay time was significantly longer in the admission group.

We compared the clinical characteristics between patients who received nonoperative management (NOM) and operative management (OM) (Table 2). More patients in the OM group than in the NOM group were managed in RECs (62.8% vs. 44.5%, P = 0.001). The OM group showed significantly lower systolic blood pressure and a higher rate of admission to the intensive care unit (ICU). None of the patients died after NOM, whereas 10 patients (5.8%) who received OM died. The transferred patients showed a significantly longer time from injury to ED (43 minutes vs. 101 minutes), higher ICU admission rate (21.3% vs. 43.7%), and higher mortality (2.2% vs. 7.7%) (Table 3).

The number of patients admitted was significantly different among EDs in Incheon (Table 4). Hospital B (both the RTC and REC) had the highest patient volume, managing 46.1% of the total patients and 58.2% of the OM patients. The ICU admission rates varied from 15.8% to 71.7% among hospitals, and hospital

### Table 2. Comparison of NOM and OM groups (n=345)

<table>
<thead>
<tr>
<th>Variable</th>
<th>NOM group (n=173)</th>
<th>OM group (n=172)</th>
<th>P-value</th>
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</thead>
<tbody>
<tr>
<td>Classification of emergency center</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Regional emergency center</td>
<td>77 (44.5)</td>
<td>108 (62.8)</td>
<td>0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Local emergency center</td>
<td>93 (53.8)</td>
<td>58 (33.7)</td>
<td></td>
</tr>
<tr>
<td>Direct transportation</td>
<td>145 (83.8)</td>
<td>148 (86.0)</td>
<td>0.334</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>129.9±30.0</td>
<td>119.5±37.8</td>
<td>0.005&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Pulse rate (beats/min)</td>
<td>87.5±21.4</td>
<td>91.3±23.3</td>
<td>0.117</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>19.6±4.0</td>
<td>20.1±4.1</td>
<td>0.218</td>
</tr>
<tr>
<td>Time from injury to ED (min)</td>
<td>57 (30–79)</td>
<td>51 (30–60)</td>
<td>0.750</td>
</tr>
<tr>
<td>ED stay time (min)</td>
<td>173 (88–199)</td>
<td>87 (52–143)</td>
<td>0.440</td>
</tr>
<tr>
<td>Time from injury to ED disposition (min)</td>
<td>211 (140–325)</td>
<td>150 (98–224)</td>
<td>0.110</td>
</tr>
<tr>
<td>Admission to ICU</td>
<td>53 (30.6)</td>
<td>122 (70.9)</td>
<td>&lt;0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Discharged to home</td>
<td>153 (88.4)</td>
<td>147 (85.5)</td>
<td>0.028&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Died in hospital</td>
<td>0</td>
<td>10 (5.8)</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as number (%), mean±standard deviation, or median (interquartile range).
NOM, nonoperative management; OM, operative management; ED, emergency department; ICU, intensive care unit.
<sup>a</sup>Statistically significant differences between the groups.

### Table 3. Comparison of patients group by route of emergency department admission (n=752)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Direct (n=687)</th>
<th>Transferred (n=65)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classification of emergency center</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional emergency center</td>
<td>279 (40.6)</td>
<td>42 (64.6)</td>
<td>0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Local emergency center</td>
<td>408 (59.4)</td>
<td>23 (35.4)</td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>117.9±43.9</td>
<td>120.9±42.6</td>
<td>0.605</td>
</tr>
<tr>
<td>Pulse rate (beats/min)</td>
<td>81.6±27.7</td>
<td>88.7±24.5</td>
<td>0.300</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>18.5±6.2</td>
<td>20.4±5.5</td>
<td>0.100</td>
</tr>
<tr>
<td>Time from injury to ED (min)</td>
<td>43 (30–60)</td>
<td>101 (60–240)</td>
<td>&lt;0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>ED stay time (min)</td>
<td>76 (34–137)</td>
<td>92 (55–149)</td>
<td>0.555</td>
</tr>
<tr>
<td>Time from injury to ED disposition (min)</td>
<td>138 (82–235)</td>
<td>218 (159–450)</td>
<td>0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Admission to ICU</td>
<td>146 (21.3)</td>
<td>29 (44.6)</td>
<td>&lt;0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mortality</td>
<td>15 (2.2)</td>
<td>5 (7.7)</td>
<td>0.027&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values are presented as number (%), mean±standard deviation, or median (interquartile range).
ED, emergency department; ICU, intensive care unit.
<sup>a</sup>Statistically significant differences between the groups.
B had the largest number of patients admitted to the ICU during the 5-year study period. The shortest ED stay for all admitted patients was 61 minutes, and the longest stay was 286 minutes. In addition, there was a significant variation in the ED stay time of patients who were directly transferred to the operating room (from 48 minutes to 157.5 minutes) (Fig. 2).

**DISCUSSION**

In this study, penetrating torso injuries accounted for 1.1% and 0.1% of all penetrating injuries and all injuries, respectively. Although a direct comparison is difficult due to differences in the clinical characteristics of the study population, this study showed a relatively low incidence of penetrating torso injuries in Incheon over the last 5 years, similar to other industrialized countries [9–11]. Moreover, the incidence and mortality rates of penetrating torso injuries requiring hospitalization were relatively low [12–14]. Unlike in the United States and South Africa, firearms are prohibited in Korea, which may, in part, contribute to the low incidence of penetrating injuries [15,16].

Most patients were directly transported to the ED for treatment, and the median time from injury to ED arrival was 48 minutes. However, 8.6% of the patients did not receive definitive management in the ED where they initially arrived. Moreover, patients who required hospitalization had a lower rate of direct transportation and longer stays in the ED. This is supported by the opinion that the roles of the RTC and other emergency medical centers are not clearly distinguished, meaning the emergency triage system is not efficient at the prehospital level in Korea [17].

As a result, patients with severe trauma were not concentrated in the RTC.

The transferred patients had a longer time from injury to the final ED arrival than the other patients. Furthermore, they showed a higher rate of ICU admission and mortality, suggesting that a delayed arrival to the final ED due to transfer could be a risk factor for poor outcomes. Therefore, we need to focus on these transferred cases to improve the outcomes after penetrating injuries.

Fu et al. [7] reported that trauma centers with a high volume of penetrating trauma patients were associated with good outcomes. In Incheon, only hospital B has an RTC in addition to an REC. This hospital has managed a substantial number of patients in the last 5 years. Our findings showed that the rates of OM and ICU admission were higher in hospital B than in the other REC. Despite this, the ED stay time in hospital B was shorter than that in other hospitals. Of note, patients who were directly transferred to the operating room had a significantly shorter stay in the emergency room in hospital B than in other hospitals. Hoyt et al. [18] reported that direct transport to the operating room for resuscitation was associated with better outcomes in patients with penetrating torso injuries. Meizoso et al. [19] argued that protocols to shorten the ED stay for patients requiring surgery are essential. To improve the clinical outcomes of penetrating torso injuries, it is necessary to establish a trauma governance system that allows direct transfer of patients.

**Limitations**

This study had some limitations. First, as with other retrospective studies with large databases, this study has the potential for selection bias. Second, the NEDIS data lack granular clinical information.
tion, such as hemodynamic changes and transfusion requirements. Third, a comparative analysis of data from other regions with similar characteristics would have made it possible to better understand the characteristics of patients with penetrating injuries in Incheon. Despite these limitations, this study is the first to analyze specific injury mechanisms in the metropolitan area of Korea and will be helpful in establishing trauma governance in Incheon.

Conclusions
The number of patients with penetrating torso injuries in Incheon Metropolitan City was small enough to be managed at a single definitive treatment facility. Transferring patients to other hospitals is associated with delayed arrival to the final ED, which can cause poor outcomes. To address these factors, appropriate triage guidelines are needed to allow direct transfer to the RTC for patients with penetrating torso trauma in Incheon.

ARTICLE INFORMATION

Author contributions
Conceptualization: BY, JL; Data curation: SBJ, SHL; Formal analysis: YK, JC, JG, YP, YM; Methodology: KKC, MAL, GJL; Visualization: BY, SBJ, SHL, JL; Writing–original draft: YK, JC, JG, YP, KKC, MAL, GJL; Writing–review & editing: all authors. All authors read and approved the final manuscript.

Conflicts of interest
Gil Jae Lee is the Editor-in-Chief, Min A Lee is the Associate Editor, and Seung Hwan Lee, Jayun Cho, and Kang Kook Choi are Editorial Board members of the Journal of Trauma and Injury, but were not involved in the peer reviewer selection, evaluation, or decision process of this article. The authors have no other conflicts of interest to declare.

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

Additional information
This study was presented at the 9th Pan-Pacific Trauma Congress in June 2022 in Gyeongju, Korea.

REFERENCES

5. Ball CG. Current management of penetrating torso trauma.
Impact of nonphysician, technology-guided alert level selection on rates of appropriate trauma triage in the United States: a before and after study

Megan E. Harrigan, BS, Pamela A. Boremski, MS, Bryan R. Collier, DO, Allison N. Tegge, PhD, Jacob R. Gillen, MD

Purpose: Overtriage and undertriage rates are critical metrics in trauma, influenced by both trauma team activation (TTA) criteria and compliance with these criteria. Analysis of undertriaged patients at a level I trauma center revealed suboptimal compliance with existing criteria. This study assessed triage patterns after implementing compliance-focused process interventions.

Methods: A physician-driven, free-text alert system was modified to a nonphysician, hospital dispatcher-guided system. The latter employed dropdown menus to maximize compliance with criteria. The preintervention period included patients who presented between May 12, 2020, and December 31, 2020. The postintervention period incorporated patients who presented from May 12, 2021, through December 31, 2021. We evaluated appropriate triage, overtriage, and undertriage using the Standardized Trauma Assessment Tool. Statistical analyses were conducted with an α level of 0.05.

Results: The new system was associated with improved compliance with existing TTA criteria (from 70.3% to 79.3%, P=0.023) and decreased undertriage (from 6.0% to 3.2%, P=0.002) at the expense of increasing overtriage (from 46.6% to 57.4%, P<0.001), ultimately decreasing the appropriate triage rate (from 78.4% to 74.6%, P=0.007).

Conclusions: This study assessed a workflow change designed to improve compliance with TTA criteria. Improved compliance decreased undertriage to below the target threshold of 5%, albeit at the expense of increased overtriage. The decrease in appropriate triage despite compliance improvements suggests that the current criteria at this institution are not adequately tailored to optimally balance the minimization of undertriage and overtriage. This finding underscores the importance of improved compliance in evaluating the efficacy of TTA criteria.

Keywords: Trauma centers; Triage; Trauma severity scores; Work flow
INTRODUCTION

Background
In the United States, trauma injuries exert an extensive toll on the population and the healthcare system [1]. The efficient and effective care of trauma patients relies heavily on consistent and accurate triage prior to their arrival at the trauma center. Unfortunately, for a variety of reasons, some patients are mistriaged, meaning that they did not receive the appropriate trauma team activation (TTA) based on the severity of their injuries. Patients who are undertriaged face an increased risk of mortality and adverse outcomes [2,3], whereas overtriage leads to inefficient use of time and resources and can also contribute to provider dissatisfaction [4,5].

Of the two forms of mistriage, undertriage is considered more detrimental. In fact, the American College of Surgeons Committee on Trauma (ACS-COT) defines optimal rates of undertriage as less than 5% and overtriage as less than 35% [6]. However, hospitals worldwide find it challenging to meet these standards, with some reporting undertriage rates nearing 30% and others noting overtriage rates as high as 71% [2,7–9]. Regular assessments of appropriate triage and mistriage rates are conducted by trauma centers. The Standardized Triage Assessment Tool (STAT) is a commonly used method for evaluating triage patterns [10–12]. With the STAT, each patient is assigned a triage designation based on a combination of Injury Severity Scores (ISSs) and the requirement for specific trauma interventions (Fig. 1).

Designing the ideal trauma triage system remains an elusive goal. Much of the previous research has concentrated on identifying patient populations that are often misclassified, with the aim of adjusting the TTA criteria to better serve these patients [13–15]. More recently, research has shifted towards evaluating and improving compliance with triage criteria [3,16,17]. However, no consensus yet exists on the best way to minimize rates of...

Fig. 1. Workflow of the Standardized Triage Assessment Tool (STAT), used to determine triage rates. The STAT is a combination of the Cribari Matrix Method (CMM) and the Need for Trauma Intervention (NFTI) tool. AT, appropriate triage; OT, overtriage; UT, undertriage; ISS, Injury Severity Score.
mistriage. Given this lack of clarity and the fact that trauma impacts a large proportion of the population, it is crucial to explore potential solutions.

Compliance with a specific institution’s clinical guidelines for TTA is shaped by a complex interplay of numerous factors. These include the quantity and complexity of the guidelines [18,19], the ease of referencing criteria within the workspace [20], the number of staff members involved in implementing the criteria [21], staff education about the criteria [22], and feedback loops for staff regarding clinical performance [20,23]. The influence of human factors, educational infrastructure, and the institutional team culture cannot be overstated. Furthermore, the behavioral tendency of physicians to disregard protocols to avoid so-called cookbook medicine can also affect compliance [24].

Thus, efforts to improve compliance with TTA criteria must include assessment of each of these elements and more.

**Objectives**

This study explores the execution of a compliance-focused intervention at a level I trauma center. A physician-oriented free-text alert system was transformed into a nonphysician, hospital dispatcher-driven dropdown menu alert system through a series of workflow interventions (Fig. 2). The first objective of the study was to evaluate the compliance rates with TTA criteria before and after the intervention. The second objective was to examine changes in triage patterns preintervention and postintervention. The primary outcome measured was the rate of appropriate triage determined using the STAT. Secondary outcomes included
overtriage and undertriage rates, as well as clinical outcomes. We hypothesized that appropriate triage rates would rise in correlation with improved compliance with the existing TTA criteria. Furthermore, we anticipated a decrease in undertriage and overtriage rates in relation to increased compliance with these criteria.

**METHODS**

**Ethics statement**

This study was approved by the Institutional Review Board of Carilion Clinic (No. 21-1320). The requirement for informed consent was waived due to the retrospective nature of the study.

**Study design and population**

This before-and-after study involved a retrospective review of trauma patients who presented at a level I trauma center between May 2020 and December 2021. The data selected for extraction were guided by the current TTA guidelines at the trauma center (Fig. 3), as well as previous analyses identifying mistrigated populations and those examining non-compliance with triage guidelines [3,14,15,17]. Direct admissions, patients without TTA, and patients lacking a recorded date of arrival were excluded from the analysis (Fig. 4). We assessed patient demographics, injury patterns, prehospital vital signs, and outcomes to demonstrate equivalence between groups. All data referenced in this study were sourced from the hospital trauma registry and electronic medical records.

**Fig. 3.** Trauma team activation criteria for this institution. CPR, cardiopulmonary resuscitation; GCS, Glasgow Coma Scale; LOC, loss of consciousness; TBSA, total body surface area; TBI, traumatic brain injury.

**Fig. 4.** Inclusion and exclusion criteria for this study.
Process intervention
Two workflow changes were implemented to transform a physician-driven, free-text alert system into a nonphysician, hospital dispatcher-driven alert system. The latter system utilizes dropdown menus to ensure maximum compliance (Fig. 2). The first change involved altering who was responsible for assigning the TTA level. In the original system, first responders arriving on the scene would relay a patient report to the attending physician in the emergency department. This physician would then assign the TTA level for the incoming patient. In the revised system, first responders provide their report to trained hospital dispatchers, who may be registered nurses, paramedics, or emergency medical technicians. These dispatchers are then responsible for assigning the TTA level. The attending physician is only contacted if the dispatcher has a question or concern. The second major workflow intervention was the introduction of a dropdown menu within the computer-based interface used for TTA alerts. Previously, the reason for TTA was entered into a free-text box. In the updated system, hospital dispatchers select the TTA indication from a dropdown menu. This provides just-in-time reminders of the TTA criteria and encourages adherence to these criteria. These changes were implemented sequentially, with the first change taking effect on March 10, 2021, and the second on May 12, 2021. We defined the preintervention period as May 12, 2020, through December 31, 2020, and the postintervention period as May 12, 2021, through December 31, 2021. We chose these time periods so that the months would align between cohorts, considering the seasonal variations in trauma patient presentations.

Compliance
We measured compliance with trauma triage guidelines by examining trauma patients who met at least one objective predetermined prehospital criterion for full TTA, as recorded by emergency medical services (EMS). For our trauma center, these criteria included a heart rate of ≤ 60 or ≥ 120 beats/min, a systolic blood pressure of < 100 mmHg, a respiratory rate of < 10 or > 29 breaths/min, and a Glasgow Coma Scale score of 8 or lower. We classified each patient as either compliant or noncompliant, based on whether the correct TTA was initiated before the patient arrived. If a patient’s TTA level was upgraded or downgraded during transport, we grouped them with their final classification.

Defining appropriate triage and mistriage
All trauma patients were evaluated using the STAT [10–12]. This tool is a combination of the widely used Cribari Matrix Method (CMM) and the Need for Trauma Intervention (NFTI) method (Fig. 1). With the CMM, patients are evaluated based on their ISSs, a measure that reflects both the number and severity of injuries across different body regions. According to the CMM, any patient with an ISS greater than 15 should be given the highest level of TTA, hereafter referred to as a full alert. In the NFTI method, in contrast, patients are classified based on their need for specific emergency hospital interventions. Patients who require these interventions (NFTI+ patients) should also be assigned a full alert. NFTI criteria include receiving a blood transfusion within 4 hours of arrival, being discharged to the operating room within 90 minutes of arrival, being discharged to interventional radiology, being discharged to the intensive care unit, having an intensive care unit stay of at least 3 days, requiring mechanical ventilation during the first 3 days (excluding anesthesia), or dying within 60 hours of arrival [10]. Consequently, at the institution in the present study, undertriaged patients were defined as those with an ISS greater than 15 and a positive NFTI designation who were not assigned a full alert. Conversely, overtriaged patients were defined as those assigned a full alert despite having an ISS less than 15 and a negative NFTI designation.

Statistical analysis
The Fisher exact test was used for all categorical variables, while the Welch t-test was employed for continuous variables, with an α value of 0.05. All statistical analysis was conducted using R ver. 4.1.3 (R Foundation for Statistical Computing).

RESULTS
Patient characteristics
A total of 4,953 patients presented to our trauma center during the study period. After application of the exclusion criteria, the number was reduced to 3,693. These patients were divided into two groups, with 1,647 patients in the preintervention group and 2,046 in the postintervention group. We characterized patient demographics, injury patterns, and physiological parameters both before and after the process interventions (Table 1). Generally, the characteristics of patients in both groups were similar, with the exception of age and average ISS.

Compliance
The overall compliance rates with the objective vital sign criteria for a full alert significantly improved, rising from 70.3% in the preintervention group to 79.3% in the postintervention group.
(P = 0.023). When examining compliance with individual objective vital sign criteria, we noted a significant increase in compliance for bradycardia, from 44.8% to 79.2% (P = 0.005). Trends also indicated improved compliance in all categories except for tachypnea (Fig. 5). Furthermore, we observed a trend suggesting a decrease in trauma consultations that met the isolated objective vital sign criteria for a full alert, falling from 4.5% to 3.3% (P = 0.274) (Table 2).

**Triage patterns**

Rates of appropriate triage decreased in association with the process intervention (Fig. 6). Following the implementation of this intervention, undertriage rates dropped by almost 50% (from 6.0% to 3.2%, P = 0.002), crossing an important threshold to reach the optimal undertriage rate as outlined by the ACS-COT guidelines (< 5%) [6]. However, rates of overtriage increased from 46.6% to 57.4% (P < 0.001). This substantial increase in overtriage ultimately led to a decrease in the rate of appropriate triage, from 78.4% to 74.6% (P = 0.007). Alongside the increased rates of overtriage, we noted a decrease in the number of consults (the lowest level of TTA), which was accompanied by an increase in partial and full alerts (Table 3).

**Clinical outcomes**

Virtually no significant differences in clinical outcomes were observed between the cohorts (Table 4). The exception was an in-

---

**Table 1. Patient characteristics in the preintervention and postintervention groups (n=3,693)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preintervention (n=1,647)</th>
<th>Postintervention (n=2,046)</th>
<th>P-value (α=0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td>0.060</td>
</tr>
<tr>
<td>Male</td>
<td>1,075 (65.3)</td>
<td>1,273 (62.2)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>572 (34.7)</td>
<td>773 (37.8)</td>
<td></td>
</tr>
<tr>
<td><strong>Age (yr)</strong></td>
<td>54.2±21.8</td>
<td>55.8±21.9</td>
<td>0.027</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td>0.439</td>
</tr>
<tr>
<td>White</td>
<td>1,308 (79.4)</td>
<td>1,671 (81.7)</td>
<td></td>
</tr>
<tr>
<td>Black or African American</td>
<td>250 (15.2)</td>
<td>271 (13.3)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>10 (0.6)</td>
<td>15 (0.7)</td>
<td></td>
</tr>
<tr>
<td>American Indian</td>
<td>4 (0.2)</td>
<td>4 (0.2)</td>
<td></td>
</tr>
<tr>
<td>Native Hawaiian</td>
<td>2 (0.1)</td>
<td>1 (0.05)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>13 (0.8)</td>
<td>22 (1.1)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>60 (3.6)</td>
<td>62 (3.0)</td>
<td></td>
</tr>
<tr>
<td><strong>Injury category</strong></td>
<td></td>
<td></td>
<td>0.462</td>
</tr>
<tr>
<td>Blunt</td>
<td>1,445 (87.7)</td>
<td>1,816 (88.8)</td>
<td></td>
</tr>
<tr>
<td>Penetrating</td>
<td>178 (10.8)</td>
<td>197 (9.6)</td>
<td></td>
</tr>
<tr>
<td>Burn</td>
<td>16 (1.0)</td>
<td>24 (1.2)</td>
<td></td>
</tr>
<tr>
<td>Other or NA</td>
<td>11 (0.7)</td>
<td>9 (0.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Injury mechanism</strong></td>
<td></td>
<td></td>
<td>0.099</td>
</tr>
<tr>
<td>Fall</td>
<td>700 (42.5)</td>
<td>925 (45.2)</td>
<td></td>
</tr>
<tr>
<td>Motor vehicle crash</td>
<td>429 (26.1)</td>
<td>518 (25.3)</td>
<td></td>
</tr>
<tr>
<td>Assault</td>
<td>96 (5.8)</td>
<td>90 (4.4)</td>
<td></td>
</tr>
<tr>
<td>Gunshot wound</td>
<td>92 (5.6)</td>
<td>87 (4.3)</td>
<td></td>
</tr>
<tr>
<td>Stab wound</td>
<td>23 (1.4)</td>
<td>26 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>307 (18.6)</td>
<td>400 (19.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Injury Severity Score</strong></td>
<td>10.4±9.4</td>
<td>8.7±8.6</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td><strong>EMS vital sign</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>136.7±31.9</td>
<td>135.5±31.5</td>
<td>0.253</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>94.6±24.9</td>
<td>94.3±26.4</td>
<td>0.723</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>18.6±5.7</td>
<td>18.4±5.5</td>
<td>0.282</td>
</tr>
<tr>
<td>GCS score</td>
<td>13.3±3.4</td>
<td>13.5±3.1</td>
<td>0.065</td>
</tr>
</tbody>
</table>

Values are presented as number (%) or mean±standard deviation. The Fisher exact test was used for categorical variables, while the Welch t-test was employed for continuous variables.

NA, not available; EMS, emergency medical services; GCS, Glasgow Coma Scale.

*Cohen d = 0.2.
crease in the average length of stay in the emergency department in the postintervention group.

DISCUSSION

This study examined the relationship between a new compliance-focused process intervention and the rates of appropriate triage at a level I trauma center. We observed significant improvements in compliance with TTA criteria and undertriage rate. The decrease in the undertriage rate was especially noteworthy, as it brought this metric to an optimal level according to ACS-COT guidelines [6]. However, the rate of appropriate triage ultimately fell due to a substantial increase in the overtriage rate. Despite these unanticipated results, this study offers valuable insights into an easy-to-implement workflow modification that can improve compliance with TTA criteria. Furthermore, the dra-

Fig. 5. Compliance rates among trauma patients with objective, isolated trauma team activation (TTA) criteria in the preintervention (May 12, 2020–December 31, 2020) and postintervention (May 12, 2021–December 31, 2021) groups. The Fisher exact test was used. Includes all three TTA tiers (full, partial, and consult). EMS, emergency medical services; SBP, systolic blood pressure; HR, heart rate; RR, respiratory rate; GCS, Glasgow Coma Scale.

Table 2. Assessment of trauma consults in the preintervention and postintervention groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preinterventiona</th>
<th>Postinterventionb</th>
<th>P-value (α=0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma consults meeting isolated EMS vital sign criteria</td>
<td>31 (4.5)</td>
<td>24 (3.3)</td>
<td>0.274</td>
</tr>
<tr>
<td>UT trauma consults meeting any EMS vital sign criteria</td>
<td>6 (13.0)</td>
<td>3 (10.7)</td>
<td>&gt;0.999</td>
</tr>
</tbody>
</table>

Values are presented as number (%). Vital sign criteria include EMS measurements of systolic blood pressure <100 mmHg, heart rate ≤60 or ≥120 beats/min, respiratory rate <10 or >29 breaths/min, and Glasgow Coma Scale score ≤8. The Fisher exact test was used.

EMS, emergency medical services; UT, undertriaged.

a691 Trauma consults and 46 UT trauma consults. b721 Trauma consults and 28 UT trauma consults.

https://doi.org/10.20408/jti.2023.0020
Appropriate triage, overtriage, and undertriage in the preintervention (May 12, 2020–December 31, 2020) and postintervention (May 12, 2021–December 31, 2021) groups. The American College of Surgeons Committee on Trauma recommends upper limits for overtriage and undertriage of 35% and 5%, respectively. The Fisher exact test was used.

### Table 3. Alert types in the preintervention and postintervention groups (n=3,693)

<table>
<thead>
<tr>
<th>Alert type</th>
<th>Preintervention (n=1,647)</th>
<th>Postintervention (n=2,046)</th>
<th>P-value (α=0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>631 (38.3)</td>
<td>838 (41.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Partial</td>
<td>325 (19.7)</td>
<td>487 (23.8)</td>
<td></td>
</tr>
<tr>
<td>Consult</td>
<td>691 (42.0)</td>
<td>721 (35.2)</td>
<td></td>
</tr>
</tbody>
</table>

The Fisher exact test was used.

### Table 4. Clinical outcomes in the preintervention and postintervention groups (n=3,693)

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Preintervention (n=1,647)</th>
<th>Postintervention (n=2,046)</th>
<th>P-value (α=0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>121 (7.4)</td>
<td>138 (6.7)</td>
<td>0.518</td>
</tr>
<tr>
<td>Discharged to home</td>
<td>1,154 (70.1)</td>
<td>1,426 (69.7)</td>
<td>0.836</td>
</tr>
<tr>
<td>Hospital LOS (day)</td>
<td>5.7±8.8</td>
<td>5.3±8.2</td>
<td>0.157</td>
</tr>
<tr>
<td>ED LOS (hr)</td>
<td>10.4±12.0</td>
<td>13.5±14.0</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are presented as number (%) or mean±standard deviation. The Welch t-test was used for continuous variables, while the Fisher exact test was used for categorical variables. LOS, length of stay; ED, emergency department.

Schematic shifts in triage rates underscore the importance of improving compliance as a crucial step in accurately evaluating an institution’s TTA criteria and guiding future adjustments.

The workflow modifications in this study were designed to increase compliance by simplifying the identification of criteria for a TTA, as well as by reducing the number of designated staff members responsible for assigning the TTA level (from 56 attending physicians preintervention to 10 hospital dispatchers postintervention). Before the intervention, TTA criteria were displayed on the badges of attending physicians and on the desks of hospital dispatchers. However, presenting the criteria in a dropdown menu format offers consistent visual repetition, which enhances memory and retention of the criteria. Previous research has shown that compliance with guidelines in various clinical settings can be improved by making the guidelines more accessible, simplifying them, and optimizing team efficiency and education [18–22]. Therefore, it is likely that both the dropdown menu modification and the dispatcher-driven system contributed to the overall improvement in compliance.

The present study also provides the valuable insight that doctors may not need to shoulder the responsibility of assigning each TTA level. The 2022 Physician Burnout and Depression Report highlights that emergency department physicians reported the highest burnout rates among specialties, at 60%, a rise from 43% in the previous year [25]. Given this escalating burnout rate, the importance of eliminating an unnecessary task for emergency department physicians is paramount, especially as hospitals nationwide continue to deal with the burden of the COVID-19 pandemic.

Interestingly, only compliance with bradycardia showed significant improvement in isolation despite a significant improvement in overall compliance. Additionally, compliance with some criteria (bradypnea, tachypnea) remained low, even in the postintervention period. Bradypnea and tachypnea had the smallest postintervention sample sizes across all isolated, objective criteria, with only four and 20 patients, respectively. Additionally, the dropdown menu was limited to 10 options, including “other,” which were selected based on the frequency of patients presenting to this institution with the alert criteria. Respiratory rates were not included as a criterion on the dropdown menu due to their low frequency, although dispatchers were trained to identify these criteria and could trigger a corresponding alert via the “other” category. Consequently, it is plausible that dispatchers were less likely to identify these criteria as being met, given their lower frequency and absence from the dropdown menus.

Another important observation is that despite a significant increase in overall compliance, the rate of compliance with isolated, objective criteria reached only 79.3%. One possible explanation is that patients who present with a traumatic injury mechanism but
meet no other criteria aside from an abnormal vital sign, may seem less severely injured and more susceptible to a downgraded alert. Furthermore, the actual overall compliance rate at this institution for all patients could potentially be higher, as many patients fulfill multiple criteria and are therefore more likely to trigger TTA.

Previous research has pinpointed TTA criteria and compliance as potential areas for improvement in order to increase appropriate triage rates and decrease mistriage rates. However, changes in compliance with TTA criteria are seldom reported alongside mistriage rates. Tignanelli et al. [3] investigated these factors together and discovered that improved adherence to the ACS-COT minimum criteria led to a decrease in undertriage and an increase in overtriage. This study, however, analyzed only the six mandatory criteria. Many institutions heavily augment these criteria to better cater to their specific patient populations. Alternatively, many studies have individually tackled the question of which criteria, if any, should be added to the ACS-COT minimum criteria. The overarching goal of these studies is often to reduce undertriage. For instance, both Benjamin et al. [13] and Bardes et al. [26] advocated for the inclusion of age as a TTA criterion, while Schellenberg et al. [27] proposed a higher cutoff for the Glasgow Coma Scale TTA criteria in patients with a head injury. However, these studies had a limitation: each trauma center caters to a unique patient population, which may not all benefit equally from such changes in criteria.

Other studies have focused on enhancing compliance in order to improve the accuracy of triage rates. Stonko et al. [16] suggested a question-based system to boost adherence to existing alert criteria. In their single-center study involving 520 patients, the trauma activation protocol was modified from a PDF-based flow chart to an automated web tool. This tool guided dispatchers through a series of questions based on prehospital EMS data and automatically assigned a TTA level, resulting in a reduction of mistriage rates by over 50%. Notably, in that study, mistriage was defined as incorrect TTA leveling based on EMS data, a definition resembling that of non-compliance in the present study. While the intervention of Stonko et al. [16] shares mechanistic similarities with the workflow interventions discussed in our study, our research examines both compliance and triage patterns within a larger sample size and over a longer period.

In addition to triage patterns and compliance rates, clinical outcomes are a common metric among studies seeking to optimize trauma triage. Tignanelli et al. [3] described an association between increased compliance with the ACS-COT minimum criteria and decreased mortality. However, in the present study, no significant decrease in mortality was observed in the postintervention group. Moreover, we found an increase in the average length of stay in the emergency department for the postintervention group. This finding could potentially be attributed to the burden placed on this hospital by COVID-19. Throughout much of the latter half of 2021, the trauma center, the emergency department, and the hospital as a whole were functioning at an unusually high capacity.

At our institution, we have identified patterns of patients who are frequently overtriaged, and we have adjusted the TTA criteria to reflect these patterns. We are currently analyzing the impact of these changes. While undertriage is generally viewed as less desirable than overtage, it is well-known that overtage is linked to higher costs [28]. As a result of the observed changes in triage patterns, we anticipated and observed an increase in the percentage of full alerts (Table 3). In 2021, the cost of a full alert at this institution was $8,605. Therefore, the 10.8% increase in overtage rates in the postintervention group would have led to an estimated additional healthcare cost of approximately $1,901,430 over 7.5 months. By nature, triage involves a balancing act between overtage and undertriage. Each institution must evaluate and establish its own ideal balance to effectively cater to its unique patient population. In the end, we expect that a dual approach of improved compliance and adjusted alert criteria will help achieve optimal levels of appropriate triage and mistriage.

Limitations

This study had several limitations. First, we lacked a reliable method to determine which patients had their TTA level assigned through physician discretion within the trauma database or electronic health record. Physician discretion is a mandatory component of the minimum criteria for a full TTA, as per the ACS-COT minimum criteria [6]. In the newly implemented TTA system, hospital dispatchers contact a physician in cases of uncertainty about an incoming trauma patient. The physician can then manually assign the alert level. Likewise, a physician can upgrade or downgrade an alert after activation based on their clinical judgment. Future research may focus on developing a reliable method to examine the frequency of TTA due to physician discretion and evaluate its impact on triage patterns. Second, this study did not analyze nonobjective criteria, so we did not assess compliance with other criteria such as penetrating trauma proximal to the knee or mangled extremity. Given the complexity and subjective nature of many of these criteria, it was not feasible to assess compliance retrospectively within the trauma registry. Third, the data presented here were recorded during
the COVID-19 pandemic, with potential implications on the study population or the functioning of hospital processes. Fourth, the decision to activate a trauma team was based on information from the prehospital EMS environment, as is standard practice at trauma centers. Currently, no measure is available of how accurately this data corresponds to a patient’s clinical presentation upon arrival. However, barring EMS equipment failure, the objective alert criteria used in this study should have provided an accurate representation of the patient’s clinical condition at the time of the alert. Finally, all of the data were collected retrospectively, making the analysis potentially subject to errors in data entry or confounding variables.

Conclusions
The implementation of a technology-based alert system, driven by hospital dispatchers, was linked to a significant increase in compliance with existing TTA criteria. However, it also led to an unexpected decrease in appropriate triage due to a substantial rise in overtriage. Interestingly, the increased compliance with TTA criteria was associated with a decrease in undertriage rates, shifting our system from exceeding to falling below the target for optimal undertriage rates. The decline in appropriate triage, despite improvements in compliance, suggests that the current TTA criteria at this institution may not be sufficiently tailored to our patient population to achieve an optimal balance between minimizing both undertriage and overtriage. This observation underscores the importance of improved compliance as a crucial step in assessing the effectiveness of existing TTA criteria and will inform revisions to the current TTA criteria at this institution. Furthermore, future research may explore the relationship between compliance with TTA criteria and the provision of regular feedback to hospital dispatchers about their performance in assigning TTA levels using objective criteria.

ARTICLE INFORMATION

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

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

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

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Additional information
The preliminary data from this project was presented at the 2022 American College of Surgeons Annual Meeting, Virginia Chapter on April 29–30, 2022, at the Kingsmill Resort in Williamsburg, Virginia.

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Pediatric blunt pancreatic trauma at a single center in Korea: a retrospective review from 2007 to 2022

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Purpose: Blunt pancreatic trauma in pediatric patients is relatively rare, yet it is associated with high risks of morbidity and mortality. This study aimed to review pediatric patients with blunt pancreatic trauma treated at a single center and provide treatment guidelines.

Methods: This study included patients under the age of 18 years who visited our center’s pediatric emergency department and were diagnosed with pancreatic injury due to abdominal trauma via radiological examination between January 2007 and December 2022. Patients’ medical records were retrospectively reviewed and analyzed.

Results: Among 107 patients with abdominal trauma, 14 had pancreatic injury, with a median age of 8.2 years (interquartile range, 3.1–12.3 years). Eight patients were male and six were female. The most common mechanism of injury was falls from a height and bicycle handlebars (four cases each). Six patients had associated injuries. Two patients had American Association for the Surgery of Trauma grade I or II, eight had grade III, and four had grade IV or V injuries. Eight patients underwent surgical resection, and four were discharged with only an intervention for duct injuries.

Conclusions: Patients with blunt pancreatic trauma at our center have been successfully treated with surgical modalities, and more recently through nonsurgical approaches involving active endoscopic and radiologic interventions.

Keywords: Abdominal injuries; Wounds and injuries; Pancreas; Pancreatectomy
and is still a subject of debate. However, the most crucial factor is maintaining the integrity of the main pancreatic duct [6,7]. Depending on the location of the injury, surgical intervention may be required to excise the damaged section. Other techniques, such as endoscopic retrograde cholangiopancreatography (ERCP), have also been reported as effective treatment alternatives.

Nonoperative treatment is the mainstay of treatment for low-grade injuries. However, for injuries of grade III or higher that affect the main pancreatic duct, a variety of treatments have been employed, including nonoperative methods, drainage procedures, and surgical interventions [8–10].

Objectives
This study aimed to retrospectively review pediatric blunt pancreatic trauma patients treated at a single center, including the causes of their injuries, treatment methods, and outcomes, and to provide treatment recommendations for patients with blunt pancreatic trauma.

METHODS

Ethics statement
This study was approved by the Institutional Review Board of Seoul National University Hospital (No. 2302-108-1407). The requirement for informed consent was waived due to the retrospective nature of the study. This study was conducted in accordance with the principles of the Declaration of Helsinki.

Study design
We enrolled patients aged <18 years who presented to the pediatric emergency room at our hospital and were diagnosed with pancreatic injuries due to abdominal trauma between January 2007 and December 2022. Patients who underwent surgery or intervention for pancreatic injuries at other hospitals were excluded.

The medical records of these patients were retrospectively analyzed, and the following factors were examined: age, weight, sex, mechanism of injury, accompanying injuries to other organs, Pediatric Traumatic Score (PTS), Injury Severity Score (ISS), Glasgow Coma Scale, vital signs at the time of emergency room admission, initial laboratory data, transfer status from other hospitals, use of imaging or endoscopic interventions, whether surgery was performed or not, type of surgery, length of hospital stay, length of intensive care unit (ICU) stay, early and late complications, and mortality. The data of all patients were collected. For the analysis, patients were divided into those who underwent surgery and those who did not undergo surgery, and the details of their treatment were analyzed. The pancreatic injury grade was defined according to the American Association for the Surgery of Trauma (AAST) scale and ranged from minor (grade I) to devastating (grade V).

Statistical analysis
Statistical analyses were performed using IBM SPSS ver. 20.0 (IBM Corp). Means and standard deviations or medians with interquartile ranges are provided for continuous variables. Categorical variables were calculated as percentages. The patients were compared according to whether or not they underwent surgery. Comparisons between categorical variables were performed using the Kruskal-Wallis test because of the nonparametric nature of the data. A P-value < 0.05 was considered statistically significant.

RESULTS

During the study period, out of 107 patients suffering from abdominal trauma, 14 were hospitalized for treatment of confirmed pancreatic injuries. These injuries, identified via computed tomography, included parenchymal fractures, lacerations, pancreatic edema, hematomas, active bleeding, and fluid accumulation between the splenic vein and the pancreas. The median age of the patients with pancreatic injuries was 8.2 years (interquartile range, 3.1–12.3 years), and they consisted of eight boys and six girls. Of these patients, eight underwent surgical procedures (Table 1).

The most frequent causes of injury were falls from heights and bicycle accidents, each responsible for four cases. These were followed by incidents involving pedestrians and passengers in traffic accidents, each contributing two cases. One case of child abuse was reported, where the injury resulted from a father’s kick and the child being crushed by soccer goalposts. The mechanism of injury did not differ between patients who required surgery and those who did not.

In total, six patients presented with associated injuries, of whom three had more than two injuries in addition to their pancreatic damage. Within the abdominal cavity, two instances of liver injury and one instance of splenic injury were observed. There were also three cases of limb fractures, two instances of thoracic injuries, and one instance of head or facial injury.

The median PTS was 11, while the median ISS was 9; these figures were not associated with the decision to perform surgery.
Out of the 14 patients in question, 13 (92.9%) were transferred to other medical facilities.

Two patients were classified as AAST grade II or lower, eight were grade III, three were grade IV, and one was grade V. A sequential evaluation of these patients showed that the initial eight patients with injuries of grade III or higher (from 2007–2011) all received surgical treatment. One patient with severe injuries underwent radiological interventions, including percutaneous catheter drainage (PCD) insertion and arterial embolization, both before and after surgery (Table 2). Two patients with grade I injuries were admitted and monitored for 2 and 9 days, respectively, before subsequent discharge without requiring any additional treatment. Four patients who sustained injuries of grade III or higher after 2014 showed improvement and were discharged following intervention and conservative treatment. The duration of hospital stays for all patients varied from 2 to 49 days, and 12 patients required admission to the ICU for periods ranging from 1 to 16 days. There were no fatalities among the patients.

In patients who had surgery, two individuals with proximal injuries underwent a pylorus-preserving pancreaticoduodenectomy (PPPD), while distal pancreatectomy was performed on those with distal injuries (Table 3). Of the two patients who sustained liver injuries, one only required bleeding control, while the other, who had nearly severed the S2 segment, underwent an S2 segmentectomy. All surgical procedures were carried out via laparotomy. One patient encountered early complications (ileus) 2

<table>
<thead>
<tr>
<th>Table 1. Patient demographics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic</strong></td>
</tr>
<tr>
<td>Age at trauma (yr)</td>
</tr>
<tr>
<td>Body weight at trauma (kg)</td>
</tr>
<tr>
<td>Male sex</td>
</tr>
<tr>
<td>Mechanism of injury</td>
</tr>
<tr>
<td>Bicycle accident</td>
</tr>
<tr>
<td>Pedestrian in MVA</td>
</tr>
<tr>
<td>MVA (on board)</td>
</tr>
<tr>
<td>Assault (child abuse)</td>
</tr>
<tr>
<td>Run over</td>
</tr>
<tr>
<td>Associated injury</td>
</tr>
<tr>
<td>Spleen</td>
</tr>
<tr>
<td>Extremity</td>
</tr>
<tr>
<td>Thorax</td>
</tr>
<tr>
<td>Head and neck</td>
</tr>
<tr>
<td>Pediatric Traumatic Score</td>
</tr>
<tr>
<td>Injury Severity Score</td>
</tr>
<tr>
<td>Glasgow Coma Scale score</td>
</tr>
<tr>
<td>Vital sign at ED</td>
</tr>
<tr>
<td>Pulse (beats/min)</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
</tr>
<tr>
<td>Body temperature (°C)</td>
</tr>
<tr>
<td>Initial laboratory value</td>
</tr>
<tr>
<td>pH</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
</tr>
<tr>
<td>Amylase (U/L)</td>
</tr>
<tr>
<td>Lipase (U/L)</td>
</tr>
<tr>
<td>Transfer to other hospital</td>
</tr>
<tr>
<td>Radiological intervention</td>
</tr>
</tbody>
</table>

Values are presented as median (interquartile range), number (%), or mean ± standard deviation. NOM, nonoperative management; OM, operative management; MVA, motor vehicle accident; ED, emergency department.
A radiologic or endoscopic intervention was performed in patient 1 and in all patients who did not undergo surgery. Three patients underwent PCD insertion, while endoscopic retrograde pancreatic drainage (ERP) insertion via ERCP was performed on two patients. Subsequently, embolization was performed (Table 4). Notably, patients 12 and 14 sustained injuries to the head of the pancreas. However, they were discharged without any complications following intervention or supportive management. Since then, no early or late complications have been identified.

### DISCUSSION

In our study, pancreatic injury was confirmed in 14 of 107 pediatric patients with abdominal trauma. These patients visited our hospital over a span of 16 years. This finding is not significantly different from other studies or meta-analyses, which reported pancreatic injuries in 13.1% of total patients [10,11]. Among these patients, 42.9% had concurrent injuries to other organs in the abdominal cavity, limbs, chest, and so on. This aligns with other studies that have reported that pediatric pancreatic injuries often coincide with other injuries [10,11]. Generally, the mortality rate for pediatric blunt pancreatic injury is reported to be around 5%. However, in our study, we did not report any deaths [2,11,12]. This could be due to the small patient sample size, but it could also be seen as a testament to the role our hospital plays as a tertiary referral hospital in Korea.

The primary causes of injury were falls and accidents involving bicycle handlebars. This study differed from others because it did not include any incidents related to gunshots, which can be attributed to the restricted ownership of firearms in Korea. The significant number of injuries resulting from bicycle and car accidents, as well as falls, aligns with findings from other reports on injury mechanisms [9,13,14].

In this study, we compared patients who underwent surgical treatment with those who did not. Upon examining the demographic data, no discernible differences were found between the two groups, nor were there any differences in the mechanisms of injury. There were no significant findings in either vital signs or initial laboratory data, which could potentially be attributed to the small patient sample size. However, it is worth noting that all instances of surgery were carried out early in the enrollment pe-

---

**Table 2. Summary of patients (chronological order)**

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Injury</th>
<th>Mechanism of injury</th>
<th>Serum pancreatic amylase (U/L)</th>
<th>Serum lipase (U/L)</th>
<th>Injured area of pancreas</th>
<th>Injury grade</th>
<th>ISS</th>
<th>ICU stay (day)</th>
<th>Operation</th>
<th>LOS (day)</th>
<th>Clinical course</th>
<th>Interventions</th>
<th>Survival</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>Male</td>
<td>Bicycle accident</td>
<td>Bicycle accident</td>
<td>1,085</td>
<td>56</td>
<td>Head, body</td>
<td>IV</td>
<td>34</td>
<td>11</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embolization</td>
<td>Alive</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>Male</td>
<td>Falls from height</td>
<td>Falls from height</td>
<td>264</td>
<td>184</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>16</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>Male</td>
<td>Bicycle accident</td>
<td>Bicycle accident</td>
<td>1,085</td>
<td>56</td>
<td>Head, body</td>
<td>IV</td>
<td>34</td>
<td>10</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>Male</td>
<td>Bicycle accident</td>
<td>Bicycle accident</td>
<td>2,150</td>
<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>16</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
<td>No</td>
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<tr>
<td>5</td>
<td>7</td>
<td>Male</td>
<td>Bicycle accident</td>
<td>Bicycle accident</td>
<td>2,150</td>
<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>16</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>7</td>
<td>Female</td>
<td>Falls from height</td>
<td>Falls from height</td>
<td>1,350</td>
<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>10</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
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<tr>
<td>7</td>
<td>7</td>
<td>Female</td>
<td>Falls from height</td>
<td>Falls from height</td>
<td>1,350</td>
<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>10</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
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<tr>
<td>8</td>
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<td>Female</td>
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<td>Falls from height</td>
<td>1,350</td>
<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>10</td>
<td>No</td>
<td>10</td>
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<td>Embo.</td>
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<td>Falls from height</td>
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<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>10</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
<td>No</td>
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<tr>
<td>10</td>
<td>7</td>
<td>Male</td>
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<td>Bicycle accident</td>
<td>2,150</td>
<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>10</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
<td>No</td>
</tr>
<tr>
<td>11</td>
<td>7</td>
<td>Male</td>
<td>Bicycle accident</td>
<td>Bicycle accident</td>
<td>2,150</td>
<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>10</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
<td>No</td>
</tr>
<tr>
<td>12</td>
<td>7</td>
<td>Male</td>
<td>Bicycle accident</td>
<td>Bicycle accident</td>
<td>2,150</td>
<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>10</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
<td>No</td>
</tr>
<tr>
<td>13</td>
<td>7</td>
<td>Male</td>
<td>Bicycle accident</td>
<td>Bicycle accident</td>
<td>2,150</td>
<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>10</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
<td>No</td>
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<tr>
<td>14</td>
<td>7</td>
<td>Female</td>
<td>Falls from height</td>
<td>Falls from height</td>
<td>1,350</td>
<td>10</td>
<td>Head, body</td>
<td>IV</td>
<td>12</td>
<td>10</td>
<td>No</td>
<td>10</td>
<td>Yes</td>
<td>Embo.</td>
<td>Alive</td>
<td>No</td>
</tr>
</tbody>
</table>

**Note:** ISS, Injury Severity Score; PTS, Pediatric Trauma Score; LOS, length of stay; ICU, intensive care unit; MVA, motor vehicle accident.

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According to the American Association for the Surgery of Trauma classification.
Table 3. Summary of operative findings

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Procedure name</th>
<th>Time from injury to operation (day)</th>
<th>Operation year</th>
<th>Operation time (min)</th>
<th>EBL (mL)</th>
<th>Early complication</th>
<th>Late complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>Male</td>
<td>PPPD, liver bleeding control</td>
<td>83</td>
<td>2007</td>
<td>Open</td>
<td>365</td>
<td>280</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>Male</td>
<td>Spleen-preserving DP</td>
<td>6</td>
<td>2007</td>
<td>Open</td>
<td>230</td>
<td>300</td>
<td>Ileus</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Female</td>
<td>Spleen-preserving DP</td>
<td>0</td>
<td>2008</td>
<td>Open</td>
<td>75</td>
<td>300</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>Male</td>
<td>Spleen-preserving DP, liver S2 segmentectomy</td>
<td>0</td>
<td>2008</td>
<td>Open</td>
<td>120</td>
<td>600</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
<td>Female</td>
<td>PPPD</td>
<td>2</td>
<td>2010</td>
<td>Open</td>
<td>320</td>
<td>100</td>
<td>Ileus</td>
</tr>
<tr>
<td>6</td>
<td>11</td>
<td>Female</td>
<td>DP</td>
<td>2</td>
<td>2010</td>
<td>Open</td>
<td>155</td>
<td>-</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>Male</td>
<td>Spleen-preserving DP</td>
<td>1</td>
<td>2011</td>
<td>Open</td>
<td>265</td>
<td>130</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>Female</td>
<td>DP</td>
<td>0</td>
<td>2011</td>
<td>Open</td>
<td>215</td>
<td>210</td>
<td>None</td>
</tr>
</tbody>
</table>

EBL, estimated blood loss; PPPD, pylorus-preserving pancreaticoduodenectomy; DP, distal pancreatectomy.

Table 4. Summary of radiologic and endoscopic interventions

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Procedure name</th>
<th>Intervention year</th>
<th>Injured area of pancreas</th>
<th>Injury grade</th>
<th>Early complication</th>
<th>Late complication</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8</td>
<td>Male</td>
<td>PCD insertion, gastroduodenal artery embolization</td>
<td>2007</td>
<td>Head</td>
<td>IV</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>Male</td>
<td>ERPD insertion with ERCP</td>
<td>2014</td>
<td>Body</td>
<td>III</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>Male</td>
<td>PCD insertion</td>
<td>2016</td>
<td>Head, body</td>
<td>IV</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>13</td>
<td>6</td>
<td>Male</td>
<td>PCD insertion</td>
<td>2022</td>
<td>Tail</td>
<td>III</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>14</td>
<td>12</td>
<td>Female</td>
<td>ERPD insertion with ERCP</td>
<td>2022</td>
<td>Head</td>
<td>V</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

PCD, percutaneous catheter drainage; ERPD, endoscopic retrograde pancreatic drainage; ERCP, endoscopic retrograde cholangiopancreatography.

According to the American Association for the Surgery of Trauma classification.

period, suggesting a possible evolution in treatment methods over time. All eight patients who underwent surgery did so prior to 2012, a time when the hospital was not actively employing radiologic or endoscopic interventions for pediatric trauma patients. Consequently, any differences in demographic and clinical characteristics between the surgical and nonsurgical groups could not be definitively determined.

In the analysis of surgical patients, all patients underwent open surgery. PPPD was performed for injuries to the head of the pancreas, while distal pancreatectomy was used for injuries below the neck. In instances of concurrent splenic vascular damage, the spleen was removed. While the surgical treatment of AAST grades III to VI pancreatic trauma in adults is well understood, there has been less discussion regarding surgical intervention in pediatric patients. However, there have been reports of pancreatic duct recanalization in children who have experienced complete pancreatic transection [13,15]. For class II distal duct injuries, the preferred approach is distal pancreatectomy, with the preservation of the spleen and blood supply. Previous studies conducted early spleen-sparing distal pancreatectomies in eight out of 18 children with distal duct injuries, and they advocate for this treatment as the preferred method [1,13].

Both operative and nonoperative management strategies have been used to treat pediatric patients with pancreatic trauma. Recent studies have highlighted the effectiveness of nonsurgical management in these cases. In 2021, Ishikawa et al. [9] reported that early endoscopic retrograde pancreatography with stent placement or endoscopic nasopancreatic drain (ENPD) insertion proved beneficial in 10 patients with pancreatic duct injuries. This aligns with the findings of a prior study that successfully utilized stent placement via ERCP in three patients [8]. A multicenter study conducted in 2017 analyzed the treatment outcomes of patients with grades III to V injuries, suggesting that nonsurgical management could be effective if initial enzyme levels and associated symptoms were taken into account. This study also established the presence of a standard clinical pathway related to this treatment strategy [16]. Our study’s findings align with these results, as we successfully treated four patients with grades III to V injuries using nonsurgical management. These results seem to contradict the assertion made by Mattix et al. [4] that high ISS and injury grades III to V are indicators of nonsurgical management failure. However, this discrepancy could be due to advances
in pediatric interventions and shifts in treatment paradigms from 2007 to the present.

Simple external drainage is often recommended as the standard surgical procedure for treating contusions or small lacerations when there appears to be no or minor ductal injury during nonoperative management [3,17]. Moreover, even when ERCP is unsuccessful, there are reports of effective nonsurgical treatment through appropriate drainage [18]. In this study, we successfully treated patients with multiple injuries to the pancreas and tail using PCD insertion and tube check procedures. Notably, patient 12, who suffered damage to the head and body from a bicycle handlebar accident, was difficult to treat with stent insertion even with ERCP. However, through two PCD insertions and changes in tube location, we were able to treat the patient conservatively, and they were discharged without any complications. To establish clear treatment guidelines for pediatric pancreatic trauma, we suggest conservative treatment, which includes hospitalization, fluid resuscitation, and close monitoring, for AAST grades I and II. For grade III or higher injuries, surgical intervention may be considered at medical institutions equipped for such procedures. However, if endoscopic and radiological interventions are available, damage control can be achieved through interventions such as ERCP for ERPD and ENPD, and PCD insertion. By closely monitoring symptom improvement, successful nonsurgical management can be accomplished.

Limitations
A limitation of this study is that it presents the results of a retrospective analysis conducted on a relatively small patient group from a single institution. In the future, a comprehensive analysis of treatment outcomes, facilitated by a multicenter registry, will be required. This necessitates the development of a nationwide registry for pediatric patients who have experienced abdominal trauma. It is also crucial to establish a cohort system and gather prospective data. Consequently, it is essential to create a treatment protocol specifically for pediatric patients with traumatic pancreatic injuries.

Conclusions
This case series examines the clinical characteristics and treatment outcomes of pediatric patients with traumatic pancreatic injuries at a single institution. The majority of patients transferred from other hospitals were effectively treated through either surgical or nonsurgical means. For patients with grades I and II pancreatic injuries, conservative treatment typically proves effective and results in positive outcomes. However, for more severe injuries (grade III or higher), determining whether surgical or nonsurgical treatment is more advantageous is challenging based solely on these data. These patients can be treated with minimal complications, whether the chosen treatment method is surgery or endoscopic or radiologic intervention.

ARTICLE INFORMATION

Author contributions
Conceptualization: JKY, HYK; Data curation: HBY; Formal analysis: JKY, DK; Methodology: JKY, HYK; Writing–original draft: JKY, HBY; Writing–review & editing: JKY, HBY, DK, HYK; All authors read and approved the final manuscript.

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

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

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Management of a trauma patient with alcohol withdrawal who developed neuroleptic malignant syndrome in Korea: a case report

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Neuroleptic malignant syndrome (NMS) is a rare but fatal condition, with a high mortality rate. NMS is characterized by altered mental status, fever, myoclonus, autonomic dysfunctions, and elevated creatinine phosphokinase. The clinical manifestations may be confused with alcohol-related symptoms, trauma, sepsis, postoperative agitation, or malignant hyperthermia. A 69-year-old male patient with alcohol withdrawal was admitted to the operating theatre to rule out septic shock due to mesenteric injury after multiple trauma. He was suspected NMS with abrupt increase body temperature to 41.7°C after haloperidol administration. Active cooling and rapid fluid infusion was done during anesthesia. Delayed diagnosis and treatment of NMS lead to catastrophic result. Therefore, if the patient’s past medical history is unknown or clinical symptoms develop that are suggestive of NMS, early treatment must be considered.

Keywords: Alcohol withdrawal delirium; Neuroleptic malignant syndrome; Wounds and injuries; Case reports

INTRODUCTION

Neuroleptic malignant syndrome (NMS) may be confused with several medical conditions that occur during the perioperative period and may be overlooked. NMS is characterized by altered mental status, fever, myoclonus, autonomic dysfunctions, and elevated creatinine phosphokinase (CK) [1]. NMS is an uncommon condition, with an incidence of 0.01% to 3% in patients taking neuroleptic agents. However, the mortality is as high as 5% to 20% [2]. The mechanism of NMS has not been clearly elucidated. One explanation is that the blockage of central dopamine receptors in the hypothalamus causes symptoms related to dysautonomia, including hyperthermia [3]. Blocking of the nigrostriatal dopamine pathways induces rigidity or tremor [3].

Haloperidol is a first-generation antipsychotic drug that is frequently used to prevent and treat postoperative delirium [4]. Haloperidol is also used to treat agitation caused by alcohol abuse [5]. Importantly, the use of antipsychotic agents to treat delirium...
or agitation can cause NMS [6].

Here, we describe the management of a patient with alcohol withdrawal who had trauma surgery under general anesthesia and developed NMS after haloperidol use, along with a literature review.

CASE REPORT

A 69-year-old male patient (170 cm, 76 kg) was placed in the operating room for an emergency laparotomy. The patient had been on medication for diabetes and hypertension. He has also been medicated for major depressive disorder for 20 years but did not remember the name of his medication. Six years ago, the patient had a history of cranioplasty due to a fall during a suicide attempt. He was recently admitted to a psychiatric hospital for the treatment of alcoholism. The patient had been drinking almost every day for 30 years. At that hospital, the patient was given lorazepam. On the day of the transfer to Gachon University Gil Medical Center (Incheon, Korea), the patient was given lorazepam and haloperidol as he was irritable and aggressive. He was transferred to our hospital, a level I trauma center, following trauma due to the patient breaking a window of the first-floor ward and jumping out. The patient had multiple rib fractures without dyspnea, and hemoperitoneum was suspected. Diagnostic laparoscopy was performed in the operating room under general anesthesia to differentiate the intraabdominal damage. Bleeding control of the mesenteric injuries was conducted. The patient’s vital signs were stable, and he was admitted to the general ward after surgery. The patient’s systolic blood pressure was relatively stable at 120 to 130 mmHg, heart rate was 110 to 120 beats/min, body temperature was 36.5 °C, and oxygen saturation (SpO₂) was 95% to 98%. The patient’s CK level was 515 U/L. On postoperative day 1, the patient was irritable. His SpO₂ intermittently decreased to 80%–90%. His body temperature was 37.4 to 37.7 °C. Hence, the patient was provided with oxygen 5 to 8 L/min via a facial mask. Lorazepam and haloperidol were administered. Subsequently, the patient’s consciousness was lowered, and his vital signs were as follows: blood pressure of 133/60 mmHg, heart rate of 115 beats/min, SpO₂ of 83%, despite oxygen supply with tachypnea. The patient’s body temperature abruptly increased to 41.5 °C and he was sweating. The patient was transferred to the intensive care unit, and tracheal intubation was performed after using midazolam and vecuronium. To exclude the septic shock due to his intraabdominal injury, an emergency laparotomy was performed. In the operating room, the patient’s vital signs measured as follows: blood pressure of 115/59 mmHg, heart rate of 163 beats/min, SpO₂ of 96%, and body temperature of 41.7 °C. He was sweating excessively. The color of his urine was dark. In the operating room, midazolam 2 mg and rocuronium 50 mg were administered after standard anesthetic monitoring, and controlled ventilation was initiated. Central catherization was performed in the right internal jugular vein, and a radial arterial line was inserted. Arterial blood gas analysis revealed a pH of 7.34, PaCO₂ of 36 mmHg, and PaO₂ of 72 mmHg in fraction of inspired oxygen (FIrO₂) of 0.8, K⁺ of 5.2 mmol/L, and hematocrit of 35%. Cooling was initiated with a cold blanket, and normal saline and 6% hydroxyethyl starch were administered at a rapid rate. Anesthesia was maintained with sevoflurane (0.3–1.0 vol%) for a target bispectral index of 50 to 60. No intraabdominal lesions were detected during surgery. At the end of the 45-minute operation, the patient’s vital signs were as follows: blood pressure of 120/46 mmHg, heart rate of 115 beats/min, SpO₂ of 100%, and esophageal temperature of 37.7 °C. The arterial blood gas analysis indicated a pH of 7.33, PaCO₂ of 36 mmHg, PaO₂ of 153 mmHg in FIO₂ of 0.8, K⁺ of 3.4 mmol/L, and hematocrit of 24%. The total infused fluid volume was 1,800 mL, and the urine output was 140 mL. There were no specific findings on brain or abdominal computed tomography. The immediate postoperative CK was 2,004 U/L, and the white blood cell count was 17,130/ mm³. The patient was alert the next day. His systolic blood pressure was maintained at 110 to 150 mmHg. His heart rate was 90 to 110 beats/min. His body temperature was 37.5 to 37.8 °C. His SpO₂ was 96% to 100%. As the vital signs were stable, the patient was extubated. Thyroid function tests, including T3, free T4, and thyroid-stimulating hormone, were normal. The patient’s condition remained stable during his hospital stay. He was transferred to a psychiatric hospital on postoperative day 4.

Ethics statement

The study was approved by the Institutional Review Board of Gachon University Gil Medical Center (No. GCRIB2022-130). The requirement for informed consent was waived because this was a retrospective review conducted using medical records.

DISCUSSION

In this case, although the patient has some complex situations that can be confusing with alcohol withdrawal, sepsis, injury for trauma, and postoperative delirium, there were clear findings suggestive of NMS. Despite symptoms such as confuse mentality, decreased oxygen saturation, tachycardia, fever, and increased CK level might appear in all of the above-mentioned situations,
an abrupt and extreme high fever after use of neuroleptic drug strongly suggest NMS. Also, proper imaging studies, surgical observations, and laboratory test helped to rule out other diagnoses that could be confused with NMS and provided a basis for convincing that it was NMS.

Alcohol withdrawal mimics NMS with characteristic hyperadrenergic responses, altered mentality, rigidity, and elevated CK [7]. However, the mechanism is distinct from that of NMS. Chronic alcoholism causes downregulation of the γ-aminobutyric acid receptors and upregulation of the N-nitrosodimethylamine receptors with increased glutamate production [8]. When alcohol intake is abruptly reduced, hyperadrenergic responses occurred, as the changes from these activities are unmasked and glutamate-mediated central nervous system excitation increases [8]. The conjugation of haloperidol and benzodiazepine is commonly prescribed for alcohol-related agitations [5]. In our patient, a combination of lorazepam and haloperidol was administered to control agitation in both the psychiatric hospital and our trauma center, leading to NMS.

Treatment of NMS begins with the discontinuation of the causative agent, followed by supportive care [5]. Supportive care consists mainly of cooling to improve hypothermia and hydration to prevent renal injury due to rhabdomyolysis [9]. Bromocriptine, a dopamine D2 receptor agonist, and dantrolene, a muscle relaxant, are useful medical treatment options [10]. In particular, dantrolene is used in emergencies during general anesthesia. It is a familiar drug that is used with caution by anesthesiologists because it causes malignant hyperthermia (MH). MH is characterized by a rapid increase in body temperature, abrupt increase of the end-tidal carbon dioxide concentration, tachycardia, hyperkalemia, and elevated CK. MH is an autosomal dominant disease triggered by inhalation anesthetics or depolarizing neuromuscular blocking agents [11]. If the patient in this case developed the above symptoms during anesthesia, most anesthesiologists would suspect MH rather than NMS, and would not hesitate to use dantrolene. In this case, the patient had no specific event during the previous surgery and no family history of MH. His symptoms aggravated after the administration of haloperidol in the ward. As a result, MH was excluded. Moreover, the patient’s response to cooling was good, and the end-tidal carbon dioxide concentration was within normal limits. The body temperature was corrected quickly, and tachycardia was corrected smoothly and in line with volume replacement. Therefore, for our patient, the use of additional dantrolene was not considered.

The use of dantrolene in NMS is controversial. Treatment with dantrolene and other drug combinations may delay clinical recovery. Moreover, dantrolene monotherapy increases the mortality risk [12]. Therefore, dantrolene should not be used for the routine management of NMS, although it should be considered as a treatment option if NMS arises.

The risk of NMS is increased in patients using selective serotonin reuptake inhibitors. This is because serotonin inhibits dopamine release and enhances the hypodopaminergic status induced by antipsychotics [13]. In this case, although the exact drug is unknown, the patient had been taking an antidepressant for a long time. It is known that tricyclic antidepressants can also cause NMS. As such, for patients with a history of antidepressant medications, there is a risk of NMS [14].

When looking after patients who are confused, such as our patient, the patient’s underlying and/or chronic diseases or drug history may not be accurately provided to the clinicians. Head injury or sepsis may show similar symptoms to NMS. Therefore, these should be considered and excluded [10].

NMS was a rare clinical situation. Traditionally, the mortality rate of NMS was more than 25% [15]. Although the mortality rate has recently improved, it remains relatively high [15]. Early detection and timely active treatment can lead to full recovery within 2 to 14 days. In contrast, delayed recognition of NMS may lead to severe renal and cardiovascular morbidity and mortality [15].

In conclusion, NMS and alcohol withdrawal symptoms or postoperative agitation have similar clinical presentations. This similarity may delay the diagnosis and treatment of NMS. Additionally, traumatic symptoms may mask the manifestations of NMS. Therefore, if the patient’s past medical history is unknown or clinical symptoms develop that are suggestive of NMS such as extreme high fever after exposure to dopaminergic blocking agent, muscle rigidity, altered mentality, autonomic irritability, excessive increase in CK level, early treatment must be considered.

ARTICLE INFORMATION

Author contributions
Conceptualization: all authors; Data curation: YYJ; Methodology: all authors; Project administration: all authors; Visualization: YYJ; Writing–original draft: BY, JYL, YYJ; Writing–review & editing: YBK, HYP, JJ, YYJ. All authors read and approved the final manuscript.

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

REFERENCES

Penetrating right ventricular injury following a single gunshot to the left flank in Iraq: a case report

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2Shorsh Military Teaching Hospital, As Sulaimaniyah, Iraq

INTRODUCTION

A century ago, cardiac injuries usually resulted in death. However, despite all the advances in medicine, these injuries still have high mortality and morbidity rates. In the present case, we describe a patient with a bullet injury to the right ventricle who survived at our hospital despite the limitations of our center with regard to modalities and equipment. A 30-year-old man was brought to our emergency department with a bullet wound to his left flank. He was hemodynamically unstable. After only 8 minutes in the hospital and without further investigations he was rushed to the operating room. During laparotomy, a clot was visible in the left diaphragm, which dislodged and caused extensive bleeding. The decision was made to perform a sternotomy in the absence of a sternal saw. An oblique 8-cm injury to the right ventricle was discovered following rapid exploration. It was repaired without the need for cardiopulmonary bypass surgery. After a few days in the hospital, the patient was discharged home. In the event of a penetrating cardiac injury, rapid decision-making is crucial for survival. Whenever possible, the patient should be transferred to the operating room, as emergency department thoracotomies are associated with a high mortality rate.

Keywords: Penetrating cardiac injury; Gunshot; Heart ventricles; Emergency department thoracotomy; Case reports
described throughout history, cardiac injuries are complex and need highly specialized centers to receive the best possible treatment. We report the case of a patient who survived at Shar Teaching Hospital despite the lack of proper diagnostic and therapeutic modalities to deal with cardiac injuries.

CASE REPORT

On August 30, 2022, a 30-year-old man was brought to our emergency department following a bullet injury to his left flank. The accident happened at a location about 10 minutes away from the hospital. At the scene, he had developed cardiac arrest, as reported by his friend who was a paramedic in the police department, and cardiopulmonary respiration was started immediately. The patient was immediately brought to the hospital without waiting for an ambulance.

On arrival, the patient was conscious, dyspneic, agitated, and pale. The vitals included a blood pressure of 85/55 mmHg, an oxygen saturation of 88% without an oxygen mask, and a pulse rate of 114 beats/min. The patient was in stage III hemorrhagic shock.

The patient was managed according to the principles of Advanced Trauma Life Support. On inspection of the trunk, there was a wound in the right parasternal region at the third intercostal, with a round irregular outline (Fig. 1A). There was no sucking air and no paradoxical movement. There was almost no air entry on the right side of the chest. We noted mild subcutaneous emphysema and tenderness on palpation. Immediate tube thoracostomy was commenced. An air leak was present with no drainage of blood.

On examination of the abdomen, there was a small (approximately 1 cm) round wound on the left flank (midaxillary line) with tattooing around the edges (Fig. 1A). The abdomen was rigid on palpation. There were no other associated injuries. A focused assessment with sonography for trauma (FAST) scan was negative at the time of the initial assessment.

The decision to perform emergency exploratory laparotomy and sternotomy or thoracotomy was based on a clinical examination and the general condition of the patient. A massive transfusion protocol was followed, and the patient was transferred to the operating room. The vital signs improved, and the patient became hemodynamically stable. With the exception of a FAST scan, no imaging was done.

Intraoperatively, under general anesthesia, the patient was intubated. The general surgery team started with their laparotomy while the cardiothoracic team was on standby. After the peritoneum was opened, 200 mL of blood was drained. Upon examination, a 2-cm injury to the greater curvature of the stomach and a 3-cm injury to the left dome of the diaphragm was found. No other intraabdominal organ was injured according to a systematic check. There was no retroperitoneal hematoma. The patients’ vitals were stable, so the general surgery team commenced

![Intraoperative photos. (A) Two wounds on the patient’s inlet (black arrow) and outlet (blue arrow). (B) Repaired injury to the anterior wall of stomach. (C) A clot in the left hemidiaphragm (black arrow) after the initial injury to the diaphragm.](https://doi.org/10.20408/jti.2022.0073)
with the repair of the stomach (Fig. 1B). After completing the repair of the stomach, a clot dislodged from the left dome of the diaphragm and severe bleeding from the injury filled the abdomen (Fig. 1C).

Immediate median sternotomy was started by the cardiothoracic team. The central tendon of the diaphragm was also simultaneously opened to find and control the source of bleeding with pressure. The sternum was opened using a hammer and chisel, which were the only tools available at the emergency department. It took less than a minute. After the pericardium was opened, an obvious right ventricular defect was identified. There was no bleeding because of the light manual pressure exerted by one of the cardiothoracic surgeons (Fig. 2A). The injury was an 8-cm oblique linear defect on the anterior aspect of the right ventricle, not extending to the right coronary artery.

Primary repair of the injury was performed without putting the patient on bypass, since no bypass facilities were available. In addition, a small left parenchymal injury was identified at the left lower lobe of the lung. It was repaired and the blood drained from the left side of the thorax (Fig. 2B). The right third and fourth ribs were partially fractured 2 cm lateral to the sternal edge. No other intrathoracic injuries were found. Chest drains were placed in the mediastinum and the left pleura. The diaphragm injury was also repaired. After proper hemostasis and another systematic check of the thorax and abdomen were done to exclude any other missed injuries and the presence of surgical material, the sternotomy and laparotomy were closed. A corrugate drain was left in the abdomen. The patient was subsequently transferred to the intensive care unit. After 24 hours, the patient was hemodynamically stable. Blood gases were normal, and the patient was extubated successfully.

After being discharged from the intensive care unit after 48 hours, all the vital signs were stable, and the patient’s only complaint was mild right-side chest pain. Echocardiography showed good cardiac contractility with no collection in the mediastinum. Ultrasonography showed no collections in the pleural spaces. The patient stayed in the cardiothoracic ward for 5 days. On day 4, the chest tubes were removed. He was then discharged safely.

Ethics statement
The study was approved by the Ethical Committee of Shar Teaching Hospital (No. 11489). The patient provided written informed consent for publication of the research details and clinical images.

DISCUSSION

Depending on the presentation, cardiac injuries can be classified into five categories as defined by Saadia et al. [6]: lifeless, critically unstable, cardiac tamponade, thoracoabdominal injuries, and benign presentation. Thoracoabdominal injuries are defined as being in the epigastrium. These injuries are usually masked by the intraabdominal injury in which the abdomen is accessed first [6].

Our patient presented with a gunshot to the left flank and was first dealt with by the general surgery team. One of the most important considerations is the prehospital management of penetrating cardiac injuries. It is paramount that the retrieval time of a patient to a hospital be rapid enough that even proper resuscitation be postponed if it causes delay. This might offer better chances of survival, with less than 10 to 12 minutes being a good predictor [1,7].

Before the advent of ultrasonography, cases with suspected cardiac injury were diagnosed and managed using a subxiphoid pericardial window. Ultrasonography of the pericardium showed to be a significant modality even in unstable patients, with sensitivity reaching close to 100% for pericardial effusion at some centers [8]. In a case series by Patel et al. [9], ultrasonography performed by the surgeons had a sensitivity of 87%. In our patient, a FAST scan was the only investigation performed. It turned out to be negative.

The decision of the preferred incision in penetrating cardiac injury depends on the available surgical modalities, surgical experience, and type of injury. Both thoracotomy and sternotomy are options, and their significance varies based on the factors previously mentioned [10]. We performed a sternotomy because the

Fig. 2. Intraoperative pictures 2. (A) A right ventricular injury controlled with one’s finger. (B) The left lower lobe injury after repair.
patient was prepared for a laparotomy and the source of bleeding indicated a cardiac origin. With one hand to control the bleeding, an immediate sternotomy was performed.

According to the literature, in penetrating cardiac injuries, the most common site of injury is the right ventricle, followed by the left ventricle [5]. Another important consideration is the presence of concomitant coronary artery injury. This usually carries a very high mortality rate (up to 50%) and requires emergent cardiopulmonary bypass. The most common injury is to the left anterior descending artery [5]. These are considered complex injuries. They can also be associated with valvular and septal injuries, which manifest as tamponade, hemothorax, and echocardiographic changes [3,11].

Surgery on a beating heart is difficult and requires patience and extensive surgical experience. This is especially true if there is an injury to the coronary arteries that requires revascularization [12]. Fortunately, our patient had no associated coronary artery injury, as visualized in Fig. 3.

The survival of such patients also depends on the type and place of operation. Emergency department thoracotomy carries a high mortality rate (near 95%). Operating room thoracotomy, in contrast, has a 64% chance of survival [7]. The presence of an intraabdominal injury and field cardiopulmonary resuscitation are independent risk factors for mortality [7].

In conclusion, for patients presenting with a penetrating injury to the trunk, we cannot rule out cardiac injury even if the injury is not located in the cardiac box. A high index of suspicion is needed based on the patient's overall clinical state, and decision-making should be rapid and precise. It is also important to note that emergency department thoracotomy carries a high mortality rate and should not be sought if there is time to transfer the patient to an appropriate operating theater, as was done in our scenario.

ARTICLE INFORMATION

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

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

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The authors did not receive any financial support for this study.

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

REFERENCES

Traumatic rupture of the right hemidiaphragm occurred following a high-velocity motor vehicle collision in the case presented herein. The resulting herniation of small bowel loops into the thorax resulted in hemodynamic and respiratory compromise due to pressure effects on the right heart and major vessels. The patient’s hemodynamic status improved with reduction of enterothorax, and the diaphragmatic defect was repaired. We discuss the available literature and learning points from this rare case.

Keywords: Trauma; Diaphragm; Rupture; Case reports

INTRODUCTION

A 59-year-old man was involved in a high-speed motor vehicle collision as a restrained driver. On retrieval by paramedics the patient was in respiratory distress with a Glasgow Coma Scale score of 7; therefore, he was intubated at the scene. Due to absent breath sounds on the right side, there was a concern for a right-sided hemopneumothorax. Needle decompression was performed, followed by an intercostal chest drain with minimal bloody output.

CASE REPORT

On arrival at the emergency department, the patient was hypotensive and tachycardic with an unstable anteroposterior compression fracture of the pelvis on X-ray (Fig. 1). A chest X-ray was interpreted as being consistent with pulmonary contusion (Fig. 2) and a focused assessment with sonography for trauma scan was negative. Therefore, whilst being resuscitated with blood products, the patient was taken to the hybrid operating room for iliac angiography, which demonstrated proximal cutoff of the left and right internal iliac arteries. These were both embolized, followed by a temporary improvement in the patient’s hemodynamic status. Following this, the patient proceeded to a computed tomography (CT) trauma scan, which revealed a traumatic right diaphragmatic rupture with almost the entire small bowel herniating into the right hemithorax with mediastinal shift and compression of the right heart chambers and inferior vena cava (Fig. 3). The patient deteriorated from a hemodynamic standpoint during the CT scan and was taken to the operating room for a trauma laparotomy where the small bowel loops were reduced by gentle traction into the abdomen until complete.
A 10-cm diaphragmatic defect was found anterior to the liver (Fig. 4). Access to the defect required ligation and division of the falciform ligament, and the defect was repaired using a running 0-Ethibond suture (Ethicon Inc). The patient’s hemodynamic status improved markedly following reduction of enterothorax.

**Ethics statement**

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

**DISCUSSION**

Traumatic diaphragmatic ruptures occur in only 1% to 7% of major blunt trauma patients but are found more frequently in cases of penetrating trauma (10%–15%). On the right side, the liver typically provides a protective effect due to its mass effect, resulting in only a 19% incidence of herniation, in comparison to 58% of left diaphragmatic ruptures [1].

Tension enterothorax is extremely rare, with only a small number of case reports in the published literature [1–4]. In addition to trauma, instances of postoperative enterothorax have been reported, such as following Ivor Lewis esophagectomy [4]. We propose that the pathophysiology of tension enterothorax involves the small bowel becoming obstructed at the diaphragmatic defect and then going on to distend and occupy increasing space within the thoracic cavity. This then impedes venous return through a
pressure effect on the major vessels and right heart, as occurs in tension pneumothorax.

There are a number of important learning points to take from the case we describe. An intercostal chest drain was inserted for suspected hemopneumothorax. Clearly, intercostal chest drain insertion in a patient with enterothorax could have caused significant harm. Subsequent to this, a chest X-ray was misinterpreted as showing pulmonary contusion. Had enterothorax been recognized at this stage, the patient would have proceeded directly to laparotomy. Instead, the patient’s hemodynamic status was attributed to bleeding from an unstable pelvic fracture. Awareness of enterothorax in the differential diagnosis for respiratory distress following blunt abdominal trauma is important for avoiding potential harm.

In conclusion, although a rare phenomenon, diaphragmatic rupture with enterothorax must be considered in the differential diagnosis of patients with respiratory distress following blunt abdominal trauma.

**ARTICLE INFORMATION**

**Author contributions**
Conceptualization: AG, DAY; Data curation: MM, AG; Formal analysis: NA; Writing–original draft: MM, AG; Writing–review & editing: all authors. All authors read and approved the final manuscript.

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

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

**REFERENCES**

Pancreaticoduodenectomy as an option for treating a hemodynamically unstable traumatic pancreatic head injury with a pelvic bone fracture in Korea: a case report

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INTRODUCTION

Pancreatic trauma occurs in 0.2% of blunt trauma patients and 5% of severe abdominal injuries, which are associated with high morbidity and mortality rates [1]. The American Association for the Surgery of Trauma (AAST) scale for pancreatic injuries was introduced in 1990; these guidelines divide pancreatic injuries into five stages, and pancreaticoduodenectomy (PD) is the procedure of choice for grades 4 and 5 [2]. Operating on the pancreatic head is technically challenging and requires delicate resection and complex reconstruction. Such a procedure necessitates exceptional surgical training and expertise [3]. The initial reconstruction in severely injured patients with complex pancreatic injuries worsens their initial status by causing hypothermia, coagulopathy, and acidosis, which increase the risk of early mortality [4]. The concept of damage control surgery has been established in recent decades [5], and hemodynamically unstable patients have an initial damage control operation followed by subsequent PD and reconstruction once they are stable [6]. We report the case of a patient who was treated by staging PD for a pancreatic head injury.

CASE REPORT

A previously healthy 30-year-old male sergeant was transferred to the Armed Forces Trauma Center by air-ambulance from a...
community hospital. He had suffered a crush injury due to a military towing car accident. Contrast-enhanced abdominal-pelvic computed tomography (APCT) at the community hospital showed a pancreatic head injury, extensive hemoperitoneum, liver laceration (grade 2) (Fig. 1), and an open-book type pelvic bone fracture (Fig. 2A). The initial vital signs were a blood pressure of 80/60 mmHg, a heart rate of 112 beats/min, a respiratory rate of 18 breaths/min, and a temperature of 36.2 °C. Focused assessment with sonography for trauma showed positive results in the right flank area. Since the patient’s vital signs were unstable, we decided to perform an exploratory laparotomy without hesitation with the traumatic orthopedic team.

Exploratory laparotomy was conducted with collaboration between the trauma team, hepato-biliary-pancreas (HBP) team, and orthopedics (OS) team. The grade 2 liver laceration was controlled with hemostatic gauze. Next, bleeding control was performed on the lateral side of the superior mesentery vein, the main pancreatic duct injury was identified, and the duodenal perforation site was repaired with primary sutures (Fig. 3). Two-branch indwelling Jackson-Pratt drains were placed around the pancreatic injury site to drain the pancreatic juices. During laparotomy, external screw fixation was simultaneously performed in the pelvic bone by the OS team (Fig. 2B). After damage control surgery was finished, the patient was sent to the trauma intensive care unit. At 24 hours postoperatively, the patient was resuscitated in the trauma intensive care unit and given a transfusion and

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**Fig. 1.** Initial abdominal-pelvic computed tomography. (A) Coronal view shows liver laceration (red arrow) and pancreas head injury (yellow arrow). (B) Axial view shows the pancreas head injury (arrow).

**Fig. 2.** Abdominal-pelvic computed tomography (A) at the trauma bay shows an open-book type pelvic bone fracture and (B) after the operation shows the external screw fixation state.
fluid therapy until vital signs were stabilized.

The PD operation began 24 hours after the initial damage control surgery. The pancreatic head was crushed, the main duct was disrupted, and pancreatic juice leakage was confirmed (Fig. 4). The pancreas was resected at the neck level to maintain a healthy main duct and avoid pancreaticojejunostomy site leakage. Duct-to-mucosa anastomosis at the pancreaticojejunostomy was performed with a short silicone catheter inserted through the site of anastomosis. The postoperative course went smoothly. APCT detected no complications at postoperative day (POD) 7 and POD 28. The patient was discharged in good condition on POD 42 with an injury severity score of 50 without complications. New-onset diabetes mellitus did not occur at postoperative 6 months.

**Ethics statement**

The study was approved by the Institutional Review Board of the Armed Forces Capital Hospital (No. AFCH IRB 2022-09-001). The Institutional Review Board waived the requirement for written informed consent. Our study was conducted in accordance with the Declaration of Helsinki.

**DISCUSSION**

Howell et al. (as cited in Israr et al. [7]) were the first to report PD for treating trauma patients in 1961. PD for trauma is seldom necessary and should be reserved for severe pancreatic head injuries that cannot be preserved otherwise [8]. There are specific indications for PD for trauma. First, there needs to be extensive devitalization of the head of the pancreas or duodenum with no prospect of repair. Second, there needs to be a ductal disruption in the pancreatic head with an AAST grade of 5 and injuries to the duodenum and distal common bile duct. Lastly, there needs to be an injury to the ampulla of Vater, with a disruption of the main pancreatic duct from the duodenum [6,9].

Operative mortality after blunt trauma to the pancreas has been reported in up to 60% of cases because of acute complications such as pancreatic juice leakage, pseudoaneurysm, and bile leakage. Moreover, despite trauma bay resuscitation, pancreatic injury patients have severe associated injuries and major blood loss, acidosis, coagulopathy, hypothermia, and persisting hypotension [4,9,10]. For these reasons, surgeons may face a dilemma regarding the need to perform damage control surgery followed by definite PD when encountering these patients. Additionally, the management of pancreatic injuries is complex and often requires a multidisciplinary approach. Experienced trauma and HBP surgeons, intensive care unit physicians, and radiologists should collaborate intensively to offer patients the best results. In our case, a multidisciplinary approach between the trauma, HBP, and OS teams started before the patient’s arrival.

Numerous pancreatic injury patients are in a hemodynamically unstable condition, and since the introduction of the damage control strategy in 1983, staging PD has become an increasingly viable option that has decreased the high mortality rate of pancreatic injuries [11,12]. Our patient was hemodynamically unstable with hemoperitoneum and a pelvic bone fracture. For these reasons, our multidisciplinary hospital team decided on damage control surgery.
control surgery followed by PD. The PD was conducted by an experienced HBP team, which reduced the risk of acute postoperative complications.

Our successful treatment of staging PD for a traumatic pancreatic injury demonstrates that PD after damage control surgery in hemodynamically unstable patients is a viable option.

ARTICLE INFORMATION

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

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

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

Additional information
This study was presented at the 9th Pan-Pacific Trauma Congress (PPTC) in June 2022 in Gyeongju, Korea.

REFERENCES


Removal of broken syndesmotic screw with minimal bone defects in Korea: a case report

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Ankle fractures with syndesmotic injuries often require fixation, where metal screw fixation is a popular method. However, as the patient begins weight-bearing, most syndesmotic screws tend to loosen or break, and removal of such screws has been challenging for the surgeons, as the available techniques require predrilling or trephination and are associated with risks of bone damage. This study presents a case with technical tip for the removal of broken tricortical-fixed non-cannulated syndesmotic screws. It implements the generation of a small cortical window in the medial distal tibia and the use of pliers to engage the screw tip and remove through the medial side. The technique presented in the current study overcomes these limitations and facilitates minimal bone damage and reduced exposure to radiation.

Keywords: Ankle fractures; Syndesmotic screw; Intraosseous breakage; Corticotomy; Case reports

INTRODUCTION

Ankle fractures often accompany syndesmotic injuries and require fixation. While various methods such as suture-button or bioabsorbable screw fixation have been used recently, metal screw fixation remains the mainstay [1]. However, as the patient begins weight-bearing, most syndesmotic screws tend to loosen or break, where intraosseous breakage is associated with higher rates of implant removal compared to that in the clear space [2]. Although previous studies have reported techniques to remove a broken syndesmotic screw [3–5], there exists limitations concerning the removal of a tricortical-fixed non-cannulated screw. Furthermore, as a case of distal tibial fracture following syndesmotic screw removal has been previously reported [6], caution is required.

Therefore, we present a technical tip for removing a broken tricortical-fixed non-cannulated syndesmotic screw. It implements the generation of a small cortical window in the medial distal tibia and the use of pliers, for minimizing bone defects.

CASE REPORT

A 20-year-old male patient presented to the outpatient clinic with a chief complaint of intermittent right ankle pain. He had undergone open reduction and internal fixation of an ankle fracture with syndesmotic screw fixation 4 weeks before the visit. He insisted that he started weight-bearing with walker boots for a few days. Physical examination showed no definite sign of swelling or tenderness at the level of the ankle joint. A plain radiograph revealed intraosseous breakage of the 3.5-mm syndesmotic screw.
in the distal fibula (Fig. 1A). However, the screw was within the appropriate position, and considering that it was too early to remove, the patient was recommended another 4 weeks of conservative treatment by following toe touch partial weight-bearing with walker boots.

Eight weeks postoperatively, the patient reported no aggravation in pain; however, a plain radiograph showed that the displacement of the broken syndesmotic screw had worsened (Fig. 1B). We decided to remove the screw 12 weeks postoperatively as previous studies reported that it takes approximately 12 weeks for the recovery of syndesmotic soft tissues, and too early removal of the screws may lead to syndesmotic diastasis [7,8]. At 12 weeks postoperatively, the plain radiograph showed a slightly bony erosion at the broken gap (Fig. 1C).

Following spinal anesthesia, the patient was placed in a supine position. Initially, the level of the broken screw tip was identified using fluoroscopy. A 2-cm to 3-cm incision was made, and careful dissection was performed to avoid any saphenous nerve and vein injury. Further, a 1 × 1-cm square-shaped cortical window was created with a saw, and the depth of corticotomy was calculated from the preoperative computed tomography images (Fig. 2). The tip of the broken screw was exposed when the depth of the cortical window reached 8 to 10 mm (Fig. 3A). A plier (Aesculap Inc., Center Valley, PA, USA) was used to engage the screw tip, and it was removed through the medial side by rotating in a counterclockwise direction (Fig. 3B, C). Autogenous bone grafting was performed using bones from the original tibial cortex combined with a cancellous bone chip allograft to cover the bone defect area. Subsequently, a 1-cm incision was made on the lateral side, and the remnant screw head was removed easily with a driver (Fig. 3D). The wound was closed, and an ankle brace was applied for 4 weeks postoperatively. The patient was instructed to bear a tolerable amount of weight while avoiding heavy sports and activities during those periods.

Four months postoperatively, successful consolidation of the

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**Fig. 1.** Serial radiographs following syndemotic fixation. (A) Breakage of a 3.5-mm syndesmotic screw at the intraosseous portion of fibula observed at 4 weeks postoperatively. (B) Aggravated displacement of the broken syndesmotic screw at 8 weeks postoperatively. (C) A slightly bony erosion at the broken gap observed at 12 weeks postoperatively.

**Fig. 2.** A preoperative computed tomography image used to calculate the depth (line) of corticotomy.
cortical window was observed with minimal bone defects near the previous screw site (Fig. 4). At this point, the patient experienced no pain or difficulty sustaining daily activities or playing sports.

**Ethics statement**
We conducted this study in compliance with the principles of the Declaration of Helsinki. This study was approved by the Institutional Review Board of the Armed Forces Medical Command (No. AFMC-202207-HR-034-02). Written informed consent for publication of the research details and clinical images were obtained from the patient.

**DISCUSSION**
Although breakage of syndesmotic screws is a commonly encountered complication, their removal may be challenging for surgeons, especially a tricortical-fixed non-cannulated screws compared to quadricortical-fixed cannulated screws. A previously introduced technique necessitated predrilling of the far cortex of distal tibia during syndesmotic screw fixation while anticipating possible breakage [3]. Furthermore, impacting with a blunt instrument onto a small area of the distal fibula may exert stress. The other reported technique of hollow milling from the medial...
side may induce a fairly wide bone defect near the screw thread across the entire tibial width [5]. In addition, if not skilful, it is not easy to perform trephination through the two perfect circles at once, which may eventually lead to several trials, causing larger bone defects and higher radiation exposure.

Contrary to the aforementioned limitations, the technique described presently has several advantages. First, it provides direct visualization of the screw tip, which could minimize excessive bone defects. Only a small distal portion of the screw needs to be exposed, sufficient to engage with the plier. Once the screw tip is engaged with the plier and rotated in a counterclockwise direction, only a hollow area as wide as the screw thread remains. While Riedel et al. [5] demonstrated a similar technical tip of removal of screws through trephination of the entire tibial width, their postoperative radiograph showed bone defects of 1.5 to 2 times the thickness of the screw thread [5]. Furthermore, if we extend the indication of our method, the technique can also be utilized in the removal of quadricortical-fixed or cannulated syndesmotic screws. Second, additional instruments required during the screw removal, such as a saw and plier, are readily available. Third, as intraoperative fluoroscopy is only employed to check the level of the screw tip, this technique facilitates reduced radiation exposure.

Despite the advantages, there are a few limitations to this technique. First, it requires an additional corticotomy at the medial side of the distal tibia to expose the screw tip. It would be a concern if the area of bone defect is large; however, in our representative case, it was merely 5% of the total area. In addition, successful consolidation of the tibial cortex was achieved by autologous bone grafting from the original tibial cortex combined with a cancellous bone chip allograft. Second, there is a possibility of saphenous vein and nerve injury associated with the technique; however, careful dissection of structures on the medial side can reduce this risk.

We believe that the technique presented herein will be of great advantage to foot and ankle surgeons who encounter a challenging case of the broken non-cannulated syndesmotic screw within the intraosseous portion during the follow-up period.

**ARTICLE INFORMATION**

**Author contributions**

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

**Conflicts of interest**

The authors have no conflicts of interest to declare.

**Funding**

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**Data availability**

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

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Posttraumatic bilateral thigh Morel-Lavallée lesions without an underlying bone fracture in the United Kingdom: a case report

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A Morel-Lavallée lesion results from a degloving injury between the muscle fascia and the subcutaneous layer. It is most commonly found in the trochanteric area but can occur at other sites. The treatment of the condition varies according to the medical circumstances, as well as the size and chronicity of the condition. A case of large (18×6 and 10×5 cm) bilateral posttraumatic Morel-Lavallée lesions with no underlying bone fracture is presented; the case occurred in a 49-year-old male patient 4 weeks posttrauma. Ultrasound scans showed bilateral large collections of anechoic fluid, which were aspirated under ultrasound guidance and further managed by compression bandages. There were no further complications. The objective of this case report is to present this unique and educational case, as well as to provide an overview of the pathophysiology, diagnosis, and management of Morel-Lavallée lesions. We conclude by discussing the importance of having a high index of suspicion to ensure early detection and prompt treatment of such lesions to avoid complications.

Keywords: Morel-Lavallée lesion; Diagnostic imaging; Case reports
wound has not been reported to date. We report the clinical and radiological features of a 49-year-old male patient with bilateral large anterolateral thigh closed Morel-Lavallée lesions, which were diagnosed and treated with a minimally invasive procedure without recurrence. We also reviewed the relevant literature to highlight the importance of musculoskeletal ultrasound for diagnosing soft tissue disorders with high accuracy and providing therapeutic interventions at the same time [2,3].

**CASE REPORT**

A 49-year-old male patient was involved in a road traffic injury (car vs. car). He lost control of his vehicle at high speed and was hit on the passenger side by a Range Rover. He was agitated at the scene, with an initial Glasgow Coma Scale of 6 out of 15. He was intubated and ventilated. He underwent a left thoracostomy for left pleural effusion with associated atelectasis prehospital by a doctor who was part of the air ambulance team. He was then transferred to a major trauma center after immobilization of his cervical spine and having Kendrick splints applied to both lower limbs according to the prevailing medical setup guideline for polytrauma patients.

His trauma CT showed brain injury (occipital contusions and intraventricular hemorrhages), chest trauma (multiple rib fractures, scapula fracture), and abdominal injuries (spleenic laceration, adrenal hematoma, perihepatic hematoma). There was a full passive range of motion in the knee and hip joints, with good oxygen saturation (94%) from both great toes. The capillary refill time was less than 2 seconds. There was a superficial abrasion to the right inguinal region, without other swellings, wounds, or bony deformity/crepitus. Whilst no tenderness could be elicited in the lower limbs, a precise physical examination was limited in this respect due to the man’s reduced level of consciousness.

He was initially treated in intensive care for 17 days before being transferred to the hyperacute rehabilitation unit for trauma rehabilitation, where he was treated for 12 weeks. He developed bilateral large anterolateral thigh swellings at 1 month posttrauma.

He was referred for an ultrasound scan to evaluate the nature and extent of the swellings. Using a low-frequency curvilinear transducer, simple fluid collections were detected in both anterolateral thighs, measuring 18 × 6 cm (left) and 10 × 5 cm (right).

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**Fig. 1.** Preaspiration ultrasound visualization of Morel-Lavallée lesion in the right thigh. (A–C) Different views of the right thigh collections.
These collections were present superficially to the muscle and deep to subcutaneous fat, appearing as anechoic collections of fluid with no signs of internal septations (Figs. 1, 2). The lesions were compressible without Doppler signals and were diagnosed as Morel-Lavallée lesions. They were differentiated from other soft tissue pathologies, including abscess or hematoma, by their typical appearance and location. Ultrasound-guided aspiration of both Morel-Lavallée lesion collections was performed under an aseptic technique, and serosanguineous fluid was aspirated to the point of dryness on the spot (approximately 550 mL of fluid from the left side and 150 mL from the right side), without any immediate complications. Compression dressings were applied bilaterally, and a sample was sent to the laboratory for routine analysis.

A postaspiration scan revealed bilateral reduced Morel-Lavallée effusions involving the anterolateral proximal thighs, particularly extensive on the left, where the collapsed collection extended into the left buttock and exceeded 30 cm in the cranio-caudal extent. Despite the large size of the collections, the muscle and overlying fascia leaflets were closely located. The collapsed collections measured no more than 2 mm in total thickness on the right, and 3 mm on the left (Fig. 3). There was no significant fluid component amenable to drainage after the procedure.

It was difficult to explain to the patient the rationale of compression bandages as he had significant cognitive difficulties secondary to his traumatic brain injury and was inconsistently compliant with the compression bandages. Nevertheless, the swelling of his thighs subsided 6 weeks postaspiration. There have since been minor recurrences of the swelling, but the patient’s condition has been gradually improving with further conservative management.

Despite some persistent swelling within the first few days after aspiration, the condition has remained painless; his physical and cognitive rehabilitation was never affected (Figs. 4, 5). His functional activity, measured using the Functional Independence Measure (FIM) and Functional Assessment Measure (FAM) scales, showed significant improvements in both physical and cognitive ability with multidisciplinary rehabilitation. The admission FIM was 29 (motor FIM, 24; cognitive FIM, 5), whereas the
Fig. 3. Postaspiration ultrasound visualization of the (A) left thigh and (B) right thigh.

Fig. 4. The clinical photograph of the anterior view.

Fig. 5. The clinical photograph of the lateral view.
Table 1. FIM and FAM scores on admission and discharge

<table>
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<th>Admission</th>
<th>Discharge</th>
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</table>

FIM, Functional Independence Measure; FAM, Functional Assessment Measure.

discharge FIM was 106 (motor FIM, 84; cognitive FIM, 22). The FAM score increased from 43 on admission to 162 on discharge (Table 1).

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

**DISCUSSION**

A Morel-Lavallée lesion is a posttraumatic soft tissue degloving injury, which was first observed around 1863 by the French surgeon Victor Auguste Francois Morel-Lavallée in a patient who fell from a moving train. These lesions are mostly unilateral, but bilateral lesions have been described in association with underlying complex pelvic trauma or fracture of a distal extremity [4]. To the best of our knowledge, this is the only case of bilateral large Morel-Lavallée lesions after blunt trauma without an underlying fracture or open wound.

Morel-Lavallée lesions have been known to present as early as a few hours after the causative trauma. However, between one-third to two-thirds of Morel-Lavallée lesion patients are overlooked and present months or even years after the initial trauma, mainly requesting cosmetic surgery for an abnormal contour. These lesions may present with long-term morbidity with the presence of infection or sepsis, which can complicate the picture. Skin necrosis, chronic pain, or misdiagnosis as a soft tissue tumor can also occur [5].

The main causes are road traffic injuries (particularly motorcycle crashes) and sports injuries, but Morel-Lavallée lesions can occur in nontrauma settings such as postoperatively after liposuction and abdominoplasty [6]. The lesions can occur in isolation but often are associated with pelvic and/or acetabular fractures or polytrauma [7]. They may present as either open wounds or as closed degloving injuries with intact overlying skin. The most common sites of closed degloving injuries are usually adjacent to bony prominence, and have been described along the greater trochanter, thigh, hip, and flank. Less commonly, they have been reported at the knee, shin, calf, lumbar spine, abdomen, shoulder, elbow, and chest [2,8].

The commonly used Mellado-Bencardino classification of Morel-Lavallée lesions into six types is based on MRI features; this classification focuses on the shape, signal, and enhancement characteristics, as well as the presence or absence of a capsule [9]. Blunt trauma with a tangential impact is reported to be the most common form of injury, resulting in shearing of the subcutaneous fat and skin from the underlying firmly secured fascia, thus creating a potential space. The shearing forces cause damage to the perforating blood and lymphatic vessels, releasing their contents into the newly created cavity. With continuous spillage of the contents into the cavity, it is filled with blood, lymph, and necrotic fat. This process is followed by an inflammatory reaction that converts the newly created cavity into a cystic mass surrounded by a fibrous capsule—this is called a pseudocyst, which represents the chronicity of the lesion [7]. These lesions are frequently misdiagnosed, presenting late as contour deformities [6], and may mimic subcutaneous abscesses, lipomas, or soft tissue tumors. The diagnosis is made through a combination of a history, a clinical examination keeping a high level of suspicion, and imaging studies. Pain and swelling are the most frequent complaints in patients with a history of trauma. On examination, the swelling may be compressible and fluctuant with overlying skin changes, such as dryness, cracks, discoloration, or necrosis. Cutaneous hypoesthesia or anesthesia may be present [10]. MRI is the diagnostic modality of choice [6]. MRI descriptions of these lesions are available in the literature, but relatively few case reports of Morel-Lavallée lesions have described their sonographic appearance. The use of musculoskeletal ultrasound has gained importance in the recent years and has assumed an important role in the assessment of soft tissues [11]. This is particularly true in rehabilitation settings, where it is used as both a diagnostic and interventional modality. Sonography is convenient, inexpensive,
noninvasive, repeatable, and does not require any exposure to radiation. Furthermore, ultrasound plays a growing role in the diagnostic algorithm for a wide spectrum of musculoskeletal disorders because it can provide dynamic imaging, comparisons, and therapeutic interventions all at the same time [1].

On ultrasound imaging, one can differentiate different layers from the skin to underlying bones. The uppermost layer is the epidermis, followed by the dermis, superficial adipose tissue, superficial fascia, deep adipose tissue, deep fascia, and finally muscle with the underlying bone [12]. The superficial fascia appears as a thin hyperechoic layer in the subcutaneous tissue, deep to the dermis and epidermis. The deep fascia is a thick hyperechoic layer separated from the superficial fascia by deep fat tissue, which is hypoechoic with thin horizontal hyperechoic striae inside it [12].

All Morel-Lavallée lesions are hypoechoic or anechoic, with or without internal echoes, compressible, and are located between the deep fat and overlying fascia [13]. They do not have internal vascularity on color or power Doppler. The shape may vary according to the location of the lesion and may range from fusiform, flat, to lobular, or may remain indeterminate [13].

These lesions tend to be heterogeneous and ill-defined initially as they contain blood, lymph, and fat. As the lesions age, they become more homogeneous and better defined with smooth margins, and they may include a fibrous pseudocapsule [10]. The lesions can have mixed echogenicity if there is repeat hemorrhage or if they contain nonabsorbed fat remnants.

There are no universally accepted international guidelines for the management of Morel-Lavallée lesions. The management depends upon the size of the lesion, chronicity, and the presence or absence of a capsule. It varies according to the individual surgeons’ preference and expertise, as well as institutional treatment protocols. If the lesion is very small and the symptoms are mild, then conservative treatment with a compression bandage and close follow-up may suffice [3]. Serial scans by an expert in musculoskeletal ultrasound (either a clinician or radiologist) can help to monitor the progress of these lesions. If the lesion is mild to moderate, aspiration followed by compression bandage for 6 weeks can be helpful with incremental scans.

Other treatment options include percutaneous aspiration with suction drainage, which has been used successfully [14]. To prevent fluid reaccumulating after drainage, fluoroscopic percutaneous talc sclerodesis has been used [15].

For larger lesions, many orthopedic surgeons favor early surgical drainage and debridement [7]. Surgical resection is warranted if a fibrous capsule has developed.

We recommend ultrasound-guided aspiration followed by compression bandage for 6 to 8 weeks in acute lesions, as well as follow-up scans afterwards to visualize the regression and monitor accordingly.

In conclusion, Morel-Lavallée lesions are prone to being overlooked in around one-third to two-thirds of patients, especially in cases of polytrauma and with the presence of life-threatening injuries. Therefore, it is recommended that clinicians perform a detailed secondary survey to look for this pathology in all cases of trauma with a high index of suspicion. Ultrasound can be performed at the bedside to confirm the nature and extent of a swelling and also to aspirate the fluid.

**ARTICLE INFORMATION**

**Author contributions**
Conceptualization: SR, JG, HM, CU; Formal analysis: all authors; Methodology: SR, AK; Writing–original draft: SR; Writing–review & editing: JG, AK, HM, CU, FA. All authors read and approved the final manuscript.

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

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

**REFERENCES**

Successful treatment of fungal central thrombophlebitis by surgical thrombectomy in Korea: a case report

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INTRODUCTION

Fungal thrombophlebitis of the central vein is a rare, life-threatening disease associated with significant morbidity and mortality. It requires immediate central venous catheter (CVC) removal and intravenous antifungal therapy, combined in some cases with either anticoagulation or aggressive surgical debridement [1–3]. Below we describe a patient who developed candidal thrombophlebitis of the jugular and brachiocephalic veins after major trauma and recovered dramatically after surgery.

CASE REPORT

A 70-year-old male patient injured by a falling object weighing 1,000 kg was transferred to Ulsan University Hospital. At the previous hospital, he was intubated, and a right subclavian CVC was inserted. Because a focused assessment with sonography for trauma exam showed hemodynamic instability and evidence of free intraperitoneal fluid, an emergency operation was undertaken. A multilumen access catheter (MAC) was inserted in the right internal jugular vein (IJV) for rapid administration of blood and fluid. A contained rupture of the abdominal aorta with retroperitoneal hematoma was treated with primary repair, and a small
bowel perforation with mesenteric laceration was treated with resection and anastomosis. During postoperative care in the intensive care unit, invasive mechanical ventilation was applied to achieve positive pressure. The patient received total parenteral nutrition, and tazobactam/piperacillin was administered intravenously (4.5 g every 8 hours). Previous medical records of the patient indicated hypertension and diabetes mellitus, and diabetes mellitus had been treated with insulin therapy for many years.

On hospital day (HD) 3, the patient developed a sustained fever. The right IJV MAC and right subclavian CVC were removed and cultured. A CVC was inserted in the left IJV. After extubation on HD 5, the patient was moved to the general ward. Right IJV MAC and right subclavian CVC tip cultures revealed no growth. Administration of antibiotics was stopped on HD 15. On HD 17, the patient became febrile again, and as a result, the left IJV CVC was removed and cultured. Administration of levofloxacin (750 mg/day) was started for empiric antibiotic therapy. Laboratory findings showed a white blood cell (WBC) count of 6,340/μL and a C-reactive protein (CRP) level of 0.53 mg/dL. On HD 18, a computed tomography (CT) scan with contrast was performed on the abdomen and chest to identify the source of fever, but there was no specific finding. Tazobactam/piperacillin (4.5 g every 8 hours) was administered. A spiking fever persisted on HD 19, and the laboratory findings indicated inflammation (WBC count of 8,210/μL, CRP level of 8.80 mg/dL, procalcitonin level of 0.37 μg/L). On HD 21, *Candida tropicalis* was isolated from the previous left IJV CVC tip (HD 17) and in blood cultures. Micafungin (100 mg/day) was administered immediately, and levofloxacin was stopped. Two sets of peripheral blood cultures were performed. Despite treatment with intravenous micafungin, high fever persisted on HD 22, and laboratory values indicated increasing inflammation (WBC count of 14,510/μL, CRP level of 8.37 mg/dL). The patient was transferred to the intensive care unit. Continuous electrocardiography monitoring detected frequent ventricular premature contractions. When echocardiography was performed, there was no evidence of vegetation. Because the left IJV CVC tip culture finding indicated candidal infection, bedside neck duplex ultrasonography was performed, and a left IJV thrombus was detected. To identify the extent of thrombus formation, a chest CT scan with contrast was performed. A filling defect was identified from the left IJV to the left brachiocephalic vein (Fig. 1). Emergency debridement and thrombectomy of the left IJV and brachiocephalic vein were performed on the same day (Fig. 2). The intraoperative findings were poorly organized, with thrombi and pus in the affected veins. Histological examination confirmed that the thrombus cultures contained *C. tropicalis*. After the operation, the patient’s fever subsided immediately.

![Fig. 1. Filling defect in left jugular vein (circles). (A) Coronal and (B) axial view.](https://doi.org/10.20408/ji.2022.0063)
Postoperative blood culture revealed negative results and no isolated *C. tropicalis*. Laboratory findings indicated resolution of inflammation after postoperative day (POD) 4 (WBC count of 9,210/μL, CRP level of 7.88 mg/dL, procalcitonin level of 0.28 μg/L). Enoxaparin (40 mg/day) was started for anticoagulation on POD 2, then changed to direct oral anticoagulants (apixaban, 5 mg/12 hr) on POD 5. On POD 6, a chest CT scan with contrast showed an obliterated left IJV and brachiocephalic vein due to a newly developed thrombus (Fig. 3). On POD 6, laboratory findings showed no evidence of recurrence (WBC count of 7,450/μL, CRP level of 5.24 mg/dL). The patient was treated with an antifungal agent (oral fluconazole, 150 mg/8 hr) for 4 weeks. Candidemia never recurred. No signs or symptoms of candidemia relapse were observed upon a 1-year follow-up, when a chest CT scan again showed an obliterated left IJV and brachiocephalic vein.

**Ethics statement**

This study was approved by the Institutional Review Board of Ulsan University Hospital (No. 2022-10-015). The patient provided informed consent for publication of the research details and clinical images.

**DISCUSSION**

A CVC provides useful vascular access for intravenous therapy, transfusion, and hemodynamic monitoring. However, CVC use...
may lead to venous thrombus formation, with critical complications such as catheter-associated septic thrombophlebitis. Conservative treatment to remove the infection's source is usually sufficient, including peripheral or central intravenous catheters, broad-spectrum intravenous antibiotic administration, and possibly anticoagulation. Sometimes this conservative management fails, and surgical approaches such as resection, ligation of the involved veins, or thrombectomy may be supplemented [4].

The incidence of candidiasis has increased gradually in recent decades. Its pathogenesis is not well-known. For candidal suppurative thrombophlebitis, guidelines recommend catheter removal incision and drainage or resection of the vein with administration of an intravenous antifungal agent [5]. An antifungal treatment, such as lipid formulation amphotericin B, fluconazole, or echinocandin, is recommended for at least 2 weeks. Step-down therapy to fluconazole should be considered subsequently for a stable patient who has a fluconazole-susceptible isolate. There are a few surgical treatment methods, including radical excision of the affected vein or thrombectomy. Surgical excision of the vein plays an important role in the treatment of peripheral vein candidal thrombophlebitis.

Candidal thrombophlebitis in CVC is a rare condition that tends to be underdiagnosed. Unlike peripheral vein candidal thrombophlebitis, when a central vein is involved, surgery is usually not available and radical excision is considered controversial [6]. Instead, systemic anticoagulation or thrombolytic treatment has been tried as adjunctive therapy, with insufficient data regarding effectiveness [7].

Treating recurrent patients or patients unresponsive to conservative treatment remains challenging because no definite therapeutic strategy has been established for central candidal thrombophlebitis. In contrast to one report of successful treatment of recurrent candidemia due to central candidal thrombophlebitis with a combination of micafungin and fosfluconazole [8], there has been a report of surgical thrombectomy of the brachiocephalic vein, which effectively removed the source of Candida sepsis and maintained patency of a major vein but resulted in the patient's death from multiple pulmonary emboli [9]. There has also been a successful report of vena caval thrombectomy and ligation, and the authors of that report suggested surgical intervention when septic pulmonary emboli, extensive thrombophlebitis, or refractory sepsis occur despite optimal therapy [6]. Venous thrombectomy can be a lifesaving treatment for failed conservative management in septic deep venous thrombosis, whether bacterial or candidal [10].

Herein, we performed thrombectomy with debridement without complete excision of the central vein. We decided upon an emergency operation because the patient's high fever persisted despite antifungal therapy and extension of thrombus. After thrombectomy, the vein was repaired with a Prolene suture without venoplasty. This method may be an option for thrombophlebitis with clear intima after thrombectomy. Though the remaining affected vein could be a source of recurrence, considering the risk, we chose to leave the vein in place unless it became inflamed. After surgery, anticoagulation was started on POD 2, and the patient showed early signs of recovery. At the 1-year follow-up, there was no evidence or symptom of candidemia.

Fungal central thrombophlebitis is a rare and probably underdiagnosed infectious complication of critically ill patients. Recurrent or persistent candidemia after removal of a contaminated CVC should prompt further investigation, and surgical treatment should be considered in the disease's early phases for timely recovery and prevention of fatal complications.

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Ruptured uterus in a 36-week pregnant patient with hemorrhagic shock after blunt trauma in Korea: a case report

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Traumatic uterine rupture is uncommon but can be fatal and life-threatening for both the mother and infant. In addition to complications caused by trauma itself, such as pelvic fracture, gestational complications such as placental abruption, abortion, premature labor, rupture of membranes, maternal death, and stillbirth can occur. In particular, fetuses have been reported to have a high mortality rate in cases of traumatic uterine rupture. A 35-year-old pregnant female patient fell from the fourth floor and was admitted to our trauma center. We observed large hemoperitoneum, pelvic fractures, and spleen laceration, and the fetus was presumed to be located outside the uterus. The pregnant woman was hemodynamically unstable. Although the fetus was stillborn, angiembolization and surgical treatment were properly performed through collaboration with an interventional radiologist, obstetrician, and trauma surgeons. After two orthopedic operations, the patient was discharged after 34 days. This case report suggests the importance of a multidisciplinary approach in the treatment of pregnant trauma patients.

Keywords: Uterine rupture; Blunt injuries; Stillbirth; Interdisciplinary studies; Case reports

INTRODUCTION

Traumatic injuries in pregnancy are not uncommon, accounting for 6%–7% of all traumatic injuries [1]. Even if the trauma is not serious, pregnant trauma patients are important because traumatic injuries during pregnancy are associated with abortion, premature labor, rupture of membrane, maternal death, and stillbirth [2]. Serious trauma in a pregnant woman is dangerous for both the mother and the fetus. The treatment priority of pregnant women is the same as the priority of severe trauma patients. However, it is difficult to determine the treatment plan for pregnant trauma patients due to the need to consider both the pregnant woman and the fetus. Furthermore, changes in maternal physiology and gestational age during trauma complicate an accurate evaluation of fetal outcomes [3].

In this case report, we describe a case of traumatic uterine rupture accompanied by a 36-week-old stillborn fetus removed from the abdominal cavity.
CASE REPORT

A 35-year-old female patient at 36 weeks’ gestation was transferred from an outside hospital to Gachon University Gil Medical Center (Incheon, Korea) after falling from the fourth floor. Our trauma team was provided with the pregnant woman’s information from an outside hospital. The patient had been taking medication for bipolar disorder and voluntarily stopped taking the medication 3 days previously for breastfeeding. Emergency obstetrical ultrasound was performed on the patient at the outside hospital, and we were informed that the fetus was likely to be stillborn. The patient was hemodynamically unstable even before she left the hospital. She received transfusions of 7 units of red blood cells (RBCs) and 3 units of fresh frozen plasma (FFP) from the outside hospital. Five hours elapsed between the fall and the patient’s presentation to our trauma center.

When she arrived at our trauma center, the initial vital signs included a blood pressure of 90/76 mmHg and a heart rate of 144 beats/min. Since we had been notified of the stillbirth of the fetus based on obstetric ultrasonography conducted at the outside hospital, we performed an initial computed tomography (CT) scan during an emergency transfusion. The CT scan showed a large amount of hemoperitoneum, pelvic fracture, and spleen injury. A coronal image of contrast-enhanced abdominopelvic CT showed a disrupted wall of the uterine fundus and the fetus located in the peritoneal cavity, outside the uterus (Fig. 1).

Before the patient arrived at our trauma center, we contacted an interventional radiologist and obstetrician in advance. Since a ruptured uterus causes massive bleeding, we decided to perform angioembolization first to reduce bleeding during surgery. As soon as the patient arrived in the emergency room, we performed an emergency blood transfusion for resuscitation. After resuscitation, we transferred the patient to the angiography room. Angiography confirmed that the contrast agent had leaked from both internal iliac artery and splenic artery. Bilateral iliac arteriography revealed mild hypertrophy of the bilateral uterine arteries, which were embolized using gelatin sponge particles for the right uterine artery and N-butyl-cyanoacrylate for the left uterine artery. (Fig. 2) The superior polar splenic arteries were

Fig. 1. Computed tomography. (A) An axial view shows hemoperitoneum (black arrow) and spleen laceration (white arrow). (B) A coronal view shows the fetus (black arrowhead) located in the peritoneal cavity and the disrupted wall of uterine fundus (white arrowhead).

Fig. 2. Bilateral iliac arteriography reveals mild hypertrophy of the bilateral uterine arteries (arrows), which were embolized using (A) gelatin sponge particles for the right uterine artery and (B) N-butyl-cyanoacrylate for the left uterine artery.
also embolized with gelatin sponge particles. An interventional radiologist succeeded in embolizing a damaged artery. During angioembolization, the obstetrician and trauma surgeon were on standby for immediate surgery. After angioembolization, the patient was sent to the operating room.

We consulted with an obstetrician so that the trauma surgeon and the obstetrician could operate together at the same time. First, the trauma surgeon opened the abdomen and performed gauze packing in the four quadrants of the abdominal cavity. Approximately 2,000 mL of hematoma was present in the abdominal cavity. At the same time, a stillborn fetus emerged from the ruptured uterus and was found in the intraabdominal free space (Fig. 3). The obstetrician cut the umbilical cord of the fetus and evacuated the fetus first. We then found a uterine rupture and the placenta attached to it. We isolated the placenta from the uterus, and obstetrician sutured the ruptured uterus with Vicryl 2-0 using a continuous running method (Fig. 4). Finally, the trauma surgeon operated for additional accompanying injuries, including cecal serosa tearing. There was no active bleeding other than hematoma in the lower quadrant of the retroperitoneum and a contusion of the stomach's great curvature. After removing the packing gauze from the four quadrants, the operation was terminated as the abdominal wound was temporarily closed. From hospitalization to our trauma center to the termination of laparotomy, she received six additional packs of RBCs and six additional packs of FFP. A second-look operation was performed for definite abdominal closure 2 days after the first operation.

The patient then underwent two orthopedic operations for a fracture of the left pelvic bone and a fracture of the right lateral tibial plateau during hospitalization. We consulted a psychiatrist in order for the patient to resume the psychiatric medication she had stopped for lactation. The patient was treated in the intensive care unit for 2 weeks and was discharged after 34 days of hospitalization.

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

**DISCUSSION**

In pregnant women, blunt trauma is the most common mechanism of injury [4]. Motor vehicle crashes are the leading cause of

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**Fig. 3.** Images showing (A) the stillborn fetus located in the abdominal cavity outside the uterus (arrow) and (B) the ruptured uterus (arrowhead).

**Fig. 4.** Images showing (A) the uterus repaired by an obstetrician and (B) the placenta separated from the pregnant woman.
Pregnancy causes anatomical and physiological changes. In the first trimester of pregnancy, the fetus is protected by the pelvis. At 20 weeks of gestation, the uterus is palpable at the umbilical level. At 36 weeks of gestation, the uterus enlarges, and the uterine wall becomes thinner, making it more vulnerable to trauma [6]. In pregnant women, tachycardia and hypotension may not develop until significant blood loss has occurred, which may delay the diagnosis of shock [7]. Hemorrhage during pregnancy can significantly decrease blood flow to the uterus [7]. These changes affect the patient’s symptoms, laboratory findings, and radiologic imaging finding, which makes it difficult for trauma surgeons to decide on the treatment plan.

The mechanism of injury may be direct trauma to abdomen or indirect trauma due to deceleration or a shearing force. Direct fetal trauma accounts for fewer than 1% of cases of severe abdominal trauma in pregnant women, but fetal deaths are reported in 3.7% to 17.5% of those cases [8,9]. The risk of fetal loss correlates with the severity of the trauma and the maternal condition. In particular, it has been reported that the risk is higher in patients with an Injury Severity Score (ISS) > 9 [3]. Although uterine rupture is rare, occurring in fewer than 1% of traumatic events during pregnancy, fetal mortality can reach 100% when traumatic uterine rupture occurs. In our case, the ISS of the patient was 50 and the uterus was ruptured [10]. Therefore, the risk of fetal mortality was expected to be very high.

Emergency treatment at the prehospital stage is important, and transfer to an appropriate trauma center is necessary. In our case, the patient was initially admitted to another hospital and appropriate resuscitation was not performed. When the patient presented to our trauma center, she was already in very severe shock. The initial evaluation of patients with pregnancy trauma should follow the Advanced Trauma Life Support algorithm, the same as the initial evaluation of nonpregnant trauma patients. In the early stages of hemorrhagic shock, isotonic crystalloids and massive transfusions should be considered. However, vasopressors should be considered last to support maternal blood pressure because they reduce uterine blood flow, which can lead to fetal hypoxemia [11].

Traumatic uterine ruptures are uncommon and difficult to diagnose. Furthermore, traumatic uterine rupture is dangerous for both the mother and fetus. Therefore, various specialties should be involved in caring for pregnant trauma patients, and a multidisciplinary treatment approach is very important. Caring for pregnant trauma patients requires an organized and integrated approach with an emergency medicine doctor or trauma surgeon as a team leader. A multidisciplinary treatment approach can reduce maternal-fetal morbidity and mortality, and in some cases, both the mother’s life and the fetus can be preserved. Additionally, every trauma center that cares for these patients should have a protocol to ensure a standardized approach.

**ARTICLE INFORMATION**

**Author contributions**

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

**Conflicts of interest**

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**Data availability**

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

**Additional information**

This study was presented at the 9th Pan-Pacific Trauma Congress in June 2022 in Gyeongju, Korea.

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Thoraco-laparotomy approach to salvage a life-threatening cardiac box stab injury to the inferior vena cava in Malaysia: a case report

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INTRODUCTION

Torso stab injuries near the “cardiac box” may present unique challenges due to difficulties in hemorrhage control, especially when the trajectory is bi-cavitary. Patients may experience injuries to the cardiac, lung, or great vessels (vena cava, aorta, or subclavian vein), requiring urgent operative repair. A recent large series from a level I center observed 23 stab injuries to the cardiac box in a 6-year period. The largest category (15 of 105) was cardiac injuries, followed by lung injuries, great vessel, or smaller artery injuries (i.e., injuries to the internal mammary, intercostal, or superior thoracic artery) [1]. In injuries to the heart, the repair is relatively straightforward, with access via median sternotomy. In contrast, injuries to the great vessels—in particular, the inferior vena cava (IVC)—are challenging to repair. It is worst when the vena cava tears below and close to the diaphragm, and the bleeding can be torrential. Herein, we describe a case of a self-inflicted stab wound within the “cardiac box.” The trajectory of the stab injuries went below the diaphragm and injured the infradiaphragmatic inferior vena cava. Successful emergent repair via the thoraco-laparotomy approach revived the young man. In this report, we revisit and discuss previous large series of patients with this rare vena cava injury.

Keywords: Injury; Veins; Heart; Case reports

CASE REPORT

A 35-year-old man was brought to the emergency department with multiple stab wounds within the “cardiac box” 1 hour before...
arrival. It was assumed to be a suicide attempt based on closed-circuit television recordings. He was hypotensive and received early blood transfusions to sustain a systolic pressure of 90 mmHg. He was very tachycardic, with a heart rate of 143 beats/min, and his Glasgow Coma Scale score was 3 for the eye component, 1 for the verbal component, and 2 for the movement component, which prompted endotracheal intubation for airway protection. There were three stab wounds within the cardiac box, each measuring 2 to 4 cm in length (Fig. 1). A focused assessment with sonography in trauma scan was positive for free fluid in both the right upper quadrant and pericardium (Video S1). His initial hemoglobin level was 13.1 g/dL, and the chest radiograph featured a widened mediastinum shadow (Fig. 2). He was immediately rushed to the operating room (OR). In total, prior to OR entry, he was resuscitated with 1 L of crystalloid, 1 g of tranexamic acid, and 2 units of safe O with a concurrent massive transfusion protocol (MTP). We carried out hypotensive resuscitation, and MTP was continued in the OR. A thoraco-laparotomy (via a sternotomy and midline laparotomy) found three stab wound trajectories. The first wound trajectory resulted in a large diaphragm laceration, extending to the liver and further into the pericardium. It pierced the IVC, which was bleeding profusely. The IVC perforation measured 0.5 × 1 cm, and it was repaired following the division of the diaphragm for adequate exposure (Fig. 3). There were also pericardial lacerations from the other two tracts measuring 2 and 3 cm, respectively; these severed the left internal mammary artery, which could be easily controlled.

Massive blood loss occurred during the survey, necessitating activation of the MTP for trauma. In total, 6 units of packed cells, 8 units of fresh frozen plasma, 6 units of cryoprecipitate, and 4 units of platelets were transfused intraoperatively. To make matters worse, the patient was also positive for COVID-19; thus, the operating team had to operate wearing full personal protective equipment. The patient had to be treated in a full-isolation intensive care unit postoperatively and was extubated on day 8 following surgery. After another week in the hospital, he recovered well; however, he absconded before being discharged and did not return for follow-up.

Ethics statement
Written informed consent was obtained from the patient for the publication of this case report and accompanying images. The authors conformed to the provisions of the Declaration of Helsinki.

DISCUSSION

Injuries to the IVC carry a high mortality rate, up to 53%, ac-
Mortality increases with the proximity of the wound to the heart [2]. The majority of the literature contains American data, with injuries mostly arising from the infradiaphragmatic segment of the IVC and repaired through abdominal access [2]. The mechanism of injury was due to penetrating trauma three-fourths of the time, but the survival outcomes did not vary according to the mechanism [2]. Firearms were reported as the most common mode of injury in another American series, followed by stab wounds and blunt trauma [3]. The operative strategies described included direct compression and local clamping, followed by primary repair of the vein defect. In a few extreme cases, cava ligation was performed [3]. In the follow-up from the previous series, merely primary repair was sufficient, with low rates of thrombosis and embolic complications [3].

An American level I trauma center observed 105 stab wounds in the cardiac box over a period of 6 years. Thirty percent required an exploration via thoracotomy, sternotomy, or laparotomy. Twenty-three patients needed thoracotomy or sternotomy, and 12 patients needed laparotomy. Great vessel injuries were seen in only two cases. The detailed approach was not described [4]. However, another recent case, also from a trauma center in the United States, described a successful repair of an injury to the supradiaphragmatic IVC caused by blunt trauma. The authors concluded that the factors for success included aggressive prehospital fluid resuscitation, facile transfer to the OR, early detection of the injury, an early call for cardiothoracic surgery, and prompt blood transfusion. The details of the operative steps included median sternotomy, placement of a hemostatic patch over the confluence of the IVC and the right atrium and holding it in place, exploration of the abdomen (finding small lacerations of the liver), and supraceliac aortic clamping together with maintaining digital pressure over the IVC in the pericardium. When cardiothoracic surgeons were called in for cardiopulmonary bypass (CPB), the diaphragm was taken down to the caval hiatus to expose the entire suprahepatic IVC, and the IVC was repaired with a Dacron graft. Surgery was performed with deep hypothermic circulatory arrest, as there was no area for adequate clamping of the IVC [5]. On the contrary, in this reported case, we did not need to call in a cardiothoracic surgeon for CPB, as the penetrating injury resulted in a linear tear that could be repaired by oversewing.

Furthermore, no emergency CPB service was available at the local center. In short, we summarized the success in the current case as being due to a few factors, which may be similar to those described in previous reports of blunt supradiaphragmatic IVC injuries. These factors include the following: (1) hemostatic resuscitation with an MTP; (2) early detection of a severe injury needing operative repair based on a clinical judgment of a stab box injury together with positive fluids seen on sonography; (3) penetrating injuries characterized by a linear tear pattern with a low concomitant traumatic injury burden; and (4) the presence of a senior trauma surgeon, senior anesthesiologist, and emergency trauma team care providers, as the patient arrived in the early hours.

A review by Chinese authors described a series of IVC injuries. In the current case, the IVC injury was classified as a segment 1 injury, lying between the right atrium and the second hepatic hilum [6]. Injuries around this region carry the highest risk of mortality due to its difficult access, as it hides behind the diaphragm or inside the pericardial sac. It has also been observed that injuries closer to the right atrium have a higher risk of mortality [2]. The older literature on IVC injuries from the United States contains larger series of suprahepatic IVC injuries. Operative repair includes primary repair, patch repair, or ligation. The latter two options often carry a high risk of mortality and poorer outcomes. Nearly 70% of IVC injuries reported in the older large series were due to gunshot wounds, while only 17% were due to

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**Fig. 3.** Exposure of the inferior vena cava following its repair.
stab wounds [4].

The current case described a severe self-inflicted stab cardiac box injury. The patient successfully survived after emergency chest and abdomen exploration, together with IVC repair. The previous literature from the United States observed a high risk of mortality with injury at this segment of the IVC. We summarized a few salient management strategies such as hemostatic resuscitation, early exploration, and an operative strategy involving a large thoraco-laparotomy incision allowing quick local clamping and vein repair to achieve hemorrhage control of bleeding in segment 1 of the IVC.

**ARTICLE INFORMATION**

**Author contributions**
Conceptualization: IAM, JHT; Data curation: JZT, YM; Writing—original draft: IAM, JHT; Writing—review & editing: JHT, YM, IAR. All authors read and approved the final manuscript.

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

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

**Supplementary materials**
Video S1. The presence of free fluid within the pericardial sac. Supplementary materials are available at https://doi.org/10.20408/jti.2022.0071.

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Three-column reconstruction through the posterior approach alone for the treatment of a severe lumbar burst fracture in Korea: a case report

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INTRODUCTION

Burst fractures of the thoracolumbar spine are usually caused by high-energy traumas, such as traffic accidents and falls [1,2]. These fractures may result in severe neurological deficits or spinal instabilities. Regardless of their neurological effects, unstable burst fractures require surgical intervention. Spinal surgeons have a variety of surgical options, including the posterior, anterior, and lateral approaches [1–6]. Because each approach has its advantages and disadvantages, there is no consensus regarding the ideal method. To select an appropriate approach, the surgeon must consider the degree of deformity, any neurological damage, and the surrounding anatomy. We describe a case in which three-column reconstruction was performed by inserting an expandable cage and transpedicular screw fixation after corpectomy through a single posterior approach in a patient with a burst fracture of the third lumbar vertebra and severe bodily deformity.

CASE REPORT

A 55-year-old man was admitted to Gachon University Gil Medical Center for pain in both lower extremities and the lower back, that occurred after he had fallen from the 10th story of a building. He was on medication for diabetes mellitus and major depressive disorder and had a history of surgery for a left femur fracture. Because the patient presented with right femoral subtro-
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Chanteric, left femoral shaft, and left proximal fibula fractures with accompanying damage, it was difficult to evaluate the lower extremity motor score accurately during a physical examination, but the sensory function was intact. However, sensation around the perineum was somewhat reduced, and anal tone was diminished. A severe burst fracture of the third lumbar vertebra was confirmed on whole-body computed tomography (CT) performed in the emergency department. Other injuries included a Jefferson fracture, a compression fracture of the fifth thoracic vertebra, multiple transverse process fractures, multiple spinous process fractures, right radioulnar midshaft fractures, a right proximal humerus fracture, a right scapula glenoid fracture, a left first metacarpal base fracture, and liver injuries.

Abdominopelvic CT findings showed that the burst fracture of the third lumbar vertebra was very severe, resulting in severe dural sac compression. In addition, a posterior ligament complex injury was suspected because it was accompanied by a fracture of the second lumbar spinous process (Fig. 1). Active bleeding due to liver injury was observed; therefore, hepatic artery embolization was performed. Next, bilateral traction procedures were performed for both femur fractures by orthopedic surgeons in the intensive care unit. After stabilization of the vital signs, spinal magnetic resonance imaging (MRI) was performed on the sixth day of hospitalization. Findings similar to those observed on CT were confirmed by the lumbar spine MRI (Fig. 2), and surgery was performed the following day. We selected the posterior surgical approach for the following reasons. First, the operator felt concerned because he had little experience with the lateral approach. Second, we concluded that it would be difficult to maintain a lateral position due to the traction pins applied to both proximal tibias to stabilize the bilateral femoral fractures. Third, the Jefferson fracture was an anterior arch fracture without ligament injury. In addition, the general surgery department confirmed that it would be possible to perform surgery in the prone position despite the patient's liver injury.

In the preoperative neurological examination, movements of both hip and knee joints were difficult to examine due to traction. The motion scores of both ankle dorsiflexors, long toe extensors, and ankle plantar flexors were all poor. Sensation in both lower extremities was intact except around the perineum. Surgery was performed under general anesthesia. A midline skin incision was made in the prone position, and periosteal dissection was performed to expose the lamina from the 11th thoracic to the first sacral vertebra. Pedicle screws were inserted into the first, second, fourth, and fifth lumbar vertebrae under fluoroscopic guidance. After screw insertion, total laminectomy of the third lumbar vertebral and partial laminectomy of the second lumbar vertebra were performed using a high-speed drill and laminectomy punch. Thereafter, both pedicles of the third lumbar vertebra were removed to ensure sufficient space for the corpectomy and cage insertion. Both spinal nerves of the third lumbar vertebra passing through the intervertebral foramen were subsequently exposed. Removal of both pedicles and exposure of both spinal nerves provided an adequate field of view and space to perform the corpectomy. Total disc resections were performed between the second and third lumbar vertebrae, and between the third and fourth lumbar vertebrae. While close attention was paid to the spinal nerves, the vertebral body was removed using a drill, pituitary rongeurs, and a laminectomy punch. During surgery, we dissected the spinal nerves using a nerve hook and curettes and checked for sufficient decompression. To prevent the cage from being displaced anteriorly, an additional corpectomy was performed, leaving the anterior longitudinal ligament and anterior portion of the vertebral body. When corpectomy had

Fig. 1. Abdominopelvic computed tomography performed in the emergency room. (A) Sagittal image. (B) Axial image.

Fig. 2. Preoperative lumbar magnetic resonance imaging. (A) Sagittal image. (B) Axial image.

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been performed to accommodate the cage, the expandable cage was carefully inserted and expanded while we protected the spinal nerves and dural sac. Subsequently, the rods were bent to create a lordotic curve and the space between the second and fourth lumbar vertebrae was compressed and fixed. Then, meticulous bleeding control was performed, drainage tubes were inserted, and surgery was completed using layer-by-layer sutures (Fig. 3). The findings of the neurological examination performed immediately after surgery were not significantly different from the findings of the examination performed preoperatively.

The patient received appropriate treatment for the accompanying injuries, was transferred to a rehabilitation hospital on the 61st day of admission and had subsequent follow-up on an outpatient basis. After being transferred, the patient did not receive appropriate rehabilitation because he was confirmed to be positive for carbapenemase-producing Enterobacteriaceae at the hospital and was isolated. When the patient visited the outpatient clinic 6 months after spine surgery, he was able to stand unassisted, but his ambulation was limited because of bilateral foot drop. In both legs, the foot drops were due to peroneal nerve injury, and the patient was receiving orthopedic follow-up. Both hip flexors were assessed as fair. Both knee extensors, ankle dorsiflexors, long toe extensors, and ankle plantar flexors were assessed as poor. The patient complained of hypoesthesia along the sensory distribution of both peroneal nerves, especially on the left side. In addition, he still had difficulty voiding. Lumbar spine radiographs taken immediately after surgery, 1 month, 3 months, and 6 months after surgery showed that the expandable cage and screws were well maintained without instability (Fig. 4).

**Ethics statement**

This study was approved by the Institutional Review Board of Gachon University Gil Medical Center (No. GDIRB2022-190). Written informed consent for publication of the research details and clinical images were obtained from the patient.

**DISCUSSION**

Circumferential reconstruction of the thoracolumbar spine can be achieved by combining anterior and posterior approaches, or

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**Fig. 3.** Intraoperative fluoroscopic images. (A) Anteroposterior image. (B) Lateral image.

**Fig. 4.** Postoperative plain radiographs. (A) Immediately postoperative lumbar lateral plain radiograph. (B) Lumbar lateral plain radiograph 1 month after surgery. (C) Lumbar lateral plain radiograph 3 months after surgery. (D) Lumbar anteroposterior plain radiograph 6 months after surgery. (E) Lumbar lateral plain radiograph 6 months after surgery.
lateral and posterior approaches. These anterior and lateral approaches show high fusion rates and can correct sagittal deformities [1,5]. They allow direct corpectomy, facilitate cage placement, and allow plating to be performed [7]. Despite these advantages, the anterior and lateral approaches have several disadvantages. The most important point to consider in the anterior approach is the possibility of damage to blood vessels (2%–15%); large blood vessels such as the aorta, common iliac artery, and inferior vena cava may be damaged during the process of exposing the vertebral body [8–10]. In addition, complications such as ureteral injury, hypogastric plexus injury, and incisional hernia may occur [11]. In the lateral approach, the lumbar and sympathetic plexuses may be injured during traction of the psoas muscle and exposure of the vertebral body. Intraoperative monitoring devices are needed to avoid these risks [8,12]. In the lower lumbar level, access via lateral approach is sometimes challenging because of the iliac crest [11]. Additional posterior support is required in the anterior and lateral approaches, as there is a risk of displacement of the inserted cage [8].

The single-stage posterior approach has been successfully used for circumferential decompression and reconstruction of thoracolumbar tumors [13]. However, it has several limitations. First, long-segment fixation is required to provide adequate stability [14]. There is also a risk of lower fusion rates owing to the inability to insert a larger cage, unlike the anterior and lateral approaches [6]. Meanwhile, the single-stage posterior approach also has several advantages. First, it is the most widely used technique because it is anatomically familiar to surgeons performing spinal surgery [8]. Second, it eliminates the risks of vascular or lumbar plexus injury [8–10,12]. In addition, since only one approach is used, it can promote anterior and posterior fixation, and it has the advantage of preventing cage displacement by preserving the anterior longitudinal ligament and the anterior part of the vertebral body [8,13].

As mentioned above, there are various surgical approaches for the treatment of burst fractures of the thoracolumbar spine. This case demonstrates that the posterior approach alone is sufficient for corpectomy and fusion. In a variety of cases, such as when collaboration with general or thoracic surgeons is not feasible or when equipment such as an intraoperative monitoring device is not available, the single-stage posterior approach may be an excellent option.

**ARTICLE INFORMATION**

**Author contributions**

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

**Conflicts of interest**

The authors have no conflicts of interest to declare.

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**Data availability**

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

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INTRODUCTION

Traumatic gallbladder injury is uncommon, accounting for 1.9% to 2.1% of all cases of abdominal trauma [1]. In the pediatric population, these injuries are more common with blunt trauma and are associated with liver lacerations in approximately 83% to 91% of cases [1]. Moreover, the occurrence of a gallbladder injury in a pediatric patient secondary to penetrating abdominal trauma is a rare event. An extensive literature search revealed only one reported case of a penetrating gallbladder injury in a pediatric patient that occurred more than five decades ago [2]. The case was managed with open abdominal exploration and primary repair of the gallbladder wall defect. This highlights the infrequency of these cases and the importance of describing current and more up-to-date management options and their subsequent outcomes.

CASE REPORT

Penetrating gallbladder injuries are uncommon in the pediatric population. The treatment varies according to the severity of the injury and the patient’s hemodynamics. We present the case of an 11-year-old male with an accidental pellet gunshot wound to the right upper abdomen that resulted in a grade III liver laceration and damage to the anterior gallbladder wall. The patient underwent laparoscopic cholecystectomy with drain placement. Postoperative radiography of the surgical specimen confirmed the presence of the pellet in the gallbladder. The patient recovered uneventfully and was discharged home on postoperative day 3. Laparoscopic cholecystectomy is a feasible treatment option for penetrating gallbladder injuries in hemodynamically stable patients.

Keywords: Gallbladder; Wounds and injuries; Cholecystectomy; Laparoscopy; Case reports

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Penetrating gallbladder injury in a pediatric patient in the United States: a case report

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face of the liver to the gallbladder fossa, with a small metallic object adjacent to the gallbladder fundus, pericholecystic fluid, and mild thickening along the colonic hepatic flexure (Fig. 1). Upon arrival at our institution, the patient remained hemodynamically normal. The physical examination was remarkable for a 2-mm penetrating wound in the right upper abdomen associated with tenderness to palpation with no peritoneal signs. Given the patient’s penetrating abdominal injury with associated abdominal pain and suspicion of intestinal injury, the decision was made to perform diagnostic laparoscopy. Upon entry to the abdomen and inspection of the bowel with close attention to the colonic hepatic flexure, no intestinal perforation was identified. However, there was bile spillage and blood at the right upper quadrant, as well as damage to the anterior gallbladder wall. On the anterior liver surface, a small wound from the bullet was visualized with no active bleeding. An intraoperative x-ray examination was used to localize the pellet, which was observed to be in the gallbladder. The decision was made to perform laparoscopic cholecystectomy. After the gallbladder was removed, an additional small wound was seen at the gallbladder fossa, most likely from the bullet trajectory causing the liver laceration, which was mostly intraparenchymal. No bleeding or bile leak was observed, and no additional interventions were required. An x-ray of the surgical specimen confirmed the presence of the metallic pellet inside the gallbladder lumen (Fig. 2). A drain was left in the gallbladder fossa due to the high-grade liver laceration. During the postoperative period, the patient tolerated a regular diet and pain was minimal. Once the serosanguineous drain output decreased to a satisfactory volume, it was removed on postoperative day 3, and the patient was discharged home.

**Ethics statement**
This study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent for publication of the research details and clinical images was obtained from the patient’s legal guardian and the manuscript was reviewed by the privacy coordinator prior to submission.

**DISCUSSION**

The Eastern Association for the Surgery of Trauma (EAST) guidelines recommend that the management of penetrating injuries isolated to the right upper abdominal quadrant includes observation or surgical intervention depending on the patient’s vital signs and physical examination findings. Patients with stable vital signs, a reliable examination, and minimal to no abdominal tenderness can be observed[3]. Although our patient had an isolated right upper quadrant abdominal penetrating injury, he presented with abdominal tenderness, evidence of pericholecystic fluid, and concerns for intestinal injury; thus, surgical exploration was warranted.

Advances in minimally invasive surgery have allowed patients that are hemodynamically normal to undergo diagnostic laparoscopy instead of open abdominal exploration. This technique has been shown to be safe and practical in selected patients when performed by experienced surgeons[4,5]. It enables a complete

![Fig. 1. Abdominopelvic computed tomography scan with intravenous contrast demonstrating a 3.8-cm grade III liver laceration, pericholecystic fluid, and colonic hepatic flexure thickening. A metallic object is seen near the gallbladder fundus.](https://doi.org/10.20408/jti.2023.0008)

![Fig. 2. Radiography of the surgical specimen showing the pellet inside the gallbladder.](https://doi.org/10.20408/jti.2023.0008)
evaluation of intra-abdominal viscera, reduces the incidence of nontherapeutic operations, and allows a therapeutic intervention when needed [5]. Laparoscopy allowed us to carefully evaluate the colonic hepatic flexure and surrounding structures, ruling out colonic injury without the need for open exploration and allowing identification of the gallbladder wall injury and bile spillage. Additionally, minimizing the size of the surgical scars had a positive psychological impact on the patient’s experience.

Simple gallbladder contusions or partial avulsions can be treated conservatively in patients who are hemodynamically stable and have minimal symptoms [1]. However, in the setting of a penetrating injury, the most likely injury is a gallbladder wall perforation or laceration, for which laparoscopic cholecystectomy is recommended [1,6]. Suturing of the gallbladder perforation was advocated in the past, but it carries risks of cholecystitis, re-rupture, wall necrosis, and promoting calculus formation [7].

A recent review of traumatic gallbladder perforation in children reported eight cases of blunt trauma causing gallbladder perforation that were managed with cholecystectomy with favorable outcomes [1]. Five of the eight operations were done in a laparoscopic fashion. Laparoscopic cholecystectomy can be considered a feasible treatment option for stable pediatric patients with penetrating gallbladder injuries.

**ARTICLE INFORMATION**

**Author contributions**

Conceptualization: all authors; Data curation: all authors; Formal analysis: all authors; Methodology: all authors; Project administration: RJH; Writing–original draft: NCC; Writing–review & editing: SS, DRM, CD, RJH. All authors read and approved the final manuscript.

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The authors have no conflicts of interest to declare.

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**Data availability**

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

**REFERENCES**

INTRODUCTION

Unstable pelvic ring injuries are potentially life-threatening and associated with high mortality and complication rates in polytrauma patients. The most common cause of death in patients with pelvic ring injuries is massive bleeding. With resuscitation, external fixation can be performed as a temporary stabilization procedure for hemostasis in unstable pelvic fractures. Internal fixation following temporary external fixation of the pelvic ring yields superior and more reliable stabilization. However, a time-consuming extended approach to open reduction and internal fixation of the pelvic ring is frequently precluded by an unacceptable physiologic condition and/or concomitant injuries in patients with multiple injuries. Conservative treatment may lead to pelvic ring deformity, which is associated with various functional disabilities such as limb length discrepancy, gait disturbance, and sitting intolerance. Therefore, if the patient is not expected to be suitable for additional surgery due to a poor expected physiologic condition, definitive external fixation in combination with various percutaneous screw fixations to restore the pelvic ring should be considered in the acute phase. Herein, we report a case of unstable pelvic ring injury successfully treated with definitive external fixation and percutaneous screw fixation in the acute phase in a severely injured polytrauma patient.

Keywords: Pelvic ring injury; External fixators; Percutaneous screw; Minimally invasive stabilization; Case reports

Percutaneous screw fixation and external stabilization as definitive surgical intervention for a pelvic ring injury combined with an acetabular fracture in the acute phase of polytrauma in Korea: a case report

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Pelvic ring injuries, and most bleeding in such injuries originates from the presacral venous plexus and fractured bone [3]. In patients with these injuries, pelvic ring instability can be the primary reason for hemodynamic instability, and hemorrhage control should be a part of resuscitation. Therefore, damage control in
the form of temporary mechanical stabilization such as external fixation, pelvic wrapping, or pelvic packing is necessary to control bleeding [4]. Although the contemporary literature includes new concepts such as safe definitive surgery, early appropriate care, and prompt individualized safe management [5], to ensure more stable and reliable fixation, definitive open reduction and internal fixation are usually performed during the “window of opportunity” after resuscitation and restoration of physiologic condition [5]. However, the patient’s physiologic condition may not recover sufficiently to support pelvic fracture surgery within the window of opportunity. Because pelvic fracture surgery with an extended approach is time-consuming and associated with numerous complications, this aggressive surgical impact during the acute phase as part of early total care can induce a “second hit” [5]. In contrast, external fixation and various percutaneous screw fixations are minimally invasive surgical procedures that minimize secondary complications. We report a case of a hemodynamically unstable polytrauma patient for whom future definitive surgery was expected to be precluded due to an unacceptable physiologic condition. The patient was successfully treated with definitive external fixation and percutaneous screw fixations in the acute phase.

**CASE REPORT**

An American Society of Anesthesiologists (ASA) physical status class I, healthy 33-year-old male patient was transferred to a level I trauma center after being struck by an excavator bucket at a construction site. The patient had no significant past medical history. On arrival, the patient was confused, and his vital signs included an unstable blood pressure of 95/44 mmHg, a pulse rate of 144 beats/min, and a respiration rate of 40 breaths/min. Given the patient’s unstable condition, a massive transfusion protocol was initiated with the transfusion of packed red blood cells, fresh frozen plasma, and platelets in a 1:1:1 ratio. Radiography and computed tomography demonstrated an unstable pelvic ring injury consisting of right sacroiliac joint dislocation, a non-displaced transverse fracture of the left acetabulum, right pubic rami fractures, and an anterior wall fracture of the right acetabulum.

![Initial radiographs. (A) Simple radiography indicates an unstable pelvic ring injury. (B, C) Computed tomography images show widening of the right sacroiliac joint (yellow arrows) and an anterior wall fracture of the right acetabulum (white arrow). (D, E) Computed tomography images demonstrate a transverse fracture of the left acetabulum (red arrows).](image-url)
The patient also had traumatic hemopneumothorax with multiple rib fractures, subarachnoid hemorrhage with depressed skull fracture of the temporal bone, and facial maxillary bone fracture. The patient was determined to have an Injury Severity Score of 34, indicating polytrauma. Emergent closed thoracostomy with chest tube insertion, cranioplasty with hematoma evacuation, and external fixation along with percutaneous screw fixation were performed. Because the patient's condition was life-threatening, we expected future definitive internal fixation to be precluded by an unacceptable physiologic condition. Therefore, we opted to perform minimally invasive definitive fixation in the acute phase if possible. We planned external pelvic fixation with percutaneous iliosacral (IS) screw fixation for the pelvic ring and percutaneous screw fixation for the left acetabular fracture. After application of a supra-acetabular external fixator using 6-mm–diameter Schanz pins, percutaneous IS screw fixations were performed to the S1 body using a 7.3-mm partially threaded cannulated screw with a washer in compression mode and to the S2 body using a 7.3-mm fully threaded cannulated screw in position mode. Both the S1 and S2 screws had purchase with the contralateral sacroiliac joint to ensure stability. During this procedure, an external fixator frame was utilized to reduce the posterior pelvic ring by joystick maneuver and was subsequently left in place. Percutaneous \textit{in situ} fixation of the left acetabulum was performed using a 7.3-mm cannulated screw. This screw was introduced just inferior to the pubic tubercle and was passed through the intramedullary corridor of the superior pubic ramus to the posterior column to achieve bicolumnar fixation of the SI joints.

\textbf{Fig. 2.} Intraoperative fluoroscopic images. (A) Schanz pins were introduced in the anterior inferior iliac spine for application of a supra-acetabular external fixator. Widening of the sacroiliac joint (SJJ) was observed (red line). (B) An external fixator frame was utilized to reduce the posterior pelvic ring by joystick maneuver, and a guide pin was simultaneously introduced to the S1 body. The right SJJ was reduced (red arrow). (C) Percutaneous iliosacral screw fixation to the S1 body using a 7.3-mm partially threaded cannulated screw with a washer in compression mode. Anatomic reduction of the left SJJ was achieved (yellow arrow). (D, E) Additional percutaneous iliosacral screw fixation to the S2 body using a 7.3-mm fully threaded cannulated screw in position mode. (F) Percutaneous \textit{in situ} fixation using a 7.3-mm cannulated screw of the left acetabulum.
the acetabulum (Figs. 2, 3). The patient was subsequently admitted to the intensive care unit for ongoing resuscitation. After spending 16 days in the intensive care unit, the patient was transferred to the general ward. During this critical period for lifesaving, the patient’s physiologic condition, including coagulopathy and acid-base imbalance with lactate level, had not recovered sufficiently for additional surgery [5]. On serial follow-up, radiographs indicated that reduction of the pelvis and acetabulum were well maintained, and no further displacement was observed. We decided to keep an external fixator as definitive stabilization for the anterior pelvic ring and to use adjunct stabilization with IS screw fixations for the posterior ring. However, we removed the external fixator 24 days after surgery due to pin site infection. Because no residual fluoroscopic displacement was observed after removal of the external fixator, we performed no further surgery (Fig. 4). Despite the lack of scientific evidence, a pelvic binder was applied to prevent secondary displacement after removal of the external fixator. The patient’s mental and general condition completely recovered by approximately 4 weeks after the injury. The patient was then allowed to sit and move by wheelchair as tolerated. From 6 weeks postoperatively, the patient was allowed protected weight-bearing and could transition to full weight-bearing as tolerated. Eight weeks after surgery, the patient was allowed to walk independently. At 6-month follow-up, radiographs demonstrated complete healing and favorable alignment of the pelvic ring, and the patient returned to full activity (Fig. 5).

**Ethics statement**

This study was reviewed and approved by the Institutional Review Board of Cheju Halla General Hospital (No. 2023-L05-01). The requirement for informed consent was waived, as all data were de-identified to protect patient’s right to privacy.

**Fig. 3.** Postoperative radiographs demonstrate anatomical reduction of the posterior pelvic ring with percutaneous iliosacral screws and adjunctive anterior external fixation. The retrograde intramedullary superior pubic ramus screw has purchase with both columns to stabilize the left transverse acetabular fracture in the (A) anteroposterior, (B) inlet, (C) outlet, and (D, E) oblique views.

**Fig. 4.** Radiographs demonstrate no residual displacement after removal of the external fixator in the (A) anteroposterior, (B) inlet, (C) outlet, and (D, E) oblique views.

**Fig. 5.** Follow-up radiographs at 6 months after surgery demonstrate complete healing in the (A) anteroposterior, (B) inlet, (C) outlet, and (D, E) oblique views.
Unstable pelvic ring injuries require surgical reduction and fixation to restore the pelvic anatomy and allow the patient to regain physical function [6]. However, because unstable pelvic ring injuries are life-threatening and associated with high mortality and complication rates, initial assessment and management to resuscitate is a priority [1,2]. The timing of major fracture care in polytrauma patients has been updated. The current understanding avoids the use of a “window of opportunity,” in which surgery is avoided on days 2 to 4 after injury [7]. Instead, the contemporary literature includes new concepts such as safe definitive surgery, early appropriate care, and prompt individualized safe management [5]. However, because the present patient’s physiologic condition did not recover for a long period, these new concepts were inappropriate. We decided to apply a single-bar and single-pin supra-acetabular pelvic external fixator for damage control in the acute phase. External fixation of the pelvis is associated with hemostasis due to reduction of pelvic volume, hematoma formation by the tamponade effect, and fracture fragment stabilization [8]. However, posterior stabilization cannot be achieved using an anteriorly placed external fixator. The most important step in ensuring pelvic ring stability is the reduction and fixation of the posterior sacroiliac complex [6]. A C-clamp is used to stabilize the posterior pelvic ring to control hemorrhage, particularly in vertical shear injury patterns [1,2]. Some trauma surgeons advocate the use of an anti-shock IS screw or rescue screw instead of posterior stabilization with a C-clamp [9]. In the present case, posterior ring stabilization was achieved with percutaneous IS screws to the S1 and S2 bodies. We performed percutaneous IS screw fixation to the S1 body using a 7.3-mm partially threaded cannulated screw with a washer in compression mode and to the S2 body using a 7.3-mm fully threaded cannulated screw in position mode. During this procedure, an external fixator frame was utilized to reduce the posterior pelvic ring by the joystick maneuver and was subsequently left in place. Because we expected additional surgery to be precluded due to a poor physiologic condition, we endeavored in each stage of procedures to attain anatomical reduction and simple stabilization with minimally invasive procedures during damage control surgery in the acute phase. In this case, the functions of the external fixator included not only damage control to minimize bleeding, but also definitive fixation to the anterior pelvic ring and adjunctive fixation with IS screws to the posterior pelvic ring. Several authors have reported high complication rates and poor outcomes when a pelvic external fixator is used as definitive fixation of the pelvic ring [10]. Another study indicated that pelvic external fixators have insufficient biomechanical stability and mixed outcomes after surgery [11]. In contrast, the contemporary orthopedic trauma literature suggests that a pelvic external fixator can be used for the definitive fixation of a pelvic ring injury. Tosounidis et al. [8] reported that the application of a pelvic external fixator as definitive fixation in specific polytrauma settings is a safe and efficient method for pelvic ring stabilization. In that study, they stated that the rates of complications such as infection, aseptic loosening, and neurogenic complications were low, while the overall outcomes were good. Therefore, their study showed that in polytrauma patients, external fixation can be a useful alternative to internal fixation, yielding acceptable clinical outcomes with low complication rates. In the present case, a minimally displaced transverse fracture of the left acetabulum was also stabilized by percutaneous screw fixation without reduction. A guide pin was introduced just inferior to the pubic tubercle. Then, it was passed through the intramedullary corridor of the superior pubic ramus to the posterior column to achieve bicolumnar fixation of the acetabulum. Percutaneous fixation of acetabular fractures with or without closed reduction has been proposed to prevent potential further displacement of simple fractures with minimal displacement [12]. Based on the concept of the roof arc angle, Olson and Matta [13] concluded that in fractures with roof arc measurements greater than 45° on anteroposterior (medial roof arc), iliac oblique (posterior roof arc), and obturator oblique (anterior roof arc) radiographs, sufficient weight-bearing articular surface remained intact for nonoperative treatment to be considered when the femoral head remained congruent with the superior acetabulum. In the present case, the patient’s measured roof arc angles on anteroposterior, iliac oblique, and obturator oblique radiographs were 51°, 68°, and 65°, respectively. The femoral head remained congruent with the superior acetabulum. In addition, the patient’s physiologic condition was too poor for additional surgical procedures, so we decided not to perform surgery for the anterior wall fracture of the right acetabulum to avoid surgical impact that could induce a “second hit.” The optimal timing of removal of the external fixator also raised issues. Typically, union of the pelvic ring may be achieved after 8 to 12 weeks [14]. Problematically, however, due to the lack of an indicator of ligamentous healing, the timing of removal in this case was based on a combination of factors such as surgeon clinical judgment, pin site concern, and concomitant injury. Despite every effort to maintain the external fixator as long as possible, it had to be removed 24 days after surgery due to pin site infection. Because the external fixator was used for adjunctive stabilization of the posterior ring,
no residual displacement was observed after the removal of external fixation. Although Hoyt et al. [14] reported that the timing of removal and their definition of clinical union were based on predetermined removal timing and examination under anesthesia instead of guidance by radiographic or functional milestones, we did not perform an examination under anesthesia due to fear of iatrogenic further displacement. Despite the lack of scientific evidence, a pelvic binder was applied to prevent secondary displacement after the removal of the external fixator.

A limitation of this case report is that the follow-up duration was only 9 months. This may be insufficient to evaluate all complications, including posttraumatic degenerative changes in bones and joints. Furthermore, pelvic ring injuries have various fracture and dislocation patterns, and multiple factors may affect the outcomes. Therefore, prudent decision-making in the acute critical phase is essential. Nevertheless, when additional definitive surgery is precluded by unacceptable physiologic conditions in hemodynamically unstable pelvic ring injuries, minimally invasive definitive stabilization in the acute phase can be a treatment option.

ARTICLE INFORMATION

Author contributions
Conceptualization: HL, SL; Data curation: EY; Formal analysis: SKS; Methodology: HL, SL; Project administration: MRC, SL; Visualization: EY; Writing–original draft: HL, SL; Writing–review & editing: MRC, SKS, SL. All authors read and approved the final manuscript

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

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

REFERENCES

A Morel-Lavallée lesion (MLL) is a pathologic fluid collection within an abnormally formed space, resulting from an internal degloving injury between the muscle fascia and subcutaneous fat layer. Due to its resistance to conservative treatments such as drainage or compression dressing, various therapeutic methods have been developed for MLL. However, no standardized guidelines currently exist. Recently, endoscopic debridement and cutaneo-fascial suture (EDCS) has been introduced for the treatment of MLL, particularly for large lesions resistant to conservative approaches. While this procedure is known to be effective, limited reports are available on potential complications. The authors present a case of skin necrosis following EDCS for a massive MLL.

**Keywords:** Morel-Lavallée lesion; Wounds and injuries; Sutures; Surgery; Case reports

**INTRODUCTION**

A Morel-Lavallée lesion (MLL) is a pathologic fluid collection within an abnormally formed space, resulting from an internal degloving injury between the muscle fascia and subcutaneous fat layer [1]. Due to its resistance to conservative treatments such as drainage or compression dressing, various therapeutic methods have been developed for MLL [2,3]. However, no standardized guidelines currently exist. Recently, endoscopic debridement and cutaneo-fascial suture (EDCS) has been introduced for the treatment of MLL [4–8]. This procedure is known to be effective for large MLLs that are resistant to conservative treatments. However, limited reports are available on potential complications. The authors present a case of skin necrosis following EDCS for a massive MLL.

**CASE REPORT**

A 43-year-old man was transferred to Gachon University Gil Medical Center (Incheon, Korea) following a pedestrian traffic accident. His hemodynamic status was stable. A computed tomography (CT) scan revealed multiple pelvic fractures and contrast extravasation in the pelvic cavity. The patient underwent angiography and embolization to address the pelvic bleeding. Hemorrhage from the bilateral internal iliac arteries was observed and embolized. The CT scan showed hematomas in the bilateral hips (Fig. [Image]...
On day 5 of hospitalization, the patient reported pain and fluctuation in both hips. Based on the CT scan findings and physical examination, the authors diagnosed the fluctuation as an MLL. EDCS was planned for the lesion, and the operation was performed on the same day. In the operating room, MLL was noted on the right (40 × 50 cm) and left (40 × 60 cm) hip/flank (Fig. 2). A 2-cm skin incision was made for the scope trocar, and two additional skin incisions were made for the working ports. Initially, debridement was performed using a sponge stick (Fig. 3). After debridement, saline irrigation was conducted through the skin incision (Fig. 4). Following debridement and irrigation, trocars were placed, and CO₂ gas inflation was performed. The gas-inflated pressure was approximately 10 mmHg, and it did not interfere with visibility or worsen the wound. Under videoscopy, additional debridement and hemostasis were performed (Fig. 5). The subcutaneous fat layer was attached to the fascia with an endoscopic suture using absorbable suture material, and video-assisted cutaneo-fascial suturing from the skin to fascia was performed using 1-0 nylon (Fig. 6). Two drains were placed in the cavity. The cutaneo-fascial sutures were removed sequentially over 2 weeks. After the stitch removal, necrosis of the skin (5 cm in diameter) was found on the right hip (Fig. 7). The lesion was debrided, and negative-pressure wound therapy was applied. The patient was discharged on day 32 of the hospital stay after improvement of the skin defect.

![Fig. 1. Computed tomography scan shows hematomas (arrows) in the bilateral hip. (A) Axial cut. (B) Coronal cut.](image1)

![Fig. 2. Morel-Lavallée lesions are observed on (A) the right (40×50 cm) and (B) the left (40×60 cm) hip/flank.](image2)
**Fig. 3.** Debridement performed with a sponge stick on the left hip/flank. (A) Sponge stick. (B) Gauze debridement with sponge stick. (C) Laparoscopic grasper with gauze. (D) Gauze debridement with laparoscopic grasper.

**Fig. 4.** Saline irrigation through the skin incision on the left hip/flank.

**Ethics statement**
This study was approved by the Institutional Review Board of Gachon University Gil Medical Center (No. GDIRB2023-052). Written informed consent for publication of the research details and clinical images was obtained from the patient.

**Fig. 5.** Additional debridement and hemostasis under videoscope.
Fig. 6. Cutaneo-fascial sutures and drains on (A) the right and (B) the left hip/flank.

Fig. 7. Skin necrosis on the right hip after the procedure.

DISCUSSION

MLL arises due to shearing injury and typically affects the greater trochanter, flank, and buttock [9]. Early treatment of MLL is crucial, as untreated cases may progress to further tissue necrosis and encapsulation, ultimately leading to serious infection [8,10,11].

The treatment options for MLL can be categorized into conservative (or nonsurgical therapy) and surgical intervention. Initially, conservative therapy involves external compression and percutaneous drainage [12–14]. While this approach is simple and minimally invasive, it is considered less effective than surgery and requires a longer treatment period for advanced MLL cases [5,7].

Surgical treatment should be considered for advanced or large MLLs. These often involve substantial amounts of necrotic debris, unabsorbed turbid exudate, and organized capsules. Nickerson et al. [15] demonstrated that the volume of fluid aspirated from an MLL is associated with its resolution rate. In their study, 83% of patients with more than 50 mL of fluid aspirated from the MLL experienced recurrence following percutaneous drainage.

Open debridement and primary closure is the traditional surgical approach for managing MLL. However, the long skin incision and subsequent pain are drawbacks of this method. EDCS has been developed to address these disadvantages associated with open debridement [4–8]. As previously reported, the EDCS technique shares similar components with open debridement, including drainage of all fluid collections, endoscopic removal of necrotic tissue, endoscopic or endoscopy-assisted suturing, and compression dressing [4–8]. Regarding endoscopic or endoscopy-assisted suture, a suture between the subcutaneous fat layer and fascia within the cavity is preferable to a cutaneo-fascial su-
ture. However, these authors had to employ both methods due to the friable and thin nature of the subcutaneous fat layer. While previous reports have described the use of numerous cutaneo-fascial sutures [4–8], we placed only 3 or 4 similarly-sized cutaneo-fascial sutures in the MLLs, as this was sufficient for approximation between the subcutaneous fat layer and the fascia. An excessive cutaneo-fascial suture may lead to complications such as pain, scarring, infection, and skin necrosis. The larger the MLL, the more advantageous EDCS becomes.

Unlike conventional laparoscopic surgery, no standard trocar insertion position exists for EDCS in the treatment of MLL. However, the following approach may be optimal. After closing the small skin incision from a previous debridement, the authors inserted three trocars along the long axis of the MLL to accommodate a scope and two working ports. Multiple endoscopic sutures were placed using a scope, which was inserted through the three trocars in a rotating manner. For MLLs larger than this, additional trocars might be required.

In this patient, a serious complication developed in the form of skin necrosis on the right hip, although this was relatively small compared to the total MLL (40 × 50 cm). Several possible causes existed for the skin necrosis, which may have occurred due to a combination of factors. First, the location of the necrotic lesion was the most friable site of the wound, situated in the central portion of the MLL. As a result, this area would have received less blood supply than other parts of the lesion. Based on this hypothesis, employing a minimally invasive endoscopic procedure in this case may have reduced the extent of skin necrosis. Second, the lesion was located on the greater trochanter of the femur, which is the most prominent portion anatomically. The skin and subcutaneous fat layers on the greater trochanter of the femur are thinnest in the hip area, making it particularly susceptible to necrosis. Other potential causes could relate to the surgical procedure. The cutaneo-fascial suture may have been too tight, leading to skin ischemia. Additionally, the debridement might have been too excessive, causing injury to the affected area. Given these concerns, practitioners must carefully consider these factors when implementing the EDCS technique to prevent skin necrosis. Proper attention to the tension of cutaneo-fascial sutures and the extent of debridement can help minimize potential complications and ensure a more successful outcome. Fortunately, the wound in the present case improved after using negative-pressure wound therapy alone without the need for a skin graft.

This study describes the successful management of a very large MLL using EDCS. Skin necrosis is a potential complication following the procedure. Surgeons must exercise caution when performing EDCS on vulnerable MLL lesions.

**REFERENCES**

Blunt abdominal trauma resulting in pancreatic injury in a pediatric patient in Australia: a case report

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INTRODUCTION

Visceral injuries in children account for only about 10% of all trauma cases, with the majority involving head and extremity injuries [1]. Pancreatic injuries, which are relatively rare and potentially life-threatening in children, make up 0.6% of all abdominal trauma cases in this population, and pancreatic duct (PD) injuries are even less common. A study by Canty and Weinman [2] reported that among 14,245 pediatric trauma patients admitted to a US-based hospital, a mere 0.12% had PD injuries. Studies also indicate that over 75% of pancreatic injuries in children result from blunt trauma, most commonly caused by handlebar injuries or seatbelts. It is crucial to recognize that diagnosing blunt pancreatic injuries can be challenging and requires a high degree of suspicion for proper management [3]. Furthermore, pancreatic injuries can range from minor contusions to severe damage involving the PD [4].

Our report concerns a patient who initially presented with a history and clinical symptoms suggestive of appendicitis. However, upon further examination and investigation, the true cause of his abdominal pain was revealed.
CASE REPORT

We present the case of a 10-year-old boy with no significant past medical or surgical history, who was transferred from a peripheral hospital to our pediatric emergency department. He was referred to our general surgical department for possible appendicitis in the late evening. During his initial surgical assessment, the impression was indeed that of appendicitis due to a 2-day history of gradually worsening abdominal pain accompanied by vomiting. Furthermore, upon admission, his inflammatory markers were elevated, with a C-reactive protein (CRP) of 75 mg/L and a white cell count (WCC) of $15 \times 10^9/L$. He was scheduled for a fasting review and abdominal ultrasound (USS) the following morning. The next day, the boy was evaluated by the day surgical team, and a complete history and examination were conducted once again. The child and his mother reported that he had returned home with severe abdominal pain after playing with his friends and had been asymptomatic prior to this incident.

In summary, the child experienced a gradual onset of abdominal discomfort while playing outside with his friends. Subsequently, he suffered from nausea and two instances of nonbilious vomiting. He did not exhibit any other signs of infection, such as fever or diarrhea. Based on this history, we were not convinced that the child had appendicitis, as he lacked significant infectious symptoms; his vomiting could have been a result of pain. Upon conducting further blood tests, his CRP level rose to 106 mg/L, while his WCC dropped to $11 \times 10^9/L$ (Fig. 1).

We subsequently inquired if the child had experienced any incidents while playing outside, such as an injury. He then remembered that he had been riding his quadbike and collided with a tree. Upon further questioning, he disclosed that the steering wheel had indeed struck his upper abdomen during the impact. He experienced mild abdominal pain at the time but continued to play on the trampoline. Since he appeared relatively pain-free after the quadbike incident and proceeded to jump on the trampoline, his parents did not initially attribute the pain to the accident. The child informed us that it was only after jumping on the trampoline that the pain rapidly intensified.

His observations remained stable, with no signs of fever. Upon examination, he appeared uncomfortable and exhibited a mildly distended abdomen without any visible bruising. He experienced generalized tenderness, tested positive for Rovsing sign, and displayed guarding with peritonism. Based on this comprehensive history and examination findings, our impression was that he had either sustained a blunt visceral injury or was suffering from perforated appendicitis. As planned, he underwent abdominal USS, which revealed "moderate volume free fluid with echogenic dependent debris concerning for blood products." There was no evidence of pneumoperitoneum, but an abdominal visceral injury could not be ruled out. Consequently, a nasogastric tube (NGT) was inserted, and he was started on broad-spectrum intravenous antibiotics. We also added a lipase test to his initial

![Fig. 1. Trend of (A) C-reactive protein (CRP) and (B) white cell count (WCC) during admission.](https://doi.org/10.20408/jti.2023.0013)
blood work following the USS review, which showed an elevated level of 3,680 U/L (normal level is < 45 U/L).

Upon reviewing the USS report, an urgent computed tomography (CT) scan of the patient’s abdomen and pelvis was requested for a more detailed evaluation. The CT scan revealed a pancreatic transection accompanied by a moderate volume of retroperitoneal and intra-abdominal free fluid (Fig. 2). Additional findings included thickening in the gastric pylorus region, likely due to the adjacent pancreatic injury, and a normal appendix (Fig. 3). Consequently, the child’s abdominal discomfort was indeed caused by pancreatic injury resulting from the previously mentioned blunt abdominal trauma sustained during the quadbike accident. Moreover, since the transection was located near the pancreatic head/neck junction, we had a high suspicion of PD injury.

For further specialist management, we contacted the gastroenterology team at an adult hospital located on the same campus as our hospital. This was because our pediatric gastroenterology team does not perform endoscopic retrograde cholangiopancreatography (ERCP). The child was transferred to the adult center on the same day for the procedure. During ERCP, the patient was found to have acute pancreatitis and a high-grade leak from the main PD injury at the level of the neck. There was also resistance at the site of the leak when attempting to cannulate the duct with a 5F catheter. A 3.5F catheter (the smallest available at the time) was then used to achieve deeper cannulation; however, the same resistance was noted. Eventually, a 5F single pigtail PD stent was inserted with the stent positioned just at the site of injury. It was unable to traverse to the distal body. The patient was then transferred back to our care for further post-ERCP treatment.

He remained under our care for a total of 11 days, during which he made significant progress following the ERCP. We closely monitored his blood glucose levels, liver function, electrolytes, and inflammatory markers. The acute pain team was involved in optimizing his analgesia. To support his nutritional status, he received total parenteral nutrition (TPN) for approximately 5 days. Prior to discharge, we gradually weaned him off TPN and slowly upgraded his diet from clear fluids to a full oral diet.

**Findings:**
Comparison to the preceding ultrasound.

CT angiogram of the upper abdomen followed by portal venous phase through the abdomen and pelvis
Total DLP 93 mGy cm

Moderate volume intra-abdominal and retroperitoneal free fluid is of relative low attenuation (25 HU). No collection or pneumoperitoneum.

A 5 mm low attenuation cleft extends through the pancreas at the head/neck junction. This extends to the underlying splenic and superior mesenteric venous confluence which opacify normally. The remaining pancreatic parenchyma enhances normally without ductal dilatation.

There is wall thickening and submucosal low attenuation affecting the adjacent gastric antrum/pylorus without appreciable intramural haematoma and which may be secondary to the pancreatic inflammation or reflect small contusion. Intermittent gas and fluid distension of several small bowel loops in the left hemiabdomen with appreciable wall thickening and with normal enhancement. The colon appears normal. Normal appendix.

The liver, gallbladder, kidneys, adrenals and spleen are normal. Scattered mesenteric lymph nodes are not enlarged.
Normal calibre aorta with opacification of the coeliac axis, SMA, renal arteries and IMA. The mesenteric veins opacify normally.

The lung bases are clear. No pleural or pericardial effusion. No focal bone lesion or fracture.

**Comment:**
Pancreatic transection at the head/neck junction with moderate volume retroperitoneal and intra-abdominal free fluid. No pseudoaneurysm. Thickening and submucosal low attenuation at the gastric antrum/pylorus may be secondary to the adjacent pancreatic injury or contusion. There is intermittent distension of several small bowel loops in the left abdomen without wall thickening or evidence of perforation.

**Fig. 2.** Postcontrast computed tomography imaging with arrow pointing to the site of pancreatic transection.

**Fig. 3.** Full report of the initial computed tomography (CT) abdomen and pelvis done. DLP, dose length product; HU, Hounsfield unit; SMA, superior mesenteric artery; IMA, inferior mesenteric artery.
as tolerated. We also removed his NGT. As a result, his abdomen became softer, less distended, and his pain continued to decrease. Upon discharge, his blood tests showed improvement, he was tolerating a full oral diet, and he experienced no abdominal pain. Furthermore, a repeat USS performed prior to discharge revealed no peripancreatic collection and a reduction in free fluid.

The patient subsequently underwent scheduled outpatient magnetic resonance cholangiopancreatography at 2 weeks, which revealed no pseudocyst and an interval resolution of peripancreatic free fluid. Disruption of the pancreatic neck parenchyma was observed again, but without any concerns of PD dilatation. He then proceeded to have his stent removed as a day procedure 6 weeks after the initial ERCP. Following this, a follow-up USS examination demonstrated mild thinning of the pancreatic neck, but no collection or duct dilatation. Overall, the patient has remained in good health since discharge, with appropriate weight gain.

Ethics statement
Informed consent was obtained from the patient’s parents. The anonymity of the patient was also maintained.

DISCUSSION

As previously stated, blunt pancreatic injuries in the pediatric population are uncommon and present both diagnostic and therapeutic challenges. Furthermore, pancreatic injuries can lead to high morbidity and mortality [4]. Consequently, it is crucial to consider this possibility when evaluating a child with a history of abdominal trauma, even in the absence of visible external signs. Additionally, there are various grades of pancreatic injury based on the extent of parenchymal and/or ductal damage [5]. The degree of the injury determines both the patient’s condition and the most suitable management approach. Minor contusions are typically managed conservatively, while major injuries may necessitate interventions such as an ERCP.

When a child is suspected of having abdominal trauma, it is crucial to conduct further investigations using both blood tests and imaging to ensure that a visceral injury is not overlooked. Serum amylase and lipase levels have been identified as sensitive indicators of pancreatic cell damage and can therefore be utilized in the initial workup when pancreatic injury is suspected. Specifically, lipase and/or amylase levels in the admission blood samples are a reliable sign of acute pancreatic injury, and this simple test should be performed on all patients presenting with undifferentiated and atypical abdominal pain.

In addition, various imaging modalities can be employed in such cases. Abdominal USS is typically the first modality utilized. Depending on the findings of the USS, further evaluation can be conducted using CT and/or magnetic resonance imaging [3]. Early detection through an initial CT scan, combined with other imaging modalities and follow-up scans, may enhance the prognosis [6]. Studies have reported that interventional management was beneficial in patients with high-grade pancreatic injuries, as it resulted in shorter lengths of stay and fewer complications such as pseudocyst and fistula formation [4,7].

Furthermore, reports indicate that ERCP is the most sensitive method for diagnosing PD injuries, although there is a risk of post-ERCP pancreatitis [8]. This modality can be used in select patients not only for diagnostic purposes but also for therapeutic intervention, as demonstrated in our case. A retrospective single-institution study that evaluated pediatric patients with pancreatic trauma over a 10-year period identified only four patients with PD injuries due to blunt trauma [9]. These patients underwent ERCP and stent placement without any post-procedure complications. In cases of proximal PD injuries where stent placement is not possible or has failed, conservative management may be considered, with the eventual formation and subsequent drainage of a pseudocyst. Distal injuries, in contrast, may require treatment with distal pancreatectomy [2].

The placement of a stent proximal to the site of injury, as done in our patient, has been reported to allow continuous leakage of pancreatic enzymes and/or formation of a pseudocyst. In contrast, a stent that fully bridges the site of PD injury can better promote healing by preventing further leakage [9,10]. However, inserting a stent across the site of PD injury can be challenging, especially if there is a delay in initiating treatment [9]. Nevertheless, in our case, the PD stent led to significant clinical improvement despite it being short.

Although ERCP offers direct visualization of ductal injuries and serves as a definitive management method for certain patients, their use in pediatric patients is limited. This may be due to the challenges of cannulating a small ampulla and the risk of post-ERCP complications, such as pancreatitis [9]. Furthermore, the limited availability of physicians who can perform emergency ERCP in children presents another obstacle [6].

Pancreatic trauma, especially with PD injury, is uncommon amongst pediatric patients and poses a significant diagnostic challenge. It is essential to conduct a comprehensive history to ascertain if any trauma occurred prior to a child presenting with abdominal pain, as this may lead to high morbidity and mortality. This is especially true for patients with atypical pain that does
not align with a typical infectious presentation. Early blood tests and the utilization of imaging techniques can further assist in diagnosing traumatic pancreatic injuries, enabling appropriate and timely management.

**ARTICLE INFORMATION**

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

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

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

**REFERENCES**

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