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

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

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

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Writing papers: literary and scientific

Kun Hwang, MD
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This paper aims to summarize why I write, how to find a motif, and how to polish and finish a manuscript. For William Carlos Williams, practicing medicine and writing poetry were two parts of a single whole, not each of the other. The two complemented each other. Medicine stimulated Williams to become a poet, while poetry was also the driving force behind his role as a doctor. Alexander Pope, the 18th century English poet, wrote a poem entitled “The Epistle to Dr. Arbuthnot” that was dedicated to a friend who was both a poet and a physician. In this poem, we receive an answer to the questions of “Why do you write? Why do you publish?” Pope writes, “Happy my studies, when by these approv’d! / Happier their author, when by these belov’d! / From these the world will judge of men and books.” When I write, I first reflect on whether I only want to write something for its own sake, like “a dog chasing its own tail,” instead of making a more worthwhile contribution. When my colleagues ask me, “Why do you write essays as well as scientific papers?” I usually answer, “Writing is a process of healing for me—I cannot bear myself unless I write.” When the time comes to sit down and put pen to paper, I remind myself of the saying, festina lente (in German, Ohne Hast, aber ohne Rast, corresponding to the English proverb “more haste, less speed”). If I am utterly exhausted when I finish writing, then I know that I have had my vision.

Keywords: Writing; Literature; Essay

INTRODUCTION

In 2016 I visited the National Portrait Gallery and had the opportunity to view an exhibition, entitled “Celebrating Charlotte Brontë: 1816–1855,” where I saw a portrait painted in color by the Brontë sisters’ brother Branwell that portrayed all three sisters. I saw that painting again at the National Museum of Korea in 2021. The three sisters all died before they reached the age of 40: Charlotte at the age of 38 in 1855, Emily at the age of 30 in 1848, and Anne at the age of 29 in 1849. Despite their short lives and the fact that they had no children, the literary DNA of the Brontë sisters continues to be replicated through their ongoing inspiration for countless readers.

Just like the Bronte sisters, an exemplary trio of great authors, our lives as physicians and surgeons will also come to an end. How, then, can we replicate our academic DNA as researchers and surgeons? I believe that scientific papers are the route through which our knowledge can become immortal [1].

This point leads to another question: how can we write a paper that will last for the ages? An immortal paper is one whose readers love and remember it over time. For surgeons to remember and love a paper, it must be useful—that is, it must assist in real-world patient care, in settings like the clinic, ward, or operating room. This is the purpose of the academic literature in the field
of surgery: to help patients.

I think there are commonalities between literary authors and medical doctors who write scientific papers. This paper aims to summarize why we write, how we find a motif, and how to polish and finish a manuscript.

WHY WRITE?

Royalty and nobility flocked to the funeral of Sir Isaac Newton, over which Alexander Pope (1688–1744), Newton’s friend and colleague, presided. Pope delivered an inspiring injury and then sprinkled dirt on Newton’s grave. In 1734, Pope wrote a poem entitled “The Epistle to Dr. John Arbuthnot,” which he dedicated to a friend of his who was both a poet and a physician. This poem memorialized their friendship, and it was published 1 year later—in the year of Arbuthnot’s (1667–1735) death [2]. In this poem, we find the answer to questions that I frequently receive from my pupils and friends: “Why do you write? Why do you publish?”

Happy my studies, when by these approv’d!
Happier their author, when by these belov’d!
From these the world will judge of men and books,
Not from the Burnets, Oldmixons, and Cookes [3].

William Carlos Williams (1883–1963) was a Puerto Rican-American physician, author, and poet. He worked as a pediatrician and a general physician by day but was also a painter and a successful poet—avocations that he practiced at night. People asked him, “How do you have time to write while practicing medicine? You must be superhuman, with at least two sources of energy.” He replied, “The two are two parts of one, not each of the other. The two complement each other. When one part wears me out, the other part makes me rest.” For Williams, medicine stimulated him to become a poet, while poetry was also the driving force behind his role as a doctor, as exemplified by his confession stating, “I cannot practice medicine without poetry” [4].

The human brain is like molten bronze that must be poured into a mold. When a person receives inspiration, he or she should write down or draw those ideas before they vanish. This is why Dr. Williams seized his ideas in a single moment [5].

Jean-Christophe is a famous novel written by Romain Rolland that Gilbert Cannan translated into English. The novel presents the life of Jean-Christophe Krafft, a genius composer from Germany who is a fictionalized portrayal of Beethoven. Early in Jean-Christophe’s life, he was strongly influenced by his uncle, Gottfried. After composing a piece, Jean-Christophe shared it with his uncle. Gottfried quietly listened to the composition and then asked Jean-Christophe why he felt the need to add to the world’s extant store of music.

“Why make them? There are enough [songs] for everything. […]”
“To be a great man!” […]
“You want to be a great man?”
“Yes,” […]
“What for?” […]
“To make beautiful songs!” […]
“You want to make beautiful songs, so as to be a great man; and you want to be a great man, so as to make beautiful songs. You are like a dog chasing its own tail” [6].

Seized by the desire to demonstrate to his uncle what an artist he was, Jean-Christophe showed Gottfried his compositions.

“[…] Why did you write them?”
“I don’t know, […] I wanted to write something pretty,”
“There you are! You wrote for the sake of writing. You wrote because you wanted to be a great musician, and to be admired. You have been proud […] Music must be modest and sincere—or else, what is it? Impious, a blasphemy of the Lord, who has given us song to tell the honest truth” [6].

Later, Gottfried states, “It is well enough written, but it says nothing. […] You see, my boy, everything that you write in the house is not music. Music in a house is like sunshine in a room. Music is to be found outside where you breathe God’s dear fresh air” [6].

When writing literary or scientific papers, I reflect on whether I only want to write something of interest to myself for its own sake, like the young Jean-Christophe, instead of making a more worthwhile contribution. Similar to the role that Uncle Gottfried played for young Jean-Christophe, we as academics need “mentor-reviewers” capable of pointing out when we resemble “a dog chasing its own tail” (writing for its own sake) and enlightening authors with less experience by helping them focus on the information that they truly hope to convey to readers [7].

Another example of an author-physician is Anton Chekhov (1860–1904), who wrote in a letter to a friend that “I feel more confident and more satisfied with myself when I reflect that I have two professions and not one; my lawful wife and my mistress. When I get tired of one I spend the night with the other. Though it is irregular, it is less boring this way, and besides, nei-
ther of them loses anything through my infidelity.” He added, “Medicine is my lawful wife, literature is my mistress” [8]. Chekhov practiced as a medical doctor during the majority of his literary career.

In the surgical field, surgeons and researchers develop numerous novel ideas and technical procedures. Research on its own does not strengthen science; instead, the field is only advanced through research articles that are published in scientific journals and read by members of the scientific community. Scientists have several reasons to write papers: they may be inspired to share their knowledge or skills with a wider audience, or they may need to publish in order to be promoted by the university administration. The phrase “publish or perish” aptly describes the pressure that academic researchers face to publish work constantly in order to advance or even maintain one’s career.

My colleagues sometimes ask me, “Why do you write essays as well as scientific papers?” I usually answer, “Writing is a process of healing for me—I cannot bear myself unless I write.”

FINDING A MOTIF

Improvising a motif is the single largest challenge in writing. If I cannot write the first line of a piece, I have a ritual to fix the situation. I go the kitchen and open the refrigerator, or I leave the house, walk along the street, or sit to reflect on a park bench. Nonetheless, sometimes an idea simply does not come to mind [9].

There are some historical examples of how authors found motifs for their writing. Herman Melville (1819–1891), who later became famous as the author of *Moby-Dick*, knocked on the door of old Thomas Nickerson’s (1805–1883) house. Melville paid him a sum of money and then wrote down what Nickerson told him based on his memories. Nickerson told him a story about a whaling ship from Massachusetts (the Essex) that sank after being attacked by a sperm whale in the Pacific Ocean in 1820. Most of the crew then died from starvation, and only eight crew members survived. As their conversation approached its end, Nickerson asked Melville whether he would write down everything that Nickerson told him based on his memories. Nickerson told him a story about a whaling ship from Massachusetts (the Essex) that sank after being attacked by a sperm whale in the Pacific Ocean in 1820. Most of the crew then died from starvation, and only eight crew members survived. As their conversation approached its end, Nickerson asked Melville whether he would write down everything that Nickerson told him. They agreed that Melville would write a novel “inspired” by these facts, which became *Moby-Dick*. In *Moby-Dick*, the sole survivor of a whaling ship presents the story of his captain’s obsession to hunt the white whale that caused him to walk with a crutch. *Moby-Dick* arose from the combining of Nickerson’s experience as a whaler and Melville’s narrative skills [9].

The evangelist Luke provides another instructive example. Following the Great Fire of Rome in 64 AD, Emperor Nero launched persecutions of Christians. Paul, as their most prominent leader, was arrested, subjected to trial, and sentenced to death. As Paul awaited execution in his prison cell. Luke took the risky step of visiting Paul. Together with Paul, Luke composed a written narrative of their conversions and missionary travels, and this composition eventually became the “Acts of the Apostles” in the Bible (Fig. 1) [10]. This narrative encouraged Christians who faced possible martyrdom. If Luke had not recorded these conversations in written form or if his followers had not copied the text, the New Testament would contain only 26 books, not 27, and we would not know about the apostles’ activities and ministry following Christ’s resurrection [10].

The most important source of a motif is the author’s own experience in the field. Recently, I joined the Medical Support Team of the Korean Medical Association for coronavirus disease 2019, where I served for 24 days. I worked at the quarantine center, where I sampled specimens from the nose and throat and made decisions for the admission of mild cases. During that period, I wrote four essays that would not have been possible without field experience.

CREATIVITY AND IMAGINATION

Through creativity, something novel and valuable is formed. Literary figures and surgeons both require creativity. In the late 1800s and early 1900s, the scientists Hermann von Helmholtz (1896) and Henri Poincaré analyzed creative processes, and their work was followed that of the theorist Graham Wallas. In his monograph entitled *Art of Thought* (1926), Wallas described a five-stage model of the process underlying creative insights: (1)
preparation (preparatory work focusing an individual’s mind on a problem and exploring the dimensions of the problem); (2) incubation (internalization of the problem into the unconscious mind, during which process nothing appears to be taking place to an external observer); (3) intimation (the creative person experiences a “feeling” that a solution is on the way, although this could be considered a sub-stage); (4) illumination or insight (a creative idea bursts forth from preconscious processing into conscious awareness); and (5) verification (conscious verification, elaboration, and application of the idea) (Fig. 2) [11,12]. Most types of art (e.g., writing, visual art, or music) may follow this four-stage or five-stage creative process [12].

Writing also requires imagination, which refers to the ability to form mental concepts, sensations, and images without direct perception through hearing, sight, or other senses. Denis Diderot (1713–1784), an Enlightenment philosopher who edited the Encyclopédie (1772), believed that imagination is vital to “adorn and crown” the truth, which reason and philosophy reveal. The power of imagination is a commonality shared by literary figures, including poets, and surgeons. Poets write and recite poems to express their imagination, whereas surgeons do so by changing the living bodies of patients through operations, which is a more difficult task [13].

**STARTING AND FINISHING WRITING**

I find the most challenging step of writing a new paper to be the beginning of the introduction and the initial part of the discussion. I sometimes feel as if I am facing a wall with no door. In these moments, I think of a painting entitled “Saint Matthew and the Angel,” which Caravaggio painted in 1602 (Fig. 3) [14]. In this composition, Saint Matthew holds a pen and an angel moves his hand to write the Gospel. Of course, it would be exceedingly auspicious if I were visited by an angel who would grant me a flash of inspiration or guide my hand as I write the part of a draft where I felt blocked! These considerations lead me to wish that I were a genius with creative brilliance [14].

Research takes place in a similar sequence (study, approval, and then writing) to that of love (study, approval, and then love) [1]. We must have a sense of curiosity and seek out earlier work. If we cannot find the answer to our question from the papers published by other researchers, then we can start our work. Papers must contribute something novel (in German, etwas neues). Naturally, the first author to publish a certain finding deserves credit. Therefore, we must make haste (in Latin, *festina*) when writing a manuscript and submitting it to a journal. While pre-

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**Fig. 2.** Creative process of the artist or literary writer. Adapted from Hwang [12] with permission from Wolters Kluwer Health, Inc.
paring a manuscript that I plan to submit, I remember an epigram beloved by Augustus, the Roman emperor: *festina lente* (make haste slowly; more haste, less speed). Augustus disapproved of rash decision-making among his officials, prompting him to encourage them with this phrase. The anchor-dolphin symbol in Erasmus’s book derives from a Roman coin; in this symbol, the anchor symbolizes the slow pace of deliberation and the dolphin represents the rapidity of skillful performance (Fig. 4) [15]. The German authors Goethe and Schiller repurposed this epigraph: “Ohne Hast, aber ohne Rast” (“without haste, but without rest”) (*Zahme Xenien*, sect. 2, no. 6, l. 281) [15,16].

Rushing the process of writing and submitting leads to mistakes, and the long-term results may be poorer than expected. In Buddhist terms, it is best to write in a state of flow, characterized by full engagement and the absence of a sense of time passing (freedom from all thought and ideas). When I sit down at my desk to write, I always remind myself, “*festina lente*”

A difficult step in writing is finishing—placing the final touch. If inspiration fails to strike me for finishing the last part of a paper, I remember the end of *To the Lighthouse*, a well-known novel written by Virginia Woolf (1882–1941).

The novel closes with the following paragraph: “Quickly, as if she were recalled by something over there, she turned to her canvas. There it was—her picture. Yes, with all its greens and blues, its lines running up and across, its attempt at something. It would be hung in the attics, she thought; it would be destroyed. But what did that matter? She asked herself, taking up her brush again. She looked at the steps; they were empty; she looked at her canvas; it was blurred. With a sudden intensity, as if she saw it clear for a second, she drew a line there, in the center. It was done; it was finished. Yes, she thought, laying down her brush in extreme fatigue, I have had my vision” [17].

When I am sitting at the keyboard and looking at the screen, which appears blurry due to eye strain after I have stared at it for a long time, I try to focus my eyes on the finale of the manuscript. If I finally finish it in a state of extreme fatigue, then I can say, “I have had my vision” [18].

**NOTES**

**Ethical statements**

Not applicable.

**Conflicts of interest**

Kun Hwang serves on the Editorial Board of *Journal of Trauma*.

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and Injury, but was not involved in the peer reviewer selection, evaluation, or decision process of this article. The author has no other conflicts of interest to declare.

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Acute pain management in the trauma patient population: are we doing enough? A prospective observational study

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Purpose: There is a strong correlation between trauma and pain. Pain increases the rate of depression, posttraumatic stress disorder, and even mortality in trauma patients.

Methods: This institution-based, provider-blinded and patient-blinded, observational study was conducted among trauma patients treated at Tikur Anbessa Specialized Hospital. Over the course of 3 months, this study included patients who had no prior pain management at other hospitals before presentation, and who presented within 24 hours of the traumatic event.

Results: Of the 74 patients evaluated, none of the patients had their pain level scored. The researcher-provided pain scale showed a severe subjective pain score for 79.7% of the patients and a severe functional activity score for 59.5% of the patients. Analgesia was provided at an average of 55.4 minutes after presentation and all patients received either diclofenac or tramadol. Satisfactory pain reduction after analgesia was 28.8% for patients initially complaining of severe pain, 54.6% for moderate pain, and 66.7% for mild pain, with the difference being statistically significant (P<0.05). Forty percent of patients discharged home received no analgesia after the first dose provided upon presentation.

Conclusions: Pain scoring was nonexistent during the course of the study. The poor utilization rate of analgesia combination and opioids led to unsatisfactory pain outcomes in patients evaluated and followed for 24 hours after presentation.

Keywords: Pain management; Analgesics; Injuries

INTRODUCTION

Trauma is a global health burden, with a reported 973 million injuries needing some level of medical attention, 4.8 million trauma-related deaths, and 247.6 lost disability-adjusted life years in 2013 alone [1]. Trauma-related deaths account for 9% of the total death toll worldwide, predominantly affecting the younger, economically productive segment of the population [2–4]. The Ethiopian experience with trauma is similar to the global trend with regards to the age groups affected and its impact [5].

Trauma and pain are strongly correlated, as evidenced by studies showing the prevalence of pain upon admission and dis-
charge among trauma patients to be 91% and 86%, respectively [6]. The relationship between trauma and pain is far-reaching and possibly lifelong. A large-scale study done on over 3000 patients with major trauma reported that 1 year after trauma, 62.7% of the patients complained of pain at the site of injury with pain severity in the moderate range (5.5 points on a 10-point pain scale) [7].

Pain in trauma patients potentiates the stress response, which increases tachycardia, oxygen consumption, hyper-coagulation, and immunosuppression. In addition, this response prolongs the recovery time [8]. Beyond the psychological relief when pain is decreased, management of pain in trauma patients has been shown to decrease morbidity and mortality [9]. Yet, adequate and organized pain management in trauma patients has not always been practiced in many trauma centers, especially in developing countries [10].

Studies conducted in Ethiopia on trauma and pain are scarce in the literature. Therefore, this study aimed to determine the adequacy of pain management among acute trauma patients in the emergency department of a level III hospital in the capital of Ethiopia. We assessed the practice of evaluating patients for pain, organizing pain care, and the follow-up of patients in pain, including possible changes made in the management of pain based on re-evaluation by the treating team.

**METHODS**

**Ethical statements**

Before data collection, approval was obtained from the Research Ethics Committee of the Department of Surgery, Faculty of Medicine, Addis Ababa University. All participants over the age of 18 years, were asked for their consent, and all measures of confidentiality were ensured. Those participants between the ages of 13 and 18 years were asked for assent, and consent was acquired from the parents or legal guardians on site.

**Study design and setting**

Tikur Anbessa Specialized Hospital is the largest public hospital in Ethiopia. It serves approximately 500,000 patients a year, with 24-hour, 7-day-a-week emergency services provided alongside elective and emergency multidisciplinary surgical services at a level III designation.

This was a facility-based observational study with data gathered from the patients and their charts over 3 months. The survey design was aimed at providing descriptive data of acute pain care among trauma patients in Tikur Anbessa Specialized Hospi-

tal. Each observation commenced at the time of presentation to the emergency department (ED), and the follow-up period was 24 hours for every patient or until discharge. This was a blinded study, in which both the patient and the treating team were unaware of the study, to avoid observational bias.

**Study population and variables**

All trauma patients who were admitted, observed, discharged, or referred were evaluated using a survey format only if they presented within 24 hours of the trauma and had received no analgesia at the referring facility. The independent variables were age, sex, occupation, region, time of arrival (day/night), duration between trauma and presentation, anatomic site of trauma, mechanism of injury, outcome of trauma, and training level of the evaluating physician. The dependent variables were pain scoring documentation, type and dose of analgesic given, delay of analgesia from presentation (in hours), pain rescoring after analgesia, the interval between doses of analgesia, and changes in analgesics.

**Sample size determination**

The population proportion could not be determined. Therefore, an initial pilot study of 20 patients analyzed the rate of pain scoring done by treating physicians. In the pilot study, pain scoring was done for one patient (5%) of the 20 patients who were initially evaluated, so a population proportion of 5% was used for sample size calculation.

\[
\frac{Z_{1-\alpha/2}^2 \cdot p(1-p)}{D^2} = 73
\]

**Data collection and data quality control**

Data were collected using a structured researcher-provided questionnaire. The data were collected over 1 month by a single trained data collector, with 1 month allotted for preliminary data collection to ensure that the data collector was accustomed to the data collection process. All incomplete data were discarded.

**Data processing and analysis**

The collected data were analyzed using IBM SPSS ver. 23.0 (IBM Corp., Armonk, NY, USA). A descriptive analysis was conducted to describe the sociodemographic characteristics of the study population. Univariable logistic regression was utilized to evalu-
ate the associations between pain and analgesia based on different scoring models.

RESULTS

In this study, 74 consecutive patients, fulfilling all the strict inclusion criteria, were analyzed. Among these 74 patients, 57 patients (77%) were male and 55 patients (74.3%) were under the age of 45 years. More than half (n = 41, 55.4%) of the trauma victims were married, and close to half (n = 36, 48.6%) were from Addis Ababa. Only 13 patients (17.8%) had a college education, and the same number of participants were uneducated (defined as not having attended primary school). Most patients were categorized as private employees (n = 19, 26%) and students (n = 13, 17.8%).

The time of presentation after trauma ranged from 1 to 24 hours, with a mean of 9.19 ± 7.62 hours. Fifty patients (67.9%) presented during the daytime (Table 1).

Among other characteristics, 66 patients (89.2%) were primarily evaluated by interns and 72 patients (97.3%) were evaluated by residents, either primarily or following an intern’s evaluation. Orthopedic residents were involved in patient evaluation in 48 cases (64.9%), general surgery residents in 13 cases (17.6%), emergency medicine residents in eight cases (10.8%), and neurosurgery residents in three cases (4.1%). Regarding residents’ years of training, 27 patients (36.5%) were evaluated by first-year residents, 23 (31.1%) by second-year residents, 20 (27.8%) by third-year residents, and two (2.8%) by fourth-year residents.

As for the trauma mechanisms and circumstances, blunt trauma (n = 66, 89.2%) was the most common mechanism. From the blunt trauma group, 27 (40.9%) were injured by pedestrian versus motor vehicle accidents. On the primary survey, there was no patient with airway compromise, but four patients (5.5%) had either labored or gasping-type breathing. Two patients presented with hypotension and six patients with a Glasgow Coma Scale of 13 or 12. Twenty-nine patients (39.2%) presented with tachycardia (heart rate > 100 beats/min). The most common sites of injury were the extremities, with a fracture or dislocation reported in 59 patients (79.7%). This was followed by pelvic injury in 23 patients (31.1%), and traumatic brain injury in 16 patients (21.6%). Six patients (8.1%) had alcohol intoxication at presentation. Most patients (n = 51, 68.9%) were kept at the ED for observation and investigation beyond the first 24 hours, while 15 (20.3%) were discharged home after evaluation within 24 hours of presentation (Table 2).

No patient had any pain score recorded in their charts upon the initial evaluation or during the follow-up evaluations. Researcher-provided preanalgesia scores, based on a subjective pain scale (SPS) and a functional activity scale (FAS), were calculated for all patients. Based on the SPS, 59 patients (79.7%) were in severe pain, 13 (17.6%) were in moderate pain, and two (2.7%) were in mild pain. The FAS showed severe pain in 44 patients (59.5%), while moderate/mild pain and no pain were recorded in 18 (24.3%) and 12 patients (16.2%), respectively (Figs. 1, 2).

The need for analgesia and the type of analgesia needed were determined by the researchers based on the researcher-provided pain scores and stratified, based on the World Health Organization (WHO) trauma pain management ladder, as levels I, II, or III. For prediction purposes, both functional activity scores and subjective pain scores were utilized and the more severe cases were treated with higher levels of analgesia. Researchers determined the type and the amount of analgesia needed based on the pain scores and the condition of the patients.
vere score of the two was used for designation on the WHO ladder. Based on this, 60 patients (81.1%) were initially categorized as level III on the WHO ladder, 11 (14.9%) as level II, and three (4.1%) as level I.

All patients were provided with analgesia by the treating team and all analgesics given were in levels I and II of the WHO ladder. The utilized drugs were tramadol (50 mg intravenous/intramuscular) in 65 patients (87.8%) and diclofenac (75 mg intramuscular) in nine patients (12.2%). No patient received a combination of analgesics. All patients provided with diclofenac (WHO ladder level I medication) had severe pain. The time from presentation to analgesia ranged from 20 minutes to 240 minutes, with a mean of 55.4 ± 35.3 minutes. At 60 minutes after presentation, three patients (100%) were predicted to be on level I of the WHO ladder, 10 patients (90.9%) on level II of the WHO ladder, and 54 patients (90%) on level III of the WHO ladder had received the first dose of analgesia. There was no correlation between the predicted level of the WHO ladder (as a measure of severity of pain) and time to first dose of analgesia in the logistic regression analysis (P = 0.639).

We attempted to retrieve response to analgesia data from patient chart documentation and no patient pain-level scoring after analgesia was provided. The researcher-provided pain scoring data were done at a mean time of 114.3 ± 59.7 minutes after the first dose of analgesia. Using SPS parameters, three (4.1%), 57 (77%), and 14 patients (18.9%) had severe, moderate, and mild pain, respectively. Utilizing the FAS, 39 (52.7%), 21 (28.4%), and 14 patients (18.9%) had severe, mild/moderate, and no pain, respectively. Based on satisfaction stratification (with “unsatisfactory” including residual moderate or severe pain on the SPS and severe residual pain on the FAS), 50 patients (67.6%) had an unsatisfactory pain response based on the FAS and 49 patients (66.2%) had an unsatisfactory score based on the SPS (Figs. 1, 2).

An analysis of the relationship between the predicted preanalgesic WHO ladder and satisfaction based on the postanalgesia SPS satisfaction rate showed an unsatisfactory pain response in 43 out of 60 patients (71.2%) stratified at level III on the WHO ladder and five of 11 patients (45.4%) at level II of the WHO ladder. In an analysis of the correlation between the predicted pre-

### Table 2. Mechanisms of trauma, injuries, and disposition of subjects (n=74)

<table>
<thead>
<tr>
<th>Category</th>
<th>No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trauma mechanism</td>
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<tr>
<td>Blunt</td>
<td>66 (89.2)</td>
</tr>
<tr>
<td>Penetrating</td>
<td>8 (10.8)</td>
</tr>
<tr>
<td>Blunt trauma mechanism</td>
<td></td>
</tr>
<tr>
<td>Motor vehicle collision</td>
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<tr>
<td>Pedestrian versus motor vehicle</td>
<td>27 (40.9)</td>
</tr>
<tr>
<td>Assault</td>
<td>11 (16.7)</td>
</tr>
<tr>
<td>Falling down accident</td>
<td>12 (18.2)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (3.0)</td>
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<tr>
<td>Penetrating trauma mechanism</td>
<td></td>
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<tr>
<td>Gunshot wound</td>
<td>4 (57.1)</td>
</tr>
<tr>
<td>Other</td>
<td>3 (42.9)</td>
</tr>
<tr>
<td>Primary assessment and vital sign</td>
<td></td>
</tr>
<tr>
<td>Intact airway</td>
<td>74 (100)</td>
</tr>
<tr>
<td>Labored/gasping</td>
<td>4 (5.5)</td>
</tr>
<tr>
<td>Hypotension</td>
<td>2 (2.7)</td>
</tr>
<tr>
<td>Glasgow Coma Scale 12 or 13</td>
<td>6 (8.1)</td>
</tr>
<tr>
<td>Heart rate &gt;100 beats/min</td>
<td>29 (39.2)</td>
</tr>
<tr>
<td>Anatomic site of trauma</td>
<td></td>
</tr>
<tr>
<td>Head injury</td>
<td>16 (21.6)</td>
</tr>
<tr>
<td>Face/neck injury</td>
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</tr>
<tr>
<td>Chest injury</td>
<td>3 (4.1)</td>
</tr>
<tr>
<td>Abdominal injury</td>
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</tr>
<tr>
<td>Pelvic injury</td>
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<td>Extremity fracture/dislocation</td>
<td>59 (79.7)</td>
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<tr>
<td>Penetrating extremity injury</td>
<td>3 (4.1)</td>
</tr>
<tr>
<td>Alcohol and medication history</td>
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</tr>
<tr>
<td>Alcohol intoxication</td>
<td>6 (8.1)</td>
</tr>
<tr>
<td>Medication prior to trauma</td>
<td>2 (2.7)</td>
</tr>
<tr>
<td>24 Hours disposition</td>
<td></td>
</tr>
<tr>
<td>Kept at emergency department for observation</td>
<td>51 (68.9)</td>
</tr>
<tr>
<td>Discharge</td>
<td>15 (20.3)</td>
</tr>
<tr>
<td>Emergency surgery</td>
<td>4 (5.1)</td>
</tr>
<tr>
<td>Admitted to wards</td>
<td>3 (4.1)</td>
</tr>
<tr>
<td>Referred</td>
<td>1 (1.4)</td>
</tr>
</tbody>
</table>

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**Fig. 1.** Subjective pain scale score before and after analgesia.
analgesia WHO ladder and postanalgesia FAS-based satisfaction, 44 of 60 patients (73.3%) stratified at level III of the WHO ladder had an unsatisfactory pain response and five of 11 patients (45.4%) stratified at level II of the WHO ladder had an unsatisfactory pain outcome. This difference was statistically significant in univariable logistic regression analysis, with P-values of 0.05 and 0.04, respectively (Table 3, Fig. 3).

Of the patients treated by junior residents (first-year and second-year residents), 34 of 50 patients (68%) had unsatisfactory scores. Similarly, 15 of the 20 patients (68.2%) treated by senior residents had unsatisfactory responses. The year of residency was not associated with level of satisfactory response to pain treatment (P = 0.98). The field of study of the treating residents was also not associated with the level of satisfaction with care for pain (P = 0.34).

During their stay in the ED, 14 patients (18.9%) had a change of analgesics. Five patients (6.75%), initially on diclofenac with an unsatisfactory pain response were upregulated to tramadol, while one patient with a satisfactory pain response with diclofenac was also upregulated to tramadol. Four patients (two diclofenac and two tramadol) with unsatisfactory pain responses after the initial dose were given no further analgesia while three patients initially on tramadol with a satisfactory pain response were also given no further analgesia, resulting in a total drug discontinuation rate of 9.4%. One additional patient, initially on tramadol with an unsatisfactory pain response, was downregulated to diclofenac. All patients who were kept in the ED, admitted to the wards, referred, or who underwent emergency procedures were continued on tramadol. Six of 15 patients (40%) were sent home without analgesics.

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DISCUSSION

The sociodemographic variables gathered from this study were not unique and reflected the general demographics of the country [11–15]. The majority of patients were evaluated by interns. This may not be a major factor in trauma patient pain management, as most patients were also evaluated by residents. One striking finding was the poor involvement of emergency medicine residents in the evaluation of the patients, which might have affected pain management. Regardless, a recent publication, addressing the knowledge and perception of pain management by residents, showed poor medical school curricular structures for teaching proper pain management. We have also found this to be true in Ethiopia, where no dedicated module or rotation in pain care is available during medical training [16].

The prevalence of blunt trauma over penetrating trauma, as well as the prevalence of motor vehicle-related injuries, has been reported both nationally and internationally [17–19]. A notable finding was the higher prevalence of pedestrian-vehicle traffic accidents over motor vehicle collisions, as reported in studies of Ethiopian national data [20]. The extremities and pelvis were the most common anatomic sites of injury, followed by the head. Orthopedic injury and head trauma predominated in both civilian and combat casualty patients [21,22].

The average time of patient presentation posttrauma was slightly more than 9 hours. For the patients in this study, no analgesia was given at the scene or during transport from the referring hospital. Such a delay in pain care is shown to have lasting implications for long-term physical and psychological health and is linked to an increased risk of chronic pain, depression, and posttraumatic stress disorder [23–25].

Preanalgesia pain scoring by the treating team was not performed for any of the trauma patients evaluated in this study. This is staggeringly low when compared to studies from developed countries which have reported a pain scoring rate as high as 73% [26]. Using the researcher-collected data, the preanalgesia pain score for severe pain was close to 60% and 80% with the SPS and FAS scoring systems, respectively. This correlates well with other studies [27,28]. Every patient was provided with analgesia, with a mean door-to-needle time of 55 minutes. This value is not disappointing when compared to studies from other low-income countries [10]. The predicted WHO ladder was based on both the SPS and FAS scores, with the more severe score used to predict the type of analgesia needed. The WHO ladder level predicted for more than 80% of the patients was level III (strong opioid) [9]. All analgesics provided were from the WHO ladder level I (diclofenac) and level II (tramadol). These were provided regardless of the level of pain reported by the patients. This was evidenced by the fact that all patients provided with diclofenac were in the severe pain group and were predicted to receive WHO ladder III analgesics. Failure of the treating team to score the pain level of the patients led to more than three-quarters of the patients having an unsatisfactory outcome. This is in comparison to almost half of the patients in the predicted WHO ladder level II and only a third of patients in the WHO ladder level I groups with unsatisfactory outcomes. This difference was statistically significant. This highlights the need for pain scoring before analgesia and for adherence to the regimens of the assigned WHO ladder category to achieve proper analgesia for every individual patient.

In this study, no relationship was found between the level of residency training and the primary outcome of satisfactory pain control in acute trauma patients. This indicates that the topic of comprehensive management of acute pain in trauma patients had not been addressed at any level during the residents’ training. The field of study of the residents involved in the care of the trauma patients did not have any impact on the care provided for acute pain, indicating that the lack of proper acute pain management transcends departmental boundaries.

An analysis of ongoing pain management beyond the first dose of analgesia showed that 14 of 74 patients had a change in pain regimen within 24 hours; four patients (5.4%) requiring upregulation were withdrawn from the medications instead, while three patients requiring maintenance with the initial satisfactory response were also withdrawn. This outcome is evidence that pain management was not based on patient response to analgesia, but rather depended on the discretion of the physician. A more worrying outcome is the fact that 40% of patients discharged home were sent home without analgesia. As one study from the Netherlands showed, two-thirds of patients discharged from the ED with musculoskeletal pain had moderate to severe pain at the time of discharge. This study showed the need to maintain analgesia for patients being discharged after acute trauma.

The concept of acute pain management is certainly not new, but the practice seems quite variable across centers and countries. The institution of interest, in one of the low-income countries, showed nonexistent pain scoring practice, disorganized analgesia provision, and poor pain care for discharged patients. In addition, in groups managed with some sort of analgesia, no combination of analgesics was provided and no strong opioid was prescribed. As a result, more than two-thirds of patients with severe...
pain were not treated to the level at which the pain was satisfactorily manageable for the patients. Based on these findings, we recommend curricular inclusion of pain management for all trainees and implementation of a guideline-based pain management culture. Provision of proper analgesia, including strong opioids, along with monitoring of their appropriate utilization is needed. We also recommend ensuring the availability of pain management experts in large metropolitan hospitals.

NOTES

Ethical statements
This study was approved by the Research Ethics Committee of the Department of Surgery, Faculty of Medicine, Addis Ababa University. Informed consent was obtained from all participants or the participants’ parents or legal guardian.

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

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None.

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

REFERENCES


Epidemiology and clinical characteristics of posttraumatic hospitalized patients with symptoms related to venous thromboembolism: a single-center retrospective study

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3Department of Emergency Medicine, Gachon University Gil Medical Center, Gachon University College of Medicine, Incheon, Korea

Purpose: The aim of this study was to investigate the epidemiology of trauma inpatients with venous thromboembolism (VTE) symptoms diagnosed using computed tomographic angiography (CTA) in Korea.

Methods: In total, 7,634 patients admitted to the emergency department of Gachon University Gil Medical Center, a tertiary hospital, and hospitalized between July 1, 2018 and December 31, 2020 were registered for this study. Of these patients, 278 patients who underwent CTA were enrolled in our study.

Results: VTE was found in 120 of the 7,634 patients (1.57%), and the positive diagnosis rate of the 278 patients who underwent CTA was 43.2% (120 of 278). The incidence of VTE was statistically significantly higher among those with severe head and neck injuries (Abbreviated Injury Scale, 3–5) than among those with nonsevere head and neck injuries (Abbreviated Injury Scale, 0–2; P=0.038). In a subgroup analysis, the severe and nonsevere head and neck injury groups showed statistically significant differences in known independent risk factors for VTE. In logistic regression analysis, the adjusted odds ratio of severe head and neck injury (Abbreviated Injury Scale, 3–5) for VTE was 1.891 (95% confidence interval, 1.043–3.430).

Conclusions: Trauma patients with severe head and neck injuries are more susceptible to VTE than those with nonsevere head and neck injuries. Thus, physicians must consider CTA as a priority for the diagnosis of VTE in trauma patients with severe head and neck injuries who show VTE-associated symptoms.

Keywords: Wounds and injuries; Venous thromboembolism; Computed tomography angiography; Epidemiology; Korea
INTRODUCTION

Venous thromboembolism (VTE), which clinically manifests as pulmonary thromboembolism (PTE) and deep vein thrombosis (DVT), is a significant cause of posttraumatic mortality and morbidity [1–3]. Because trauma is a risk factor for VTE, prompt diagnosis of VTE is important for patients admitted due to trauma [4].

The overall incidence of VTE among trauma inpatients ranges widely from 0.36% to 1.8%, depending on aspects of study design such as the population and the nature of patients’ injuries [1,5–7]. VTE can be diagnosed using ultrasonography, magnetic resonance imaging, and computed tomography (CT) [8]. Currently, computed tomographic angiography (CTA) is the modality of choice for VTE diagnosis owing to its high sensitivity and specificity (90% and 95%, respectively) [9–11]. Despite its usefulness, CTA is expensive and poses a risk of contrast-induced allergic reactions or nephropathy, and a report has suggested that it can cause delayed radiation-induced solid tumors. For these reasons, routine evaluation using CTA is a difficult decision for physicians [12–14]. Some rule-out criteria can help differentiate VTE. It has been reported that patients who meet all eight criteria in the pulmonary embolism rule-out criteria rule (e.g., age > 50 years, recent trauma or surgery) do not require further evaluation, including a D-dimer test, for a differential diagnosis of PTE [8,15]. Furthermore, the YEARS diagnostic algorithm can significantly reduce the use of CT for the diagnosis of PTE in patients suspected to have acute PTE using the D-dimer level and three YEARS items (clinical signs of DVT, hemoptysis, PTE the most likely diagnosis) [16]. Wells’ criteria (clinical signs of DVT, 3 points, heart rate > 100 beats/min, recent surgery or immobilization; previous PTE or DVT, 1.5 points, hemoptysis, malignancy; alternative diagnosis less likely than PTE, 1 point) are known to reliably exclude DVT based on a score of below 1 [17]. However, the fact that trauma patients often have VTE risk factors, such as the pathologic effects of trauma and a history of surgery, hinders the application of the above criteria for diagnostic purposes [4]. VTE prediction models can be applied to trauma patients. The Trauma Embolic Scoring System and Greenfield risk assessment profile can be used as appropriate calibration tools for predicting VTE in severely injured trauma patients. The Trauma Embolic Scoring System can predict VTE based on trauma patients’ Injury Severity Score (ISS), age, use of mechanical ventilation, obesity status, and lower limb injuries [18]. The risk assessment profile can predict the likelihood of PTE by considering underlying conditions, iatrogenic factors, Abbreviated Injury Scale (AIS) score, and the Glasgow Coma Scale score [19]. However, although these prediction models can be used for prediction, they are inappropriate as VTE rule-out criteria to reduce the use of CTA. Furthermore, related research on trauma patients in Korea is scarce.

The aim of this study was to shed light on the epidemiology of trauma inpatients with VTE symptoms diagnosed based on CTA and to compare VTE-positive and VTE-negative patients to identify the factors associated with VTE, thereby ultimately assisting in the decision to perform CTA.

METHODS

Ethical statements
The study protocol was approved by the Institutional Review Board of Gachon University Gil Medical Center (No. GBIRB 2021-230). The requirement for informed consent was waived.

Study design
For this retrospective study, the patient identifications of 7,634 patients admitted to the emergency department of Gachon University Gil Medical Center, a tertiary hospital, and hospitalized between July 1, 2018 and December 31, 2020 were acquired from the Korean Trauma Data Bank (KTDB). These patient identifications were entered into the picture archiving communications system to determine whether CTA was performed. A total of 278 patients underwent CTA, and these patients were enrolled in our study (Fig 1). Information regarding patient epidemiology was selected in consideration of the factors associated with VTE reported in previous studies [1–3,20–22]. From the KTDB, we obtained the following information about patients who underwent CTA: age, sex, ISS (mild and moderate, < 16; severe, 16–24; critical, > 24), AIS (head and neck, face, chest, abdomen, extremities, and pelvis), admission to the intensive care unit (ICU), and length of ICU stay (days). An electronic medical record review

Fig. 1. Flowchart of patient selection. CT, computed tomography.
was performed to confirm that CTA was performed on patients suspected of having VTE based on the attending physician’s clinical decision regarding symptoms such as dyspnea; chest pain; hypoxemia; low oxygen saturation upon monitoring; high oxygen demand; swelling, pain, erythema of the lower extremities; and elevated D-dimer levels. Information regarding the use of a mechanical ventilator, length of mechanical ventilation (days), pharmacologic prevention of VTE, use of intravenous (IV) tranexamic acid, major surgery, pelvic fracture, lower extremity fracture, spinal cord injury, and D-dimer levels were obtained from the electronic medical record.

Definitions
In this study, an ISS score below 16 was considered to indicate a mild or moderate injury, a score of 16 to 24 was considered indicative of a severe injury, and a score 25 or higher was considered to indicate a critical injury [23–25]. The AIS uses a scale from 1 to 5, with 1 for minor, 2 for moderate, 3 for severe (not life-threatening), 4 for severe (life-threatening), and 5 for critical (survival uncertain) [26]. In this study, an AIS score of 0 to 2 was defined as indicating a nonsevere injury (no to mild injury), and AIS scores of 3 to 5 were defined as indicating a severe injury (severe to critical injury). The tertiary hospital used enoxaparin (40 mg or 60 mg, administered subcutaneously) as the standard protocol for the pharmacologic prevention of VTE in trauma patients. The hospital used IV tranexamic acid as a hemostatic agent to prevent or manage early excessive bleeding.

Statistical analysis
Data were statistically analyzed using IBM SPSS ver. 24.0 (IBM Corp., Armonk, NY, USA). A univariate analysis was conducted for noncontinuous variables using the chi-square test, and non-normally distributed continuous variables were analyzed using the Mann-Whitney U-test. The factors associated with VTE onset were identified using logistic regression analysis. A P-value lower than 0.05 was considered to indicate statistical significance.

RESULTS
A total of 7,634 trauma patients were registered in the KTDB from July 1, 2018 to December 31, 2020. After excluding 7,356 patients who did not undergo pulmonary and/or femoral CTA, 278 patients were included in the final analysis (Fig. 1). Of 7,634 patients, 120 developed VTE, corresponding to an incidence rate of 1.57% (120 of 7,634), and the positive diagnosis rate of the 278 patients who underwent CTA was 43.2% (120 of 278) (Fig. 1).

The clinical characteristics of the VTE-positive and VTE-negative groups, as determined using CTA, were compared. The incidence of VTE was significantly higher among those with severe head and neck injuries (AIS, 3–5) than among those with nonsevere head and neck injuries (AIS, 0–2; P = 0.038). There was no statistically significant difference in age between the VTE-positive group (median, 66.5 years; interquartile range, 52.3–78.0 years), and the VTE-negative group (median, 63.6 years; interquartile range, 43.0–80.3). The two groups also did not show statistically significant differences in sex, ISS, AIS (chest, abdomen, extremities, and pelvis), pharmacologic prevention of VTE, use of IV tranexamic acid, major surgery, pelvic fracture, lower extremity fracture, spinal cord injury, admission to the ICU, length of mechanical ventilation (days), use of a mechanical ventilator, length of mechanical ventilation (days), and D-dimer levels. Only two and three patients in the severe injury AIS group (3–5) had AIS (face) and AIS (other) scores, respectively, so those parameters were excluded from the results (Table 1).

Subgroup analyses were performed for head and neck injuries, which showed a statistically significant difference between the two groups. The severe head and neck injury and nonsevere head and neck injury groups showed statistically significant differences in ISS (P < 0.001), use of IV tranexamic acid (P < 0.001), lower extremity fracture (P < 0.001), spinal cord injury (P < 0.001), admission to the ICU (P < 0.001), length of ICU stay (days; P < 0.001), use of a mechanical ventilator (P < 0.001), and length of mechanical ventilation (days; P = 0.018) (Table 2).

To analyze the factors associated with VTE onset, logistic regression analysis was performed with age, sex, head and neck injury, extremities or pelvis injury, and ISS. The adjusted odds ratio for VTE was 1.891 (95% confidence interval, 1.043–3.430) in patients with severe head and neck injuries (AIS, 3–5) (Table 3).

DISCUSSION
Even though posttraumatic VTE is an important complication considering its mortality and morbidity, the epidemiology of VTE in trauma patients in Korea is not well known. In a large-scale German study, Paffrath et al. [1] reported that the overall incidence of VTE in inpatients with trauma was 1.8% (146 of 7,937). In their study of 450,000 trauma patients in the United States, Knudson et al. [5] reported a VTE incidence of 0.36% (1,602 of 450,375). Wong et al. [6] found that the incidence of posttraumatic VTE in an Asian population was 0.39% (34 of 8,615) based on a Singaporean database. Boo et al. [7] reported an overall incidence of VTE of 0.87% (82 of 9,472) among Korea-
## Table 1. Baseline characteristics and demographic features of patients

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total</th>
<th>VTE (+)</th>
<th>VTE (-)</th>
<th>P-value</th>
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<tr>
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<td>120 (43.2)</td>
<td>158 (56.8)</td>
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<tr>
<td>Male</td>
<td>159 (57.2)</td>
<td>70 (58.3)</td>
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</tr>
<tr>
<td>Female</td>
<td>119 (42.8)</td>
<td>50 (41.7)</td>
<td>69 (43.7)</td>
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<tr>
<td>Age (yr), median (IQR)</td>
<td>64.5 (47.5–80.0)</td>
<td>66.5 (52.3–78.0)</td>
<td>63.0 (43.0–80.3)</td>
<td>0.416</td>
</tr>
<tr>
<td>VTE</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary thromboembolism</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep vein thrombosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISS of patients</td>
<td></td>
<td></td>
<td></td>
<td>0.076</td>
</tr>
<tr>
<td>Mild and moderate (&lt;16)</td>
<td>187 (67.3)</td>
<td>75 (62.5)</td>
<td>112 (70.9)</td>
<td></td>
</tr>
<tr>
<td>Severe (16–24)</td>
<td>61 (21.9)</td>
<td>34 (28.3)</td>
<td>27 (17.1)</td>
<td></td>
</tr>
<tr>
<td>Critical (&gt;24)</td>
<td>30 (10.8)</td>
<td>11 (9.2)</td>
<td>19 (12.0)</td>
<td></td>
</tr>
<tr>
<td>AIS of patients</td>
<td></td>
<td></td>
<td></td>
<td>0.038</td>
</tr>
<tr>
<td>Head and neck</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–2</td>
<td>220 (79.1)</td>
<td>88 (73.3)</td>
<td>132 (83.5)</td>
<td></td>
</tr>
<tr>
<td>3–5</td>
<td>58 (20.9)</td>
<td>32 (26.7)</td>
<td>26 (16.5)</td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td></td>
<td></td>
<td></td>
<td>0.536</td>
</tr>
<tr>
<td>0–2</td>
<td>218 (78.4)</td>
<td>92 (76.7)</td>
<td>126 (79.7)</td>
<td></td>
</tr>
<tr>
<td>3–5</td>
<td>60 (21.6)</td>
<td>28 (23.3)</td>
<td>32 (20.3)</td>
<td></td>
</tr>
<tr>
<td>Abdomen</td>
<td></td>
<td></td>
<td></td>
<td>0.338</td>
</tr>
<tr>
<td>0–2</td>
<td>251 (90.3)</td>
<td>106 (88.3)</td>
<td>145 (91.8)</td>
<td></td>
</tr>
<tr>
<td>3–5</td>
<td>27 (9.7)</td>
<td>14 (11.7)</td>
<td>13 (8.2)</td>
<td></td>
</tr>
<tr>
<td>Extremities and pelvis</td>
<td></td>
<td></td>
<td></td>
<td>0.447</td>
</tr>
<tr>
<td>0–2</td>
<td>141 (50.7)</td>
<td>64 (53.3)</td>
<td>77 (48.7)</td>
<td></td>
</tr>
<tr>
<td>3–5</td>
<td>137 (49.3)</td>
<td>56 (46.7)</td>
<td>81 (51.3)</td>
<td></td>
</tr>
<tr>
<td>Independent risk factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical prevention of VTE</td>
<td>94 (33.8)</td>
<td>40 (33.3)</td>
<td>54 (34.2)</td>
<td>0.883</td>
</tr>
<tr>
<td>Use of IV tranexamic acid</td>
<td>69 (24.8)</td>
<td>34 (28.3)</td>
<td>35 (22.2)</td>
<td>0.237</td>
</tr>
<tr>
<td>Major surgery</td>
<td>226 (81.3)</td>
<td>100 (83.3)</td>
<td>126 (79.7)</td>
<td>0.448</td>
</tr>
<tr>
<td>Pelvic fracture</td>
<td>42 (15.1)</td>
<td>13 (10.8)</td>
<td>29 (18.4)</td>
<td>0.083</td>
</tr>
<tr>
<td>Lower extremity fracture</td>
<td>178 (64.0)</td>
<td>76 (63.3)</td>
<td>102 (64.6)</td>
<td>0.833</td>
</tr>
<tr>
<td>Spinal cord injury</td>
<td>33 (11.9)</td>
<td>17 (14.2)</td>
<td>16 (10.1)</td>
<td>0.302</td>
</tr>
<tr>
<td>Admission to ICU</td>
<td>134 (48.2)</td>
<td>64 (53.3)</td>
<td>70 (44.3)</td>
<td>0.136</td>
</tr>
<tr>
<td>Length of ICU stay (day)</td>
<td>134 (100)</td>
<td>64 (47.8)</td>
<td>70 (52.2)</td>
<td>0.459</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>4.0 (2.0–10.0)</td>
<td>5.0 (2.0–10.0)</td>
<td>4.0 (2.0–8.3)</td>
<td></td>
</tr>
<tr>
<td>Use of mechanical ventilator</td>
<td>76 (27.3)</td>
<td>33 (27.5)</td>
<td>43 (27.2)</td>
<td>0.958</td>
</tr>
<tr>
<td>Length of mechanical ventilation (day)</td>
<td>76 (100)</td>
<td>33 (43.4)</td>
<td>43 (56.6)</td>
<td>0.635</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>4.0 (1.0–7.0)</td>
<td>4.0 (1.0–7.0)</td>
<td>3.0 (1.0–8.0)</td>
<td></td>
</tr>
<tr>
<td>D-dimer (n=204)</td>
<td></td>
<td></td>
<td></td>
<td>0.211</td>
</tr>
<tr>
<td>Elevation</td>
<td>202 (99.0)</td>
<td>89 (100)</td>
<td>113 (98.3)</td>
<td></td>
</tr>
<tr>
<td>Nonelevation</td>
<td>2 (1.0)</td>
<td>0</td>
<td>2 (1.7)</td>
<td></td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>6,526</td>
<td>6,338</td>
<td>6,640</td>
<td>0.656</td>
</tr>
</tbody>
</table>

Values are presented as number (%), unless otherwise indicated.

VTE, venous thromboembolism; IQR, interquartile range; ISS, Injury Severity Score; AIS, Abbreviated Injury Scale; IV, intravenous; ICU, intensive care unit.
Table 2. Subgroup analysis between patients with severe and nonsevere head and neck injuries

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Severe head and neck injury&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Nonsevere head and neck injury&lt;sup&gt;b&lt;/sup&gt;</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>58 (100)</td>
<td>220 (100)</td>
<td>0.038</td>
</tr>
<tr>
<td>VTE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>–</td>
<td>26 (44.8)</td>
<td>132 (60.0)</td>
<td></td>
</tr>
<tr>
<td>+</td>
<td>32 (55.2)</td>
<td>88 (40.0)</td>
<td></td>
</tr>
<tr>
<td>Pulmonary thromboembolism</td>
<td>16 (50.0)</td>
<td>44 (50.0)</td>
<td></td>
</tr>
<tr>
<td>Deep vein thrombosis</td>
<td>28 (87.5)</td>
<td>68 (77.3)</td>
<td></td>
</tr>
<tr>
<td>ISS of patients</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mild and moderate (&lt;16)</td>
<td>10 (17.2)</td>
<td>177 (80.5)</td>
<td></td>
</tr>
<tr>
<td>Severe (16–24)</td>
<td>29 (50.0)</td>
<td>32 (14.5)</td>
<td></td>
</tr>
<tr>
<td>Critical (&gt;24)</td>
<td>19 (32.8)</td>
<td>11 (5.0)</td>
<td></td>
</tr>
<tr>
<td>Independent risk factor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical prevention of VTE</td>
<td>15 (25.9)</td>
<td>79 (35.9)</td>
<td>0.150</td>
</tr>
<tr>
<td>Use of IV tranexamic acid</td>
<td>35 (60.3)</td>
<td>34 (15.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Major surgery</td>
<td>47 (81.0)</td>
<td>179 (81.4)</td>
<td>0.954</td>
</tr>
<tr>
<td>Pelvic fracture</td>
<td>10 (17.2)</td>
<td>32 (14.5)</td>
<td>0.610</td>
</tr>
<tr>
<td>Lower extremity fracture</td>
<td>21 (36.2)</td>
<td>157 (71.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Spinal cord injury</td>
<td>18 (31.0)</td>
<td>15 (6.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Admission to ICU</td>
<td>50 (86.2)</td>
<td>84 (38.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of ICU stay (day)</td>
<td>50 (37.3)</td>
<td>84 (62.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>9.5 (4.0–14.0)</td>
<td>3.0 (1.0–6.0)</td>
<td></td>
</tr>
<tr>
<td>Use of mechanical ventilator</td>
<td>37 (63.8)</td>
<td>39 (17.7)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Length of mechanical ventilation (day)</td>
<td>37 (48.7)</td>
<td>39 (51.3)</td>
<td>0.018</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>5.0 (3.0–8.0)</td>
<td>2.0 (0.0–6.0)</td>
<td></td>
</tr>
<tr>
<td>D-dimer (n=204)</td>
<td></td>
<td></td>
<td>0.437</td>
</tr>
<tr>
<td>Elevation</td>
<td>47 (100)</td>
<td>155 (98.7)</td>
<td></td>
</tr>
<tr>
<td>Nonelevation</td>
<td>0</td>
<td>2 (1.3)</td>
<td></td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>7,900</td>
<td>6,100</td>
<td>0.292</td>
</tr>
</tbody>
</table>

Values are presented as number (%), unless otherwise indicated.

VTE, venous thromboembolism; ISS, Injury Severity Score; IV, intravenous; ICU, intensive care unit; IQR, interquartile range.

<sup>a</sup>Abbreviated Injury Scale, 3–5;
<sup>b</sup>Abbreviated Injury Scale, 0–2.

Table 3. Logistic regression analysis for venous thromboembolism

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unadjusted</th>
<th></th>
<th></th>
<th>Adjusted</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odds ratio</td>
<td>95% CI</td>
<td>Odds ratio</td>
<td>95% CI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1.008</td>
<td>0.997–1.020</td>
<td>1.012</td>
<td>0.999–1.025</td>
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<td></td>
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<tr>
<td>Male sex</td>
<td>0.921</td>
<td>0.570–1.489</td>
<td>0.819</td>
<td>0.477–1.405</td>
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<tr>
<td>Head or neck injury</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>AIS (0–2)</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extremities or pelvis injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIS (0–2)</td>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AIS (3–5)</td>
<td>0.832</td>
<td>0.517–1.338</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISS of patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild and moderate (&lt;16)</td>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe (16–24)</td>
<td>1.880</td>
<td>1.049–3.371</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical (&gt;24)</td>
<td>0.865</td>
<td>0.389–1.920</td>
<td></td>
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</tbody>
</table>

CI, confidence interval; AIS, Abbreviated Injury Scale; ISS, Injury Severity Score.
an trauma patients in their 2021 study. The overall incidence of VTE among trauma inpatients found in this study was 1.57% (120 of 7,634), which is similar to other results. Conventionally, VTE incidence is known to be lower in Asian populations than in Western populations [27]. Based on our and previous study findings, there seems to be no marked difference in VTE incidence among trauma patients in different populations.

Yumoto et al. [28] reported a VTE diagnosis rate of 32% (65 of 204) among patients with symptoms of posttraumatic VTE based on CT performed at the physician’s discretion. In our study, the rate was 43.2% (120 of 278). Considering these diagnosis rates, the diagnosis should be made aggressively in trauma patients with VTE-associated symptoms.

The incidence of VTE among patients with head injuries has been extensively studied. Van Gent et al. [29] reported that VTE incidence was higher among patients with isolated traumatic brain injuries who had higher mean head-AIS scores. Knudson et al. [5] stated that a head-AIS score of 3 or higher was a significant independent risk factor for VTE. Our results showed that the VTE rate was higher among patients with severe head and neck injuries (AIS, 3–5) than in patients with no to moderate head and neck injuries (AIS, 0–2) (Table 1). Furthermore, logistic regression analysis revealed that the adjusted odds ratio for VTE was 1.891 (95% confidence interval, 1.043–3.430) in the severe head and neck injury group (AIS, 3–5) (Table 3). Regarding these results, Nekludov et al. [30] reported that elevated levels of interleukin 6 are observed in the blood samples and cerebrospinal fluid samples of patients with isolated traumatic brain injuries and that interleukin 6 may be associated with thrombus generation by increasing the release of acute-phase reactants such as fibrinogen. Mackman [31] argued that after an injury, increased tissue factor release activates the extrinsic clotting cascade. It seems that this mechanism underlies the increased incidence of VTE among patients with traumatic brain injury. Knudson et al. [5] found that lower extremity fracture (AIS ≥ 3), head injury (AIS ≥ 3), and major operative procedures were independent risk factors for VTE, and Yumoto et al. [28] reported that a higher risk of ISS score, mechanical ventilation, and longer length of ICU stay were risk factors for VTE. Myers et al. [22] also stated that the use of tranexamic acid was an independent risk factor for VTE. These risk factors are equivalent to the characteristics of patients with severe head and neck injuries obtained through the subgroup analysis in our study. Our subgroup analysis showed that the severe and nonsevere head and neck injury groups differed significantly in the ISS score, use of IV tranexamic acid, lower extremity fracture, spinal cord injury, admission to the ICU, length of ICU stay, use of mechanical ventilator, and length of mechanical ventilation (Table 2). It is speculated that the incidence of VTE may be higher among patients with severe head and neck injuries because these patients already have various VTE risk factors. Byrne et al. [32] reported that early pharmacologic VTE prophylaxis can significantly reduce the incidence of VTE in patients with traumatic brain injury and that pharmacologic VTE prophylaxis can be initiated stably within 72 hours for patients who show stable intracranial hemorrhage on repeated head CT examinations. As patients with head and neck injuries are highly likely to develop VTE, early pharmacologic prophylaxis should be administered to these patients.

In this study, we attempted to analyze epidemiological differences among patients with posttraumatic VTE-associated symptoms based on their diagnosis of VTE using CTA. No statistically significant differences were found between VTE-positive and VTE-negative patients in known risk factors for VTE, except for the severity of head and neck injuries. Knudson et al. [5] identified age ≥ 40 years, lower extremity fracture (AIS ≥ 3), head injury (AIS ≥ 3), ≥ 3 days on ventilation, venous injury, and major operative procedures as independent risk factors for VTE. In our study, the characteristics of the patients who underwent CTA were as follows: the median of total age, 64.5 years (interquartile range, 47.5–80.0 years); major surgery, 81.3% (226 of 278); lower extremity fracture, 64.0% (178 of 278); the median of the length of mechanical ventilation, 4.0 days (interquartile range, 1.0–7.0 days). This shows that patients who underwent CTA had the abovementioned risk factors for VTE. The attending physician probably considered CTA for patients at high risk of VTE, such as immobilized patients undergoing major orthopedic surgery. Therefore, patients with similar epidemiological characteristics were enrolled in this study. Hence, the lack of a statistically significant difference in the known VTE risk factors between the VTE-positive and VTE-negative groups, with the exception of head and neck injury severity, may have been because CTA was performed on symptomatic patients who already had VTE risk factors. This study is significant in that it sheds light on the need to consider CTA for VTE diagnosis in trauma inpatients with severe head and neck injuries who have VTE risk factors and show relevant symptoms.

D-dimer is known to be a useful parameter for avoiding unnecessary tests, such as CT, by ruling out VTE based on its high negative predictive value [28,33,34]. However, trauma patients have elevated D-dimer levels due to the pathological process of trauma itself [21]. Matsumoto et al. [35] reported that there were no significant differences in the D-dimer level among patients
with spinal cord injuries, which are considered severe traumatic injuries, according to their DVT diagnosis results. In our study, the median D-dimer level was 6,338 ng/mL (interquartile range, 4,004–12,950 ng/mL) in the VTE-positive group and 6,640 ng/mL (interquartile range, 2,408–14,806 ng/mL) in the VTE-negative group, showing that these patients had markedly elevated D-dimer levels relative to the normal values, even considering age-adjusted D-dimer cutoff values. Two patients in the negative group had values below the cutoff value, and the negative group had a higher median value (Table 1). Thus, according to our results, the D-dimer level is inadequate as a single screening factor for VTE detection in trauma patients. Yumoto et al. [28] reported that VTE occurred within a median of 10 days from hospitalization in trauma patients and that the D-dimer level after about 10 days of admission had moderate accuracy as a predictor of VTE onset. We observed during our data collection that D-dimer testing was sometimes not performed and serial examinations were rarely performed in trauma patients. Serial D-dimer levels from admission to 10 days later may be meaningful for trauma patients anticipated to have a prolonged hospital stay.

This study has a few limitations. First, this was a retrospective study, and the final analysis was performed on patients who underwent CTA. The decision to perform CTA was made at the discretion of the clinician based on patients’ presentation of signs or symptoms known to be risk factors for VTE. However, this leaves our study vulnerable to selection bias, as patients who developed VTE without undergoing CTA were not included. Thus, prospective studies with a strict study design including screening tests such as venous ultrasound for an early diagnosis of VTE are required.

Second, this was a single-center study. While data from 7,634 patients registered in the KTDB were reviewed, only 278 patients were enrolled in the study due to the rare nature of the disease. Thus, a large-scale multicenter study is needed to produce more statistically significant results.

In conclusion, there is no marked difference in the incidence of VTE among inpatients with trauma across populations. Trauma patients with severe head and neck injuries were found to be more susceptible to VTE than those with nonsevere head and neck injuries. Thus, attending physicians must consider CTA as a priority for the diagnosis of VTE in trauma patients with severe head and neck injuries who show VTE-associated symptoms. Aggressive and routine measurements for VTE can effectively reduce the incidence of clinically significant VTE and enable an early diagnosis of VTE in trauma patients. Attending physicians should be aware of and predict VTE risk factors and symptoms in trauma patients, and healthcare facilities should develop a VTE prevention and diagnosis protocol for this group of patients.

NOTES

Ethical statements
The study protocol was approved by the Institutional Review Board of Gachon University Gil Medical Center (No. GBIRB 2021-230). The requirement for informed consent was waived.

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

Funding
None.

Author contributions
Conceptualization: all authors; Data curation: all authors; Formal analysis: HSP, SYH, WSC, JSC, JYC; Methodology: all authors; Project administration: HSP, SYH, WSC; Visualization: HSP, SYH, WSC, JSC; Writing—original draft: HSP, WSC; Writing—review & editing: HSP, SYH, WSC, JHJ, JYC.

All authors read and approved the final manuscript.

REFERENCES


INTRODUCTION

The neck, which is located between the head and the torso, contains vital structures including the trachea, carotid arteries, and spinal cord. While relatively uncommon in comparison to other parts of the body, the potential morbidity of penetrating neck trauma is apparent, due to the high density of vital structures confined to a relatively small and poorly protected area [1]. Although penetrating neck injuries were estimated to comprise 10% of all trauma patients, the overall mortality rates were estimated to be between 3% and 6%, most commonly as a result of injury to vascular structures and hemorrhage [2].

The successful management of penetrating neck injuries depends on a clear understanding of the anatomy of the neck [3]. Anatomically, the neck can be divided into three major zones, as presented by Monson et al. [4] in 1969. Using the classification of the neck into three zones makes the initial assessment and management easier, including surgical exploration and hemorrhage control. Zone I extends from the clavicle to the cricoid cartilage, zone II extends from the cricoid cartilage to the mandibular angle, and zone III extends from the mandibular angle to the base of the skull. In zone II, the carotid arteries, jugular veins, larynx, esophagus, trachea, thyroid, and nerves gather.

This study attempted to identify the factors associated with the outcomes of open neck injuries.
survival in patients with open neck injuries and to characterize the outcomes of penetrating neck injuries.

**METHODS**

This study was approved by the Ethics Committee of Daejeon Eulji Medical Center, Eulji University. Written informed consent was not necessary due to the retrospective nature of the study. From January 2015 to December 2017, we studied neck trauma cases at the Trauma Center of Daejeon Eulji Medical Center. We included patients with neck injuries and excluded those with head, torso, and extremity injuries. All relevant patients were enrolled in this retrospective study. All medical records and operative notes were reviewed.

Descriptive statistics are expressed as mean ± standard deviation, unless otherwise specified. Continuous variables were compared using the Student t-test and the Mann-Whitney U-test, and categorical variables were compared using the chi-square test. Multiple logistic regression analysis was used to evaluate the risk factors for mortality from injury by estimating the corresponding odds ratios. All P-values of less than 0.05 were considered to indicate statistical significance. Statistical analysis was performed using IBM SPSS ver. 26.0 (IBM Corp., Armonk, NY, USA).

**RESULTS**

In this study, 6,183 patients presented to our hospital over a 3-year period, of whom 32 had open neck injuries. The study group comprised 23 male patients and nine female patients with a mean age of 50.2 years (Table 1). The injury mechanisms included 19 penetrating injuries and 13 blunt injuries. The causes of the injuries were accidents (19 patients), attempted suicide (10 patients), or attempted homicide (three patients) (Table 1).

Twenty-six patients underwent computed tomographic angiography (CTA) to evaluate their injuries. Twenty-seven patients received surgical treatment once their vital signs stabilized. The damaged structures are listed in Table 2. The most commonly injured organ was the airway (eight cases) (Table 2).

The average time to rescue team arrival in the field was 45.7 minutes. The mean systolic blood pressure (SBP) in the field was 107.5 mmHg. Three patients received cardiopulmonary resuscitation in the field and during transfer to the hospital (Table 3). The average transfer time to the hospital was 37.7 minutes. The initial mean SBP at the hospital was 101.8 mmHg, and four patients received cardiopulmonary resuscitation at the hospital, including three patients who received prehospital cardiopulmonary resuscitation (Table 3). Six patients received a transfusion, and 4 units of red blood cells were transfused on average (Table 3). Table 3 shows the Glasgow Coma Scale (GCS) at the hospital.

Twenty-seven patients required surgical treatment, consisting of primary repair and temporary tracheostomy (Table 4). The average hospital stay was 15.7 days (Table 4). There were no complications, such as wound infection, pneumonia, or sepsis. There were five deaths (mortality rate, 15.6%). The causes of death were bleeding (three patients), acute drug intoxication

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### Table 1. Patient characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr), mean±standard deviation</td>
<td>50.2±18.1</td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>23:9</td>
</tr>
<tr>
<td>Alcohol ingestion (no:yes:unknown)</td>
<td>8:9:15</td>
</tr>
<tr>
<td>Underlying psychological disease</td>
<td>3</td>
</tr>
<tr>
<td>Panic disorder</td>
<td>1</td>
</tr>
<tr>
<td>Anxiety disorder</td>
<td>1</td>
</tr>
<tr>
<td>Schizophrenia</td>
<td>1</td>
</tr>
<tr>
<td>Mechanism of injury (penetrating:blunt)</td>
<td>19:13</td>
</tr>
<tr>
<td>Homicidal</td>
<td>3:0</td>
</tr>
<tr>
<td>Suicidal</td>
<td>10:0</td>
</tr>
<tr>
<td>Accidental</td>
<td>6:13</td>
</tr>
</tbody>
</table>

### Table 2. Damaged anatomical structures

<table>
<thead>
<tr>
<th>Damaged structure</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td></td>
</tr>
<tr>
<td>Airway</td>
<td>8</td>
</tr>
<tr>
<td>Trachea</td>
<td>3</td>
</tr>
<tr>
<td>Thyroid cartilage</td>
<td>3</td>
</tr>
<tr>
<td>Pharyngolarynx</td>
<td>1</td>
</tr>
<tr>
<td>Cricoid cartilage</td>
<td>1</td>
</tr>
<tr>
<td>Arterial system (carotid artery)</td>
<td>2</td>
</tr>
<tr>
<td>Venous system (jugular vein)</td>
<td>2</td>
</tr>
<tr>
<td>Spinal cord</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>22</td>
</tr>
<tr>
<td>Muscle</td>
<td>10</td>
</tr>
<tr>
<td>Thyroid gland</td>
<td>1</td>
</tr>
<tr>
<td>Hyoid bone</td>
<td>1</td>
</tr>
<tr>
<td>Subcutaneous tissue</td>
<td>10</td>
</tr>
<tr>
<td>Associated part</td>
<td></td>
</tr>
<tr>
<td>Head</td>
<td>2</td>
</tr>
<tr>
<td>Chest</td>
<td>3</td>
</tr>
<tr>
<td>Abdomen</td>
<td>2</td>
</tr>
<tr>
<td>Vertebral and spine</td>
<td>2</td>
</tr>
<tr>
<td>Pelvis and extremity</td>
<td>3</td>
</tr>
</tbody>
</table>
from herbicide (one patient), and neurologic shock from spinal cord injury (one patient) (Table 4). The average time to rescue team arrival in the field and the average transfer time to the hospital were shorter in cases of mortality than in those of nonmortality (Table 5). There were differences in SBP and the GCS between the mortality and nonmortality groups (Table 5). Mortality was associated with initial SBP at the hospital and GCS (P<0.05) (Table 6).

**DISCUSSION**

In our study, mortality was associated with initial SBP and GCS

Table 3. Transfer time, vital signs, and Abbreviated Injury Scale of the patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td></td>
</tr>
<tr>
<td>In the field</td>
<td>107.5±47.8</td>
</tr>
<tr>
<td>At the hospital</td>
<td>101.8±44.7</td>
</tr>
<tr>
<td>Glasgow Coma Scale at the hospital</td>
<td></td>
</tr>
<tr>
<td>Mild (14–15)</td>
<td>21</td>
</tr>
<tr>
<td>Moderate (9–13)</td>
<td>5</td>
</tr>
<tr>
<td>Severe (≤8)</td>
<td>6</td>
</tr>
<tr>
<td>Transfusion</td>
<td>6</td>
</tr>
<tr>
<td>Cardiopulmonary resuscitation in the field</td>
<td>3</td>
</tr>
<tr>
<td>Cardiopulmonary resuscitation at the hospital</td>
<td>4</td>
</tr>
<tr>
<td>Abbreviated Injury Scale of the neck</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Time to rescue team arrival (min)</td>
<td>45.7±94.4</td>
</tr>
<tr>
<td>Transfer time to the hospital (min)</td>
<td>37.7±22.2</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.

Table 4. Patient outcomes

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Value (n=32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical treatment</td>
<td>27 (84.4)</td>
</tr>
<tr>
<td>Primary repair</td>
<td>27</td>
</tr>
<tr>
<td>Temporary tracheostomy</td>
<td>3</td>
</tr>
<tr>
<td>Hospital stay (day)</td>
<td>15.7±20.4</td>
</tr>
<tr>
<td>Complication (n=27)</td>
<td>0</td>
</tr>
<tr>
<td>Wound infection</td>
<td>0</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>0</td>
</tr>
<tr>
<td>Sepsis</td>
<td>0</td>
</tr>
<tr>
<td>Overall mortality</td>
<td>5 (15.6)</td>
</tr>
<tr>
<td>Bleeding</td>
<td>3</td>
</tr>
<tr>
<td>Drug intoxication (herbicide)</td>
<td>1</td>
</tr>
<tr>
<td>Spinal cord injury</td>
<td>1</td>
</tr>
</tbody>
</table>

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

Table 5. Comparison of nonmortality and mortality cases

<table>
<thead>
<tr>
<th>Variable</th>
<th>Nonmortality</th>
<th>Mortality</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>47 (36.0–58.5)</td>
<td>71 (35.0–78.0)</td>
<td>0.23</td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>20:7</td>
<td>3:2</td>
<td>0.62</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In the field</td>
<td>127.5 (110.0–140.0)</td>
<td>0 (0–0)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>At the hospital</td>
<td>120.0 (103.0–137.5)</td>
<td>0 (0–43.0)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Time to rescue team arrival (min)</td>
<td>17.5 (8.5–54.5)</td>
<td>9.0 (7.0–9.0)</td>
<td>0.01</td>
</tr>
<tr>
<td>Transfer time to the hospital (min)</td>
<td>45.5 (20.5–59.0)</td>
<td>20.0 (13.0–25.0)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Glasgow Coma Scale at the hospital</td>
<td></td>
<td></td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Mild (14–15)</td>
<td>21</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Moderate (9–13)</td>
<td>5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Severe (≤8)</td>
<td>1</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Transfusion (unit)</td>
<td>3</td>
<td>5</td>
<td>0.01</td>
</tr>
<tr>
<td>Abbreviated Injury Scale of the neck</td>
<td></td>
<td></td>
<td>0.90</td>
</tr>
<tr>
<td>1</td>
<td>13</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as median (interquartile range).
at the hospital. The neck is a particularly critical region for penetrating injuries due to the close proximity of the trachea, esophagus, blood vessels, and the spinal cord. Early volume resuscitation is considered essential for open neck injury patients. Aggressive fluid therapy during transfer to the hospital and in the field would help the patient, even if the damage is severe.

The initial evaluation of a trauma patient begins with the “ABCs” of trauma management: establish a secure airway, breathing/respiration, and volume resuscitation [5–7]. For our study, the mortality was associated with initial SBP and GCS at the hospital (Table 6). The main cause of death was hypovolemia due to bleeding. SBP is considered to be the most important factor. Therefore, volume resuscitation is as important as airway management and respiration. The GCS was developed for monitoring postoperative craniotomy patients and was subsequently applied as a measure of overall physiological derangement in the trauma field. A patient’s mental status could be depressed because of hypovolemic shock [3]. Therefore, the combined use of SBP and the GCS motor scale is effective at predicting patient survival [8].

The platysma is a thin muscular sheet that surrounds the superficial fascia of the neck. It determines whether a penetrating wound of the neck is superficial or deep. The potential for injury to a vital organ exists when this structure is penetrated. The standard management is immediate surgical exploration for patients who present with signs and symptoms of shock and continuous hemorrhage from the neck wound [5]. However, all patients with active bleeding, expanding hematoma, shock, massive subcutaneous emphysema, or significant airway compromise are admitted directly to the operating room and undergo surgical exploration, regardless of the zone of injury [5,8]. Particular importance should also be placed on the airway, because bleeding within the tight compartmentalized spaces of the neck may appear quiescent externally, yet cause progressive airway compromise and eventual complete obstruction [8]. In this study, 22 patients presented with platysma penetration; significant airway or vascular injury was found in 11 patients (Table 2). Nonetheless, mandatory exploration of all neck wounds may be the best policy in an environment in which routine serial examinations are not possible [3].

CTA is generally considered the initial diagnostic method of choice for evaluating the injured organs in penetrating neck trauma [5]. A comprehensive physical examination with CTA is adequate for identifying and excluding vascular and aerodigestive injury due to penetrating neck trauma [9]. As the accuracy of CTA increases, accompanied by a careful clinical evaluation to diagnose damage to critical structures, surgical intervention or observation can be performed safely and carefully [1]. In a trauma center with experienced staff, the frequency of operations for penetrating neck wounds without structural injuries can be minimized by selective neck exploration [10,11]. In this study, all patients with stable vital signs were taken for CTA. We determined the surgical strategy based on CTA findings.

The overall mortality rate of patients with penetrating neck injuries has been estimated at between 3% to 6%, and vascular injury was the most common reason for surgery [2,12]. In this study, five patients died, with causes that included bleeding (three patients), acute drug intoxication from herbicide (one patient), and neurologic shock (one patient).

This study has several limitations. First, the single-center retrospective design of this study is its major limitation. Second, this retrospective study consisted of patients with airway injury or vascular injury. Therefore, this study group was heterogeneous. Further studies of specific injuries, such as vascular or airway injuries, seem to be necessary. Lastly, there were only 32 patients, and further studies with a larger population would be helpful. However, our data might prove to be meaningful for the prevention of death from penetrating neck injuries.

Debate continues on the assessment and management of open neck injuries. In this study, mortality from open neck injuries was associated with the initial SBP and GCS at the hospital. Further studies of open neck injuries are needed.

### Table 6. Factors influencing mortality using multiple logistic regression

<table>
<thead>
<tr>
<th>Factor</th>
<th>Odds ratio</th>
<th>95% Confidence interval</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systolic blood pressure at the hospital</td>
<td>0.9</td>
<td>0.99–0.99</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Glasgow Coma Scale at the hospital</td>
<td>0.8</td>
<td>0.72–0.90</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Time to rescue service arrival</td>
<td>1.0</td>
<td>0.99–1.00</td>
<td>0.89</td>
</tr>
<tr>
<td>Transfer time to the hospital</td>
<td>0.9</td>
<td>0.99–1.00</td>
<td>0.49</td>
</tr>
<tr>
<td>Transfusion</td>
<td>0.9</td>
<td>0.78–1.16</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Multiple regression analysis was performed with statistically significant factors according to Table 5.
NOTES

Ethical statements
This study was approved by the Ethics Committee of Daejeon Eulji Medical Center, Eulji University. Written informed consent was not necessary due to the retrospective nature of the study.

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

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

REFERENCES

National utilization of rib fracture fixation in the geriatric population in the United States

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2Division of Trauma and Acute Care Surgery, St. Francis Medical Center, Hartford, CT, USA
3Division of Trauma and Acute Care Surgery, Baystate Medical Center, Springfield, MA, USA

**Purpose:** The use of surgical stabilization of rib fractures (SSRF) has steadily increased over the past decade. Recent literature suggests that a larger population may benefit from SSRF, and that the geriatric population—as the highest-risk population—may receive the greatest improvement from these interventions. We sought to determine the overall utilization of SSRF in the United States.

**Methods:** The National Trauma Database was analyzed between 2016 and 2017. The inclusion criteria were all patients ≥65 years old with rib fractures. We further stratified these patients according to age (65–79 vs. ≥80 years old), the presence of coding for flail chest, three or more rib fractures, and intervention (surgical vs. nonoperative management). The main outcomes were surgical interventions, mortality, pneumonia, length of stay, intensive care unit length of stay, ventilator use, and tracheostomy.

**Results:** Overall, 93,638 patients were identified. SSRF was performed in 992 patients. Patients who underwent SSRF had improved mortality in the 65 to 79 age group, regardless of the number of ribs fractured. We identified 92,637 patients in the age group of 65 to 79 years old who did not undergo SSRF. This represents an additional 20,000 patients annually who may benefit from SSRF.

**Conclusions:** By conservative standards and the well-established Eastern Association for the Surgery of Trauma clinical practice guidelines, SSRF is underutilized. Our data suggest that SSRF may be very beneficial for the geriatric population, specifically those aged 65 to 79 years with any rib fractures. We hypothesize that roughly 20,000 additional cases will meet the inclusion criteria for SSRF each year. It is therefore imperative that we train acute care surgeons in this skill set.

**Keywords:** Geriatric trauma; Rib fractures; Surgical stabilization of rib fractures; Rib fixation; Blunt trauma

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INTRODUCTION

Rib fractures are the most common blunt trauma injury, occurring in 10% of all trauma patients, yet outcomes remain poor [1]. The overall mortality of rib fractures is 10%, and mortality increases with each rib fracture [2]. Previously, the gold standard in rib fracture management was pain control [3]. However, there is now an increasing interest in surgical stabilization of rib fractures (SSRF) to improve outcomes [3].

Flail chest injuries, especially those requiring mechanical ventilation, are the most severe fracture pattern and are universally accepted as an indication for SSRF [1,4–6]. Although widely accepted for flail chest injuries, SSRF is actually only utilized for roughly 5.8% of these patients [7]. Even more recently, chest wall surgeons have demonstrated the efficacy of SSRF for patients with nonflail chest [1,3,8]. These patients tend to have lower injury severity, making it difficult to discern whether SSRF is beneficial [1,3,8]. Nonetheless, SSRF has been shown to result in decreased pain scores and improved quality of life. In addition, trends have been seen towards decreased narcotic usage in nonflail fracture patterns [7].

Rib fractures pose a greater threat to the elderly than to other populations. Patients greater than 65 years old have a higher mortality risk of 20% from rib fractures, with a 10% increase in mortality with each additional rib fracture [2,9–11]. In the elderly population, SSRF has been shown to improve outcomes [9,10,12]. However, large data sets have not been analyzed to evaluate whether SSRF is beneficial, specifically in the geriatric and octogenarian age groups.

Historically, SSRF data were challenging to extract from the National Trauma Data Bank (NTDB), as there were no specific procedure codes for SSRF. After 2016, due to changes in the International Classification of Disease, 10th Revision and the Current Procedural Terminology coding for SSRF, the data quality contained within national datasets has dramatically improved. We sought to determine the overall utilization of SSRF in the elderly population and to identify the potential number of surgical candidates. We hypothesized that by utilizing the NTDB, we would identify many more patients eligible for SSRF.

METHODS

This study was approved by Internal Review Board of the St. Francis Medical Center (No. SFH-21-24). This study protocol was approved by the local Ethics Committee and conducted in accordance with the Declaration of Helsinki and Good Clinical Practices. Informed consent was waived due to the retrospective nature of this study.

The NTDB is a nationwide database maintained by the American College of Surgeons Committee on Trauma. We retrospectively reviewed the NTDB from January 1, 2016 to December 31, 2017. The inclusion criteria were all patients ≥ 65 years old with any rib fractures. There were no exclusion criteria. We further stratified these patients by age (65–79 years old vs. ≥ 80 years old), the presence of flail chest (code S22.5), the presence of three or more rib fractures (code S22.4), and the presence of SSRF (code 21811–21813). Patient demographics included age, sex, and the Injury Severity Score (ISS). The following outcome variables were analyzed: mortality, pneumonia, length of stay (LOS), intensive care unit (ICU) LOS, ventilator use, tracheostomy rates, and the presence of comorbidities (diabetes, dementia, disability, lung disease, and smoking). The discharge destination for survivors was evaluated (home, inpatient rehabilitation [IPR], or skilled nursing facility).

Continuous data are presented as mean ± standard error or deviation if normally distributed, and as median and interquartile range (25th–75th) if nonnormally distributed. Continuous variables were assessed with the Student t-test when normally distributed and the Wilcoxon signed rank-sum test when data is skewed. The chi-square test was used to assess categorical variables. We defined statistically significant differences as those with a p-value ≤ 0.05 corresponds to a 95% confidence level. Statistical analysis was performed with Stata ver. 16 (StataCorp., College Station, TX, USA).

RESULTS

SSRF compared to nonoperative treatment in 65- to 79-year-old rib fracture patients

In total, 777 of the 57,129 patients aged 65 to 79 years old underwent SSRF (1.4%). The median age was significantly different between patients who underwent SSRF and those who underwent nonoperative treatment (NOP), with younger patients undergoing SSRF (70.8 years old vs. 71.5 years old, P < 0.001). There were no significant differences in the comorbidities reviewed between SSRF and NOP patients (P > 0.05), except that patients who had SSRF were less likely to have preexisting disability (3.5% vs. 6.6%, P = 0.001) or dementia (1.4% vs. 4.2%, P < 0.001) (Table 1).

SSRF patients had significantly higher ISS (18.8 vs. 14.0), were more likely to be admitted to the ICU (86.9% vs. 44.6%), more likely to have three or more rib fractures (54.7% vs. 46.7%)
Table 1. SSRF compared to NOP in 65- to 79-year-old rib fracture patients from 2016 to 2017

<table>
<thead>
<tr>
<th>Variable</th>
<th>NOP (n=56,352)</th>
<th>SSRF (n=777)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr), mean±SD</td>
<td>71.5±4.3</td>
<td>70.8±4.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean±SD</td>
<td>14.0±9.1</td>
<td>18.8±8.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>12 (9–17)</td>
<td>17 (13–24)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICU</td>
<td>44.6</td>
<td>86.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mortality</td>
<td>5.7</td>
<td>3.6</td>
<td>0.011</td>
</tr>
<tr>
<td>Flail</td>
<td>5.1</td>
<td>51.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>3–5</td>
<td>1.8</td>
<td>16.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6</td>
<td>1.8</td>
<td>24.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Bilateral</td>
<td>0.6</td>
<td>2.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LOS (day), median (IQR)</td>
<td>5 (3–9)</td>
<td>13 (9–20)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICU LOS (day), median (IQR)</td>
<td>0 (0–3)</td>
<td>7 (3–13)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ventilator free (day), median (IQR)</td>
<td>5 (3–8)</td>
<td>9 (7–14)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Male sex</td>
<td>61.8</td>
<td>72.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ventilator</td>
<td>15.6</td>
<td>50.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Anticoagulation</td>
<td>13.5</td>
<td>10.6</td>
<td>0.017</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>5.6</td>
<td>4.1</td>
<td>0.075</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>13.4</td>
<td>13.0</td>
<td>0.770</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
<td>3.9</td>
<td>3.1</td>
<td>0.220</td>
</tr>
<tr>
<td>Dementia</td>
<td>4.2</td>
<td>1.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diabetes</td>
<td>25.7</td>
<td>24.7</td>
<td>0.530</td>
</tr>
<tr>
<td>Ethanol use</td>
<td>6.2</td>
<td>6.1</td>
<td>0.860</td>
</tr>
<tr>
<td>Disabled</td>
<td>6.6</td>
<td>3.5</td>
<td>0.001</td>
</tr>
<tr>
<td>Hypertension</td>
<td>57.6</td>
<td>57.1</td>
<td>0.990</td>
</tr>
<tr>
<td>Liver disease</td>
<td>1.5</td>
<td>0.6</td>
<td>0.056</td>
</tr>
<tr>
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<tr>
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<td>1.0</td>
<td>5.0</td>
<td>&lt;0.001</td>
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<td>3.1</td>
<td>8.2</td>
<td>&lt;0.001</td>
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<td>Unplanned intubation</td>
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<td>&lt;0.001</td>
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<td>Rib fracture ≥3</td>
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<td>46.5</td>
<td>&lt;0.001</td>
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<td>Other</td>
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<tr>
<td>Tracheostomy</td>
<td>2.6</td>
<td>13.8</td>
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</tbody>
</table>

Values are presented as percentile unless otherwise indicated.

SSRF, surgical stabilization of rib fractures; NOP, nonoperative; SD, standard deviation; IQR, interquartile range; ICU, intensive care unit; LOS, length of stay.

and were more likely to have a flail segment (51.1% vs. 5.1%, P < 0.001). SSRF patients were significantly more likely to experience hospital-associated complications, including deep vein thrombosis (DVT) (5.2% vs. 1.1%), pneumonia (5.0% vs. 1.0%), unplanned ICU days (8.2% vs. 3.1%), and unplanned intubation (11.7% vs. 2.8%, P < 0.001).

Compared to NOP patients, SSRF patients had a longer median LOS (13 days vs. 5 days, P < 0.001), and they were admitted to the ICU for a mean of 7 days compared to 0 days (P < 0.001). SSRF patients were more likely to be placed on a ventilator (50.8% vs. 15.6%, P < 0.001). SSRF patients were more likely to undergo a tracheostomy (1.9% vs. 2.6%, P < 0.05). However, mortality was lower in SSRF patients (3.6% vs. 5.6%, P < 0.05). Furthermore, SSRF patients were significantly more likely than NOP patients to be discharged to an inpatient rehabilitation center (10.1% vs. 7.2%) or a skilled nursing facility (23.4% vs. 19.2%) than home (26.8% vs. 41.3%) (P < 0.001).

SSRF compared to nonoperative treatment in ≥80-year-old rib fracture patients

Of the 36,285 rib fracture patients who were ≥ 80 years of age, 224 underwent SSRF (0.67%). The median age was statistically similar between the patients who underwent SSRF and those who received NOP. The comorbidities were generally similar between both groups; however, patients who underwent SSRF were less likely to have a defined preexisting disability (10.7% vs. 18.26%, P = 0.001) or dementia (7.1% vs. 17.0%, P < 0.001) (Table 2).

As was seen in the 65- to 79-year-old age group, SSRF patients had significantly higher ISS (16.7 vs. 12.2, P < 0.001), were more likely to be admitted to the ICU (86.6% vs. 41.4%) and were more likely to have a flail segment (52.7% vs. 3.6%) (P < 0.01). Among the patients with three or more rib fractures, SSRF patients were more likely to suffer hospital-associated morbidities, including DVT (3.1% vs. 0.4%, P < 0.05), pneumonia (1.3% vs. 0.4%, P < 0.05), unplanned ICU admission (8.9% vs. 3.1%, P < 0.001), and unplanned intubation (9.4% vs. 2.0%, P < 0.001).

Octogenarian SSRF patients had a longer median hospital LOS (13 days vs. 5 days) and were admitted to the ICU for a median of 7 days compared to no ICU stays for NOP patients (P < 0.001). Furthermore, 40.2% of SSRF patients required ventilator support versus 10.2% of NOP patients (P < 0.001). Similar to patients aged 65 to 69 years, SSRF patients in the ≥ 80-year age group were significantly more likely to require tracheostomy (7.1% vs. 1.1%, P < 0.001). However, there was no significant difference in

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mortality between the SSRF and NOP groups (7.5% vs. 7.1%, P = 0.82).

SSRF compared to nonoperative treatment in 65- to 79-year-old patients with three or more rib fractures and LOS of 3 or more days

In total, 357 of 25,152 65- to 79-year-old patients with three or more rib fractures and LOS of 3 or more days underwent SSRF (1.4%). The median age was significantly different between patients who underwent SSRF and those who underwent NOP, with younger patients undergoing SSRF (70.6 years old vs. 71.5 years old, P < 0.001). There were no significant differences in the comorbidities reviewed between SSRF and NOP patients (P > 0.05), except that patients who underwent SSRF were less likely to have preexisting dementia (0.6% vs. 4.3%, P = 0.001) (Table 3).

In comparison to NOP patients, SSRF patients had significantly higher ISS (17.2 vs. 15.9, P = 0.002) and were more likely to be admitted to the ICU (86.3% vs. 55.7%, P < 0.001). SSRF patients were significantly more likely to experience hospital-associated complications, including DVT (4.8% vs. 1.5%), pneumonia (3.9% vs. 1.3%), unplanned ICU days (10.6% vs. 3.9%), and unplanned intubation (10.6% vs. 3.9%) (P < 0.001).

Furthermore, SSRF patients had a longer median LOS (12 days vs. 6 days, P < 0.001). SSRF patients were more likely to be placed on a ventilator (44.0% vs. 17.5%, P < 0.001) and to undergo a tracheostomy (12.3% vs. 3.5%, P < 0.001). However, there was no statistically significant difference in mortality (8.3% vs. 11.0%, P = 0.32).

SSRF compared to nonoperative treatment in ≥80-year-old patients with three or more rib fractures and LOS of 3 or more days

A total of 110 of 16,005 ≥ 80-year-old patients with three or more rib fractures and LOS of 3 or more days underwent SSRF (0.68%). The median age was not significantly different between patients who underwent SSRF and those who underwent NOP (83.6 years old vs. 84.3 years old, P = 0.03). There were no significant differences in the comorbidities reviewed between the SSRF and NOP patients (P > 0.05), except that patients who had SSRF were less likely to have preexisting dementia (6.4% vs. 17.9%, P = 0.002) (Table 3).

In comparison to NOP patients, SSRF patients had no significant difference in the ISS (15.0 vs. 14.1, P = 0.15) but were more likely to be admitted to the ICU (83.6% vs. 51.8%, P < 0.001). SSRF patients were significantly more likely to

Table 2. SSRF compared to NOP in ≥80-year-old rib fracture patients from 2016 to 2017

<table>
<thead>
<tr>
<th>Variable</th>
<th>NOP (n=36,285)</th>
<th>SSRF (n=224)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr), mean±SD</td>
<td>84.3±2.8</td>
<td>83.8±2.9</td>
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<tr>
<td>Injure Severity Score</td>
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<td></td>
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<tr>
<td>Mean±SD</td>
<td>12.2±8.2</td>
<td>16.7±9.0</td>
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</tr>
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<td>Median (IQR)</td>
<td>10 (9–14)</td>
<td>14 (10–21)</td>
<td>&lt;0.001</td>
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<td>ICU</td>
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<td>86.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mortality</td>
<td>7.5</td>
<td>7.1</td>
<td>0.820</td>
</tr>
<tr>
<td>Flail</td>
<td>3.6</td>
<td>52.7</td>
<td>&lt;0.001</td>
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<td>3–5</td>
<td>1.4</td>
<td>18.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>6</td>
<td>1.1</td>
<td>21.4</td>
<td>&lt;0.001</td>
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<td>Bilateral</td>
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<td>LOS (day), median (IQR)</td>
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<td>13 (9–18)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ICU LOS (day), median (IQR)</td>
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<td>7 (3–11)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Ventilator free (day), median (IQR)</td>
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<td>11 (8–15)</td>
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<td>Ventilator</td>
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<td>0.500</td>
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<tr>
<td>Dementia</td>
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<td>7.1</td>
<td>&lt;0.001</td>
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<td>Renal disease</td>
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<td>Smoker</td>
<td>3.3</td>
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<td>0.180</td>
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<td>Pulmonary embolus</td>
<td>0.3</td>
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<td>Deep vein thrombosis</td>
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</tr>
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<td>9.4</td>
<td>&lt;0.001</td>
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<td>Rib fracture ≥3</td>
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<td>50.5</td>
<td>0.620</td>
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<td>Destination (survivors)</td>
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<td>&lt;0.001</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Tracheostomy</td>
<td>1.1</td>
<td>7.1</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Values are presented as percentile unless otherwise indicated. SSRF, surgical stabilization of rib fractures; NOP, nonoperative; SD, standard deviation; IQR, interquartile range; ICU, intensive care unit; LOS, length of stay.
experience hospital-associated complications, including unplanned ICU days (9.1% vs. 4.0%, P = 0.01) and unplanned intubation (9.1% vs. 2.6%, P < 0.001). They were significantly more likely to experience DVT (2.7% vs. 1.0%, P = 0.06) and nonsignificantly more likely to have pneumonia (1.8% vs. 0.6%, P = 0.08).

SSRF patients had a longer median LOS (13 days vs. 6 days, P < 0.001) and were more likely to be placed on a ventilator (36.4% vs. 10.4%, P < 0.001). SSRF patients were not more likely to undergo tracheostomy (16.0% vs. 17.2%, P = 0.06). There was no significant difference in mortality (16.0% vs. 17.2%, P = 0.82).

**SSRF compared to nonoperative treatment in ≥65-year-old patients with three or more rib fractures, LOS of 3 or more days, and flail chest**

Sixty-six of 413 ≥65-year-old patients with three or more rib fractures, LOS of 3 or more days, and flail chest underwent SSRF (15.9%). The median age was not significantly different according to whether patients underwent SSRF or NOP (72.9 years old vs. 74.3 years old, P = 0.15). Diabetes was more prevalent in the SSRF patients (33.3% vs. 22.3%, P = 0.05) (Table 5).

Compared to patients who underwent NOP, SSRF patients had no significant difference in the ISS (22.6 vs. 22.0, P = 0.64) but were more likely to be admitted to the ICU (97.0% vs. 84.0%, P = 0.002). SSRF patients were not significantly more likely to experience hospital-associated complications, including unplanned ICU days (7.6% vs. 6.8%, P = 0.01), unplanned intubation (10.6% vs. 8.5%, P > 0.05), DVT (4.6% vs. 3.2%, P = 0.56), and pneumonia (7.6% vs. 5.1%, P = 0.41).

SSRF patients had a longer median LOS (15 days vs. 10 days, P < 0.01). SSRF patients were more likely to be placed on a ventilator (66.7% vs. 46.3%, P = 0.002) and were more likely to undergo tracheostomy (21.2% vs. 10.4%, P = 0.012). There was a significant difference in mortality (5.9% vs. 31.1%, P = 0.002).

**DISCUSSION**

SSRF, which is principally used in patients with flail chest, appears to be underutilized [13]. The recent Eastern Association for the Surgery of Trauma guidelines make a conditional recommendation for its use in flail chest and do not address the use of SSRF in nonflail patients, based on the available evidence at the time these recommendations were issued [6]. New literature, specifically the results from Pieracci et al. [7], suggest that a multitude of patients could potentially benefit from SSRF.

We identified over 93,638 patients older than 65 years of age who presented to a trauma center with rib fractures in 2016 to 2017. SSRF was performed at an overall rate of only 1.1%. Approximately 50% of the patients who underwent SSRF had flail...
chest (a widely accepted indication). Although mortality was lower in patients who underwent SSRF, all other metrics do not appear to suggest improved outcomes.

Patients who underwent SSRF in the 65- to 79-year-old age range had no significant differences in any preoperative comorbidities; however, they appeared to have a higher preinjury functional status, as they had fewer disability and dementia diagnoses. The SSRF cohorts for both age categories clearly had higher ISS, a higher likelihood of flail segments, more admissions to the ICU, longer median hospital LOS, and a higher likelihood of requiring ventilator assistance. Additionally, more of these patients progressed to tracheostomy. As would be expected due to longer hospital stays, patients in both age groups who underwent SSRF had a higher rate of hospital complications including DVT and pneumonia.

More importantly, the discharge destination for both age cohorts in patients who underwent SSRF was IPR. The lower rate of home discharges in SSRF patients was most likely due to the higher rate of IPR admissions.

Although the SSRF patients demonstrated higher morbidity and complication rates, it should be kept in mind that these patients were not truly a matched cohort to the NOP patients. More specifically, patients undergoing SSRF had significant chest wall injuries and were more severely injured, with mean and median ISS greater than 16. These patients most likely had longer hospital stays due to both the SSRF procedure and overall injury severity along with more in-hospital complications even in the presence of lower in-hospital mortality. The presence of higher ISS scores in this patient population clearly means that other organ systems were damaged, which in itself can lead to longer hospital and ICU stays, a longer period of ventilator use, and a higher risk of complications. Therefore, these variables seem to be related to a higher degree of patient complexity, rather than whether patients underwent SSRF. As seen in prior studies, there was a mortality benefit of SSRF, even though these patients had higher ISS scores, longer hospital LOS, and longer ICU LOS [8,9]. These data suggest that in patients selected for SSRF, the operation was performed as a last-ditch salvage effort. While survival improved, the overall outcomes were not of profound benefit, perhaps reflecting selection bias. Our data suggest that these geriatric patients are clearly severely injured.

However, in our subgroup analysis of patients with three or more rib fractures and flail chest, there were few significant differences in these parameters. Only ICU admission, need for ventilator support, and LOS remained significantly different between NOP and SSRF patients. Importantly, however, mortality was much more favorable in SSRF patients, despite their higher ISS scores, meaning they were more complex trauma patients. Nonetheless, they showed better mortality outcomes, even though there were more complications and longer hospital stays when SSRF was performed.

Upon further review of the NTDB from 2016 to 2017, we identified 36,065 patients in the 65- to 79-year-old age range, with rib fractures, who did not undergo SSRF. These patients had both flail chest (5,240 patients) and three or more rib fractures (30,824 patients). Additionally, our data showed that SSRF was only performed at a rate of 1.4% in patients with three or more rib fractures and a rate of 15.9% in patients with three or more rib fractures and flail chest, although both are widely accepted indications for SSRF. These data suggest that SSRF is underutilized, and that performing SSRF in better surgical candidates might lead to improved outcomes. Multiple studies have demonstrated benefits from a larger range of indications, and further demonstrated that age should not be a deterrent in patient selection. In fact, there is mounting evidence that patients with more comorbid conditions and less physiologic reserve stand to benefit most from surgical intervention [8,10,14]. As well, Pieracci et al. [7] demonstrated the benefit of SSRF in nonflail chest patients. They found that SSRF was beneficial for patients with lower ISS and even in patients with isolated rib fractures [7].

Large retrospective datasets have significant limitations. We in-
cluded all patients with three or more rib fractures, regardless of whether these rib fractures were displaced. We did this because it is difficult to tease out whether ribs were displaced using this large dataset. More precise data can be collected in the future if a prospective study is performed. Additionally, geriatric polytrauma patients with complex injury patterns, comorbid conditions, and frailty are challenging to analyze. We did not exclude traumatic brain injury patients nor early deaths (less than 24 hours), although early deaths were excluded from our subdata analysis. These factors could have drastically altered the mortality numbers, which warrants future study. More large multicenter prospective trials on SSRF in this patient population are needed.

In conclusion, we believe that SSRF should be considered in elderly polytrauma patients. Although this population has comorbid conditions and frailty, which make them poorer operative candidates and put them at high risk for mortality, these are specifically the patients who benefit most from SSRF. Although this analysis did not demonstrate mortality benefits in the over 80-year-old population, there is still a large cohort of individuals 65 to 79 years who had a mortality benefit from SSRF. More surgeons need to be trained in this procedure and more centers need to be developed with the resources to perform these operations. The wider application of SSRF deserves further study in a prospective multicenter study.

NOTES

Ethical statements
This study was approved by Internal Review Board of the St. Francis Medical Center (No. SFH-21-24). This study protocol was approved by the local Ethics Committee and conducted in accordance with the Declaration of Helsinki and Good Clinical Practices. Informed consent was waived due to the retrospective nature of this study.

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

Funding
None.

Author contributions
Conceptualization: VJ, MM, EJ, ARD; Data curation: EJ, ARD; Formal analysis: EJ; Methodology: EJ, ARD; Project administration: JMB, VJ, MM, ARD; Visualization: JMB, LA, VJ, ARD; Writing—original draft: JMB, LA, KS; Writing—review & editing: JMB, LA, VJ, MM, ARD.

All authors read and approved the final manuscript.

Additional information
The data of this study was presented at the 2021 Chest Wall Injury Submit in Denver, CO, USA.

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Initial assessment of hemorrhagic shock by trauma computed tomography measurement of the inferior vena cava in blunt trauma patients

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**Purpose:** Inferior vena cava (IVC) collapse is related to hypovolemia. Sonography has been used to measure the IVC diameter, but there is variation depending on the skill of the operator and it is difficult to obtain accurate measurements in patients who have a large amount of intestinal gas or are obese. As a modality to obtain accurate measurements, we measured the diameters of the IVC and aorta on trauma computed tomography scans and investigated the correlation between the IVC to aorta ratio and the shock index in blunt trauma patients.

**Methods:** We retrospectively analyzed the medical records of 588 trauma patients who were transferred to the regional trauma center (level 1) of Wonkwang University Hospital from March 2020 to February 2021. We included trauma patients 18 years or older who met the trauma activation criteria and underwent trauma computed tomography scans with intravenous contrast within 40 minutes of admission. The shock index was calculated from vital signs before trauma computed tomography scan, and measurements of the anteroposterior diameter of the IVC (AP), the transverse diameter of the IVC (T), and aorta were made 10 mm above the right renal vein in the venous phase.

**Results:** Overall, 271 patients were included in this study, of whom 150 had a shock index ≤0.7 and 121 had a shock index >0.7. The T to AP ratio and AP to aorta ratio were significantly different between groups. Cutoffs were identified for the T to AP ratio and AP to aorta ratio (2.37 and 0.62, respectively) that produced clinically useful sensitivity and specificity for predicting a shock index >0.7, demonstrating moderate accuracy (T to AP ratio: area under the curve, 0.71; sensitivity, 59%; specificity, 87% and AP to aorta ratio: area under the curve, 0.70; sensitivity, 55%; specificity, 91%).

**Conclusions:** The T to AP ratio and AP to aorta ratio are useful for predicting hemorrhagic shock in trauma patients.

**Keywords:** Injury Severity Score; Wounds and injuries; Splenectomy

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treatment of trauma patients. Hemodynamically unstable patients are rapidly transfused and intervened upon. However, in the absence of stage III or stage IV shock, the autoregulatory mechanisms of the body can readily compensate for volume depletion to maintain adequate blood pressure, pulse rate, and mental status. It is well-known that blood pressure is not decreased in states of shock until approximately 30% to 40% of the circulating blood volume has left the intravascular compartment [1]. In addition, the other signs of early shock (tachycardia, low blood pressure, pallor) may easily be overlooked or confounded by pain or anxiety, sympathetic surge, pharmaceutical and illicit drugs, and environmental factors in the trauma resuscitation room. Therefore, objective methods to diagnose early actual or impending shock following injury are needed.

The inferior vena cava (IVC) collapses with shock because of absolute or relative hypovolemia [2]. Sonography has been used effectively as a primary screening procedure upon hospital entry in mass casualty patients with trauma, with an average of 4 minutes for each patient [3]. It has been used to measure IVC diameter, but variation exists depending on the skill of the operator and it is difficult to obtain accurate measurements if the patient has a large amount of intestinal gas or is obese. Another limitation is that multiple sites cannot be measured at the same time.

Therefore, the authors measured the diameters of the IVC and descending aorta on computed tomography (CT) scans of blunt trauma patients, and indirectly assessed the volume of body fluid using the calculated ratio. The purpose of this study was to determine whether this method is useful for predicting hemorrhagic shock in blunt trauma patients.

**METHODS**

We retrospectively analyzed the medical records of 588 trauma patients who were transferred to the regional trauma center (level 1) of Wonkang University Hospital. This facility is a tertiary healthcare center with 796 beds and a referral center supporting a region with a population of approximately 300,000. The need for informed consent was exempted due to the retrospective nature of the study.

The criteria included trauma patients 18 years or older who met the trauma activation criteria and underwent trauma CT scans with intravenous contrast within 40 minutes of admission. The exclusion criteria included patients under 18 years; those with cardiopulmonary arrest on arrival, traumatic brain injury alone, or traumatic spinal cord injury alone; and those who did not receive a CT scan within 40 minutes (Fig. 1).

Emergency transfusion (ET) was defined as transfusion within 1 hour. The total transfusion amount was defined as the transfusion amount during 24 hours.

All trauma CT scans were performed with a 128-slice Stellar detector CT scanner (SOMATOM Definition Edge; Siemens, Washington, DC, USA). In our hybrid emergency room, it usually takes 5 to 10 minutes, including transfer and scanning with contrast medium, to perform CT scans in trauma patients. CT scans are typically performed within 40 minutes of arrival to the trauma center. Arterial and venous phase contrast-enhanced CT scans were reviewed. The anteroposterior diameter of the IVC (AP), the transverse diameter of the IVC (T), and aorta were measured 10 mm above the right renal vein in the venous phase (Fig. 2). AP corresponds to the smallest dimension of the IVC,

Fig. 1. Flow chart of the enrollment of study participants. CT, computed tomography.

Fig. 2. Axial view of abdominal computed tomography, 10 mm above the right renal vein in the venous phase. AP, anteroposterior diameter of the inferior vena cava; AO: aorta diameter; T, transverse diameter of the inferior vena cava.
and $T$ represents the largest dimension of the IVC. One chief resident of emergency medicine, who was blinded to patients’ vital signs and laboratory data, retrospectively reviewed each CT scan for the size of the IVC and aorta.

The following data were collected from patients’ medical records: age; sex; Injury Severity Score (ISS); vital signs, such as the mean arterial pressure (MAP), heart rate, respiratory rate, body temperature; calculated data, such as the shock index; measured data, such as the IVC diameter; laboratory data, such as hemoglobin, lactate, amount of ET, total amount of transfusion within 24 hours; and outcomes (length of intensive care unit admission and hospital stay).

Demographic factors, laboratory results, physiological variables, and resource use were summarized using descriptive statistics (Table 1). IBM SPSS ver. 26.0 (IBM Corp., Armonk, NY, USA) was used for statistical analyses. In multiple comparisons involving multiple variables, post hoc analysis was performed using the independent sample t-test and one-way analysis of variance. For continuous variables, the analysis was performed using the independent sample t-test and logistic regression analysis. A P-value < 0.05 was considered to indicate statistical significance.

**RESULTS**

In total, 588 patients suspected to have experienced major trauma who met the trauma activation criteria were admitted to our hospital during the study period. After applying the exclusion criteria, the 271 remaining patients were ultimately included in the analysis (Fig. 1). Of note, although the study protocol specified excluding patients with aortic aneurysms and aortic stenosis, there were no cases of prominent aortic aneurysms or aortic stenosis among the 588 patients.

Overall, 271 patients were included in this study, of whom 150 had a shock index $\leq 0.7$ and 121 had a shock index $>0.7$. There were no significant differences between the two groups

<table>
<thead>
<tr>
<th>Table 1. Patients’ demographic characteristics, laboratory results, physiological variables, and resource use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Sex</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Age (yr)</td>
</tr>
<tr>
<td>Injury Severity Score</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
</tr>
<tr>
<td>Heart rate (/min)</td>
</tr>
<tr>
<td>Respiratory rate (/min)</td>
</tr>
<tr>
<td>Body temperature (°C)</td>
</tr>
<tr>
<td>Shock index</td>
</tr>
<tr>
<td>$T$ (mm)</td>
</tr>
<tr>
<td>AP (mm)</td>
</tr>
<tr>
<td>T to AP ratio</td>
</tr>
<tr>
<td>Aorta diameter (mm)</td>
</tr>
<tr>
<td>AP to aorta ratio</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
</tr>
<tr>
<td>Emergency transfusion (&lt;1 hr) (unit)</td>
</tr>
<tr>
<td>Total PRC pack (24 hr) (unit)</td>
</tr>
<tr>
<td>MAP to performed CT scan (mmHg)</td>
</tr>
<tr>
<td>Time to performed CT scan (min)</td>
</tr>
<tr>
<td>Total fluid volume for resuscitation (mL)</td>
</tr>
<tr>
<td>ICU admitted days</td>
</tr>
<tr>
<td>Total hospital days</td>
</tr>
</tbody>
</table>

Values are presented as number (%) for categorical variables and mean (range) for continuous variables.

MAP, mean arterial pressure; $T$, transverse diameter of the inferior vena cava; AP, anteroposterior diameter of the inferior vena cava; PRC, packed red cells; CT, computed tomography; ICU, intensive care unit.
in age, sex, respiratory rate, body temperature, aorta diameter, hemoglobin, or time until the CT scan was performed. Significant differences between the two groups were observed in ISS, MAP, heart rate, shock index, T, AP, the T to AP ratio, the AP to aorta ratio, lactate, ET amount, total amount of transfusion within 24 hours, MAP, total fluid volume for resuscitation, length of intensive care unit admission days, and length of hospital stay (Table 1).

The T to AP ratio and AP to aorta ratio were significantly different between the groups. We also examined the sensitivity and specificity of the cutoff of a shock index > 0.7 in predicting IVC collapse via a cutoff point analysis. Cutoffs were identified for the T to AP ratio and AP to aorta ratio that produced clinically useful sensitivity and specificity for predicting a shock index > 0.7 (Table 2).

We performed a receiver operating characteristic curve analysis and calculated the area under the curve (AUC) to clarify which factor was the most useful predictor for shock (Fig. 3). Table 2 shows the respective AUCs, cutoff levels, sensitivities, and specificities for predicting shock. The cutoff of 2.37 for the T to AP ratio demonstrated moderate accuracy (AUC, 0.71; sensitivity, 59%; specificity, 87%), and a cutoff of 0.62 for the AP to aorta ratio likewise demonstrated moderate accuracy (AUC, 0.70; sensitivity, 55%; specificity, 91%).

We compared multiple indices according to the cutoff levels of the T to AP ratio and AP to aorta ratio. Significant differences between the two groups defined using these cutoff points were observed in ISS, MAP, heart rate, shock index, ET amount (within 1 hour), total amount of transfusion within 24 hours, total fluid volume for resuscitation, length of intensive care unit stay, and length of hospital stay (Table 3).

**DISCUSSION**

The detection of occult shock and impending shock in trauma patients who arrive with normal vital signs following injury remains difficult. In an earlier study, an T to AP ratio > 2.5 on CT was defined as a flat IVC, which was found to be useful as a marker for measuring occult shock or hypoperfusion [4]. Another study of 114 patients found that an T to AP ratio of 4:1 was associated with shock [5].

Given that the majority of trauma patients with stable or transient unstable vital signs undergo CT scans, we sought to determine whether the static T to AP ratio and AP to aorta ra-

---

**Table 2. Receiver operating characteristic curve analysis**

<table>
<thead>
<tr>
<th>Variable</th>
<th>AUC</th>
<th>Standard error</th>
<th>Optimal cutoff</th>
<th>P-value</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>T to AP ratio</td>
<td>0.71</td>
<td>0.032</td>
<td>2.37</td>
<td>&lt;0.001</td>
<td>0.59</td>
<td>0.87</td>
</tr>
<tr>
<td>AP to aorta ratio</td>
<td>0.70</td>
<td>0.033</td>
<td>0.62</td>
<td>&lt;0.001</td>
<td>0.55</td>
<td>0.91</td>
</tr>
</tbody>
</table>

AUC, area under the curve; T, transverse diameter of the inferior vena cava; AP, anteroposterior diameter of the inferior vena cava.

---

**Fig. 3.** Receiver operating characteristic curve of (A) transverse diameter of the inferior vena cava to anteroposterior diameter of the inferior vena cava ratio and (B) anteroposterior diameter of the inferior vena cava to aorta ratio.
on trauma CT scans are associated with hemorrhagic shock, the need for emergency blood transfusion, total fluid volume for resuscitation, length of hospital stay, or other relevant factors.

The IVC is a highly compliant vessel, the size and dynamics of which vary with changes in total body water and respiration. Although conflicting results have been published about respiration-related variations in the ultrasonographic appearance of the IVC, most authors have stated that the caliber of the normal IVC diminishes with inspiration and increases during expiration [6].

The physical examination findings and vital signs of trauma patients are often unreliable for several reasons [7]. The unreliability of physical and laboratory evaluations combined with a lack of history and patient cooperation due to serious injury or an altered level of consciousness makes the clinical assessment of blood loss in these patients a difficult task. These uncertainties can potentially lead to inappropriate resuscitation—either too little or too much [8]. Measurement of the IVC diameter, therefore, can be a very useful way to evaluate the patient’s hemodynamic status [3]. In recent years, trauma centers have been rapidly performing early CT scans to assess organ damage. These scans are also useful to check along with other shock parameters since measurements of the IVC diameter are helpful for predicting shock even before confirmation of hemoglobin decrease, lactate increase, or metabolic acidosis.

The presence of shock was assessed using the shock index. Because of the known lack of sensitivity of blood pressure as a predictor of shock, we opted to examine the correlation between the IVC ratio and the shock index. A shock index ≥ 0.7 is associated with a 20% likelihood of needing massive transfusion, and an increasing shock index has been shown to be directly proportional to worsening base deficit, ISS, and mortality risk [9–11].

An advantage of sonography is that it can be performed repeatedly as a noninvasive modality, but CT scans can detect the IVC more easily than sonography because bowel air and abdominal fat impair acoustic penetration, resulting in poorer image quality. In addition, it is difficult to attach the sonographic probe to an open wound of the abdominal wall. As a result, the use of sonography is limited for patients who are obese and those who have a full stomach or an open abdominal wound [12].

The T to AP ratio measured on CT scans was significantly elevated in patients with a shock index > 0.7, and AP to aorta ratio was significantly lower in those shock index > 0.7. In some exceptional cases, the IVC and aorta diameter did not correlate with the shock index due to fluid loading after insertion of a central line into the femoral vein or injury to a vein derived from the IVC (renal vein, lumbar vein, etc.) (Fig. 4). In a similar study, no correlation was found between IVC size and shock [11]. However, CT scans were not performed quickly in that study (in contrast to the mean interval of 13.2 minutes in our study) and CT scans were not performed in patients with unstable vital signs in this study.

At the university hospital where the study was conducted, if necessary, within 60 minutes of the patient’s arrival, an ET of up to four units of red blood cells (type O) and four units of fresh frozen plasma, regardless of the patient’s blood type, is performed. Similar to a previous study on the correlation between IVC and massive transfusion, fluid loading was significantly greater and emergency transfusions were significantly more

### Table 3. Comparison of multiple indices according to the cutoffs of the T to AP ratio and AP to aorta ratio

<table>
<thead>
<tr>
<th>Variable</th>
<th>T to AP ratio</th>
<th>AP to aorta ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;2.37 (n=166)</td>
<td>≥2.37 (n=105)</td>
</tr>
<tr>
<td></td>
<td>≥0.62 (n=174)</td>
<td>&lt;0.62 (n=97)</td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>17.7 (15.9–19.4)</td>
<td>2.9 (22.9–26.9)</td>
</tr>
<tr>
<td>Mean arterial pressure (mmHg)</td>
<td>96.5 (93.5–99.6)</td>
<td>74.5 (70.1–78.8)</td>
</tr>
<tr>
<td>Shock index</td>
<td>0.69 (0.65–0.72)</td>
<td>0.96 (0.87–1.04)</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
<td>28.5 (24.7–32.3)</td>
<td>32.5 (25.1–37.8)</td>
</tr>
<tr>
<td>Emergency transfusion (&lt;1 hr)</td>
<td>0.27 (0.16–0.37)</td>
<td>0.98 (0.44–1.19)</td>
</tr>
<tr>
<td>Total PRC pack (24 hr) (unit)</td>
<td>0.64 (0.41–0.87)</td>
<td>2.89 (2.27–3.50)</td>
</tr>
<tr>
<td>Total fluid volume for resuscitation (mL)</td>
<td>44.0 (14–74)</td>
<td>281.0 (194–368)</td>
</tr>
<tr>
<td>ICU admitted days</td>
<td>3.9 (2.9–4.9)</td>
<td>7.9 (5.5–10.3)</td>
</tr>
<tr>
<td>Total hospital days</td>
<td>17.9 (14.9–20.8)</td>
<td>28.3 (24.0–33.8)</td>
</tr>
</tbody>
</table>

Values are presented as mean (95% confidence interval). T, transverse diameter of the inferior vena cava; AP, anteroposterior diameter of the inferior vena cava; MAP, mean arterial pressure; PRC, packed red cells; ICU, intensive care unit.
common in patients with a shock index > 0.7, and the AP/aorta index was low in these patients [13] (Fig. 5).

The T to AP ratio showed a relatively high correlation with lactate in patients with an T to AP ratio ≥ 2.37, but lactate levels were not checked in all trauma patients and this association did not show statistical significance (P = 0.396) (Table 3).

The shock index showed a relatively high correlation with the ISS in patients with a shock index > 0.7, but the relevance of this finding is limited since the ISS score does not reflect only hemorrhagic shock (Fig. 6).

Other studies have reported significant correlations between the IVC/aortic index and central venous pressure or body fluid volume as evaluated through CT or ultrasound is significant [14–16]. In comparison with the previous study, this study compared the correlations between the results (central venous pressure, IVC/aorta index) on rapid CT scans in patients with unstable vital signs. However, this was a retrospective study, and in the trauma bay, central venous pressure measurements were not performed before transferring patients to the operating room or ward, limiting the comparison of correlations. Another study found significant results for the correlation between prognosis and IVC measurements in patients with septic shock; therefore, we conducted a similar comparative analysis in trauma patients [17]. However, in cases of minor trauma or limb fractures, re-
gardless of the patient’s severity, the length of hospital stay in-
creased due to complications such as infection or rehabilitation
period. Therefore, it would be difficult to say that there was a sig-
nificant correlation in all trauma patients.

This study had several limitations. First, it was a retrospective
cohort study conducted at a single center, which introduced po-
tential selection bias. Moreover, uncontrolled confounding fac-
tors may have existed. Second, factors that affect the IVC size,
such as positive end-expiratory pressure during CT, were not
evaluated because of the nature of the retrospective study. Third,
the study cohort mostly consisted of blunt trauma patients, and
the results may not be applicable to patients with penetrating
trauma. Finally, the cohort in this study was relatively small. For
these reasons, as well as given the results of previous studies, fur-
ther study will be required.

In conclusion, the T to AP ratio and AP to aorta ratio were
found to correlate with hemorrhagic shock in blunt trauma pa-
tients. Therefore, measurements of IVC size and aorta diameter
on trauma CT scans for trauma patients to calculate the T to AP
ratio and AP to aorta ratio are clinically relevant and can be used
to predict shock or rapid transfusion.

NOTES

Ethical statements
The need for informed consent was exempted due to the retro-
spective nature of the study.

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

Funding
None.

Author contributions
Conceptualization: JWC; Data curation: GHL; Formal analysis:
JWC; Methodology: JWC; Project administration: JWC; Writ-
ing—original draft: all authors; Writing—review & editing: all au-
thors.
All authors read and approved the final manuscript.

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Could the Injury Severity Score be a new indicator for surgical treatment in patients with traumatic splenic injury?

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Purpose: The purpose of this study was to determine whether a higher Injury Severity Score (ISS) could serve as an indicator of splenectomy in patients with traumatic splenic lacerations.

Methods: A total of 256 cases of splenic laceration were collected from January 1, 2005 to December 31, 2018. After the application of exclusion criteria, 105 were eligible for this study. Charts were reviewed for demographic characteristics, initial vital signs upon presentation to the emergency room, Glasgow Coma Scale, computed tomography findings, ISS, and treatment strategies. The cases were then divided into nonsplenectomy and splenectomy groups for analysis.

Results: When analyzed with the chi-square test and t-test, splenectomy was associated with a systolic blood pressure lower than 90 mmHg, a Glasgow Coma Scale score lower than 13, active bleeding found on computed tomography, a splenic laceration grade greater than or equal to 4, and an ISS greater than 15 at presentation. However, in multivariate logistic regression analysis, only active bleeding on computed tomography showed a statistically significant relationship (P=0.014).

Conclusions: Although ISS failed to show a statistically significant independent relationship with splenectomy, it may still play a supplementary role in traumatic splenic injury management.

Keywords: Spleen laceration; Injury Severity Score; Trauma; Splenectomy

INTRODUCTION

Splenic lacerations are among the most common trauma-related injuries that may require surgery [1]. According to the World Society of Emergency Surgery classification and guidelines on splenic trauma, the anatomy of the injury, hemodynamic status, anatomic derangement, and associated injuries should be considered in treatment strategies. Occasionally, splenic laceration patients are treated with splenectomy. However, with medical advances, more patients are treated without surgery when hemodynamically stable.

In cases of splenic laceration without surgery, complications such as delayed subcapsular hematoma, pseudoaneurysm rupture, and splenic abscess may occur. However, overwhelming...
postsplenectomy infections may result after surgical management and can be fatal in up to 50% of cases [2].

The Injury Severity Score (ISS) is used to assess trauma patients through an anatomical evaluation of multiple injuries in six body parts. A higher ISS is associated with higher mortality [3]. Since ISS is associated with mortality, it is used worldwide to evaluate the severity of trauma patients. According to Rosati et al. [4], traumatic splenic laceration patients undergoing splenectomy have a higher ISS, as well as higher morbidity and mortality rates, than patients successfully managed without surgery. A study on pediatric trauma patients concluded that the ISS was the best predictor of the length of hospital stay and the need for surgery [5]. This study aimed to identify whether a higher ISS could be a new indicator of splenectomy in patients with traumatic splenic laceration.

**METHODS**

The study was approved by the Institutional Review Board of the Inje University Ilsan Paik Hospital (No. 2021-02-008). Informed consent was waived due to the retrospective nature of the study. In this retrospective, single-center study, patients with splenic laceration were searched from January 1, 2005 to December 31, 2018. Among 256 patients, 74 nontraumatic cases were excluded, as were the cases that required immediate laparotomy due to other causes besides splenic injury. In total, 105 patients were eligible for this study (Fig. 1).

Chart review was conducted to extract data on patients’ demographics, hemodynamic parameters at initial presentation, Glasgow Coma Scale (GCS), focused assessment with sonography for trauma findings if performed, computed tomography (CT) findings, ISS, and treatment modalities (surgery, embolization, or observation).

The patients were divided into nonsplenectomy and splenectomy groups. Total splenectomy was performed in all cases involving a surgical intervention. There were no cases of partial splenectomy, splenorrhaphy, or even simple bleeding control with cauterization.

The initial vital signs were considered unstable when the systolic blood pressure (SBP) was lower than 90 mmHg or the GCS was lower than 13. CT findings included active bleeding and the American Association for the Surgery of Trauma (AAST) splenic laceration grade. The ISS was calculated according to the Abbreviated Injury Scale updated in 2008. Out of the six body parts, the three parts with the highest assigned injury scores were squared and added together.

The data were analyzed with IBM SPSS ver. 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean values and standard deviations and analyzed using the t-test. Categorical data were expressed as numbers and percentages and analyzed using the chi-square test. Statistically meaningful factors from the univariate analysis were reanalyzed in multivariate logistic regression to identify independent indicators for splenectomy. A P-value ≤ 0.05 was considered to indicate statistical significance.

**RESULTS**

This study compared 105 patients according to whether they

<table>
<thead>
<tr>
<th>Variable</th>
<th>Nonsplenectomy</th>
<th>Splenectomy</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>40.26±19.45</td>
<td>39.93±15.48</td>
<td>0.936</td>
</tr>
<tr>
<td>&gt;55</td>
<td>20 (25.6)</td>
<td>3 (11.1)</td>
<td>0.176</td>
</tr>
<tr>
<td>Male sex</td>
<td>59 (75.6)</td>
<td>18 (66.7)</td>
<td>0.363</td>
</tr>
<tr>
<td>SBP &lt;90 mmHg</td>
<td>7 (9.0)</td>
<td>8 (29.6)</td>
<td>0.921</td>
</tr>
<tr>
<td>GCS score</td>
<td>14.40±2.23</td>
<td>13.22±3.31</td>
<td>0.065</td>
</tr>
<tr>
<td>&lt;13</td>
<td>8 (10.3)</td>
<td>9 (33.3)</td>
<td>0.012</td>
</tr>
<tr>
<td>FAST&lt;sup&gt;a&lt;/sup&gt; (+)</td>
<td>2 (50.0)</td>
<td>3 (75.0)</td>
<td>0.462</td>
</tr>
<tr>
<td>Computed tomography (+)&lt;sup&gt;c&lt;/sup&gt;</td>
<td>20 (25.6)</td>
<td>22 (81.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Splenic laceration grade</td>
<td>2.71±1.06</td>
<td>3.78±1.05</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>≥4</td>
<td>18 (23.1)</td>
<td>19 (70.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>18.56±10.74</td>
<td>30.56±10.66</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&gt;15</td>
<td>39 (50.0)</td>
<td>26 (96.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Embolization</td>
<td>0</td>
<td>1 (3.7)</td>
<td>0.257</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation or number (%). SBP, systolic blood pressure; GCS, Glasgow Coma Scale; FAST, focused assessment with sonography for trauma.

<sup>a</sup>Due to the small number of FAST performed, it was not feasible to draw any conclusion regarding the association between positive FAST result and splenectomy. <sup>c</sup>Free intraperitoneal fluid in trauma patients.

<sup>c</sup>Computed tomography finding revealed active bleeding.
were managed without splenectomy ($n = 78$) or underwent splenectomy ($n = 27$). In the univariate analysis results shown in Table 1, the mean ages of patients were similar between the two groups (40.26 years in the non-splenectomy group and 39.93 years in the splenectomy group). In the non-splenectomy group, there was a higher proportion of patients older than 55 years (25.64%) than in the splenectomy group (11.11%), but this difference was not statistically significant. In both groups, the majority of patients were male (75.64% and 66.67%, respectively), and the between-group difference in sex distribution was not statistically significant.

Significantly more patients in the splenectomy group had an SBP lower than 90 mmHg upon presentation ($P = 0.021$): seven of the 78 patients (8.97%) in the non-splenectomy group versus eight of the 27 patients (29.63%) in the splenectomy group. The average GCS score was 14.40 in the non-splenectomy group and 13.22 in the splenectomy group. When an analysis was conducted according to whether the GCS score was lower than 13, the two groups showed a statistically significant difference. Specifically, 10.26% of patients in the non-splenectomy group had GCS scores lower than 13, while this was the case for 33.33% of the patients in the splenectomy group ($P = 0.012$).

The splenectomy group had significantly more patients with active bleeding on CT (25.64% vs. 81.48%, $P < 0.001$). The average AAST grade of the non-splenectomy group was 2.71, while that of the splenectomy group was 3.78. The proportion of patients with a splenic laceration grade greater than or equal to 4 showed a statistically significant difference between the two groups (23.08% vs. 70.37% $P < 0.001$).

The proportion of patients with an ISS greater than 15 was significantly different between the two groups: 39 of the 78 patients (50.00%) in the non-splenectomy group versus 26 of the 27 patients in the splenectomy group ($P = 0.014$).

In the univariate analysis, an SBP lower than 90 mmHg, GCS score lower than 13, active bleeding on CT, splenic laceration grade greater than or equal to 4, and ISS greater than 15 were factors that showed statistically significant relationships with splenectomy. Multivariate logistic regression analysis was performed with these factors (Table 2). Only positive CT findings showed a statistically significant ($P = 0.014$) independent relationship for determining splenectomy.

### DISCUSSION

The decision to perform splenectomy in trauma patients is important because of complications that might develop later in their clinical course. This study attempted to identify whether the ISS could serve as a new indicator of splenectomy to improve the management of multiple trauma patients.

When choosing management without surgery, patients’ age was traditionally an important factor. Patients older than 55 years were believed to have a higher rate of failure in nonsurgical management. Thus, older patients were likely to be excluded from conservative management. In this study, however, patients older than 55 years were successfully managed without surgery. This finding could be attributed to medical advances in treating trauma patients over the past decades [6–9]. Unlike the older age group, there is a tendency to attempt to salvage the spleen in pediatric patients. However, in this study, pediatric patients were not included.

Splenectomy with hemodynamic instability is a well-known factor for failure of nonsurgical management, eventually leading to splenectomy [10,11]. Hemodynamic instability, represented by an SBP lower than 90 mmHg in this study, was also considered a statistically significant factor associated with splenectomy. When choosing management without surgery, patients’ age was traditionally an important factor. Patients older than 55 years were believed to have a higher rate of failure in nonsurgical management. Thus, older patients were likely to be excluded from conservative management. In this study, however, patients older than 55 years were successfully managed without surgery. This finding could be attributed to medical advances in treating trauma patients over the past decades [6–9]. Unlike the older age group, there is a tendency to attempt to salvage the spleen in pediatric patients. However, in this study, pediatric patients were not included.

The GCS score is a readily accessible parameter since it is routinely recorded in trauma patients. The GCS score could be affected both by hemodynamic instability and traumatic brain injury. To preclude any possible confusion, patients with a low GCS score due to brain injury were excluded. In this study, a GCS score lower than 13 was associated with a significantly higher risk of splenectomy. However, according to Poletti et al. [12], patients with a GCS above 13 still had major abdominal injuries that would require surgery or embolization. Thus, it is questionable whether the GCS score should be used as a factor informing the choice of traumatic splenic injury management.

Zarzaur et al. [13] and Schurr et al. [14] demonstrated that active bleeding on abdominal CT observed upon presentation was a strong predictor of splenectomy. Through multivariate logistic regression analysis, this study also revealed that significantly more patients in the splenectomy group had active bleeding on abdominal CT observed upon presentation, which was strongly associated with splenectomy. Therefore, the GCS score and CT findings were independently associated with splenectomy in this study.

### Table 2. Multivariable logistic regression analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio</th>
<th>95% Confidence interval</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP &lt;90 mmHg</td>
<td>3.353</td>
<td>0.666–16.894</td>
<td>0.143</td>
</tr>
<tr>
<td>GCS score &lt;13</td>
<td>0.737</td>
<td>0.100–5.417</td>
<td>0.764</td>
</tr>
<tr>
<td>Computed tomography (+)</td>
<td>4.909</td>
<td>4.909–17.395</td>
<td>0.014</td>
</tr>
<tr>
<td>Splenic laceration grade ≥4</td>
<td>2.252</td>
<td>0.671–7.550</td>
<td>0.189</td>
</tr>
<tr>
<td>Injury Severity Score &gt;15</td>
<td>6.831</td>
<td>0.726–64.236</td>
<td>0.930</td>
</tr>
</tbody>
</table>

SBP, systolic blood pressure; GCS, Glasgow Coma Scale.
bleeding found on CT. However, Omert et al. [15] demonstrated that contrast extravasation alone was not an absolute indication for surgical or angiographic intervention. In another study, Teuben et al. [16] concluded that even with contrast extravasation on CT, hemodynamically stable splenic laceration patients could be managed without surgery in the absence of a concomitant hollow organ injury. Though it is important to obtain objective information on a patient’s medical condition through laboratory or imaging tests, the clinical presentation should always be taken into consideration.

Previous studies on splenic injury demonstrated that higher-grade splenic injuries are predictors of the failure of nonsurgical management. These patients should not be discharged early for further observation [17–19]. According to Olthof et al. [19] and McIntyre et al. [7], nonsurgical management was prone to fail for patients with an injury grade of 3 or more and a higher ISS (> 25). Likewise, in this study, significantly more patients in the splenectomy group had a splenic laceration grade greater than or equal to 4.

In 1987, Boyd et al. [20] established that an ISS greater than 15 could serve as a threshold to indicate a severe injury, being predictive of 10% mortality. Therefore, the ISS threshold was set at 15 for this study. However, an ISS greater than 15 may correspond to a sole splenic injury with a score greater than 4 or multiple trauma injuries including splenic injury. In order to clarify any possible confusion, sole spleen injury patients were excluded, leaving multiple trauma patients only. Peitzman et al. [21] demonstrated that patients with ISS greater than 15 were significantly more likely to undergo surgery and experience failure of nonsurgical management. Thus, they examined the ISS as a new predictor of splenectomy in the management of splenic lacerations. In a pediatric trauma study, Potoka et al. [22] demonstrated that patients who underwent splenectomy were more likely to have an ISS greater than 15. However, hemodynamic instability—a well-established factor for surgical management—did not show a statistically significant association with splenectomy in their study. A possible explanation is that surgeons who conducted splenectomy considered only the ISS, but not patients’ hemodynamic status when deciding upon a treatment strategy. This demonstrates the importance of validating a factor before utilizing it in a management protocol since it may lead to inadequate management.

At first, the ISS seemed promising as a new indicator of surgery in splenic injury management. However, the statistical significance of the ISS did not remain in the multivariate logistic regression analysis. Thus, the ISS alone may not function as an indicator of splenectomy in trauma patients. However, a point to consider is that patients with an ISS greater than 15 had a tendency for active bleeding on CT (P < 0.001) and high-grade splenic laceration (P < 0.001), and were more likely to undergo splenectomy (P < 0.001) (Table S1). Although the ISS was not proven to be suitable as a new indicator of splenectomy, it can still serve as a supplementary factor to improve the management of traumatic splenic lacerations.

Due to the development of radiologic interventions, embolization could be a possible solution for patients with active bleeding who are nonetheless hemodynamically stable [23]. In this study, there was only one case of embolization. However, this patient later developed splenic abscess and eventually underwent splenectomy (one out of 27, P = 0.257). To establish a management protocol, including embolization as a possible approach in Inje University Ilsan Paik Hospital, more recent data are needed. In addition, long-term follow-up and complications should be recorded to evaluate the most appropriate treatment strategy for patients with splenic lacerations.

This study has some limitations. Even though multiple trauma patients may deteriorate at any given time, the hemodynamic instability recorded was represented with only the initial vital signs at the lowest point observed during the emergency room stay. Another limitation relates to the study design involving retrospective chart review. The ISS was also calculated only based on the recorded data and radiologic exams performed at the time of admission. Since this was a retrospective study, trauma patients were not thoroughly examined for the purpose of ISS evaluation on presentation. However, a prospective randomized control study on trauma patient management based on the ISS alone may lead to ethical issues. Due to the rarity of embolization, the effects of angiographic interventions could not be analyzed in this study.

The purpose of this study was to identify whether the ISS could serve as an indicator for splenectomy, thereby helping to reduce any possible complications. Further research is warranted with more recent data, including embolization cases and the treatment outcomes with long-term outpatient data.

In conclusion, in this study, a higher ISS alone did not show significant relevance to splenectomy in cases of traumatic splenic laceration. Although the ISS was not confirmed as a new indicator of splenectomy, it may still play a supplementary role in traumatic splenic injury management.
SUPPLEMENTARY MATERIALS

Table S1. Univariate analysis using ISS as independent factor
Supplementary materials are available from: https://doi.org/10.20408/jti.2021.0065.

NOTES

Ethical statements
The study was approved by the Institutional Review Board of the Inje University Ilsan Paik Hospital (No. 2021-02-008). Informed consent was waived due to the retrospective nature of the study.

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

Funding
None.

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

REFERENCES


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The impact of COVID-19 on trauma patients and orthopedic trauma operations at a single focused training center for trauma in Korea

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Purpose: The objective of this study was to determine the effects of coronavirus disease 2019 (COVID-19) on the volume of trauma patients, the number of orthopedic trauma operations, and the severity of injuries. We also investigated the correlations between social distancing and these variables.

Methods: This was a retrospective review of trauma patient cases at a single focused training center for trauma in Korea from January 2017 to April 2021. The COVID-19 group included patients treated from January 1 to April 30 in 2020 and 2021, and the control group included patients treated during the same months from 2017 to 2019. The volume of trauma patients according to the level of social distancing was evaluated among patients treated from August 2, 2020 to November 23, 2020.

Results: The study included 3,032 patients who presented to the emergency department with traumatic injuries from January to April 2017 to 2021. The average number of patients was 646.7 and 546.0 in the control and COVID-19 groups, respectively. The percentage of patients injured in traffic accidents (TAs) decreased from 25.0% to 18.2% (P<0.0001). The proportions of in-car TAs and pedestrian TAs also decreased from 6.7% and 10.8% to 3.5% and 6.0%, respectively (P=0.0002 and P<0.0001). The percentage of bicycle TAs increased from 2.4% to 4.0% (P=0.0128). The proportion of patients with an Injury Severity Score above 15 and the mortality rate did not change significantly.

As the level of social distancing increased, the number of trauma patients and the number of trauma injuries from TAs decreased. The number of orthopedic trauma operations also depended on the social distancing level.

Conclusions: The number of trauma patients presenting to the emergency department decreased during the COVID-19 period. The volume of trauma patients and orthopedic trauma operations decreased as the social distance level increased.

Keywords: Epidemiology; COVID-19; Trauma; Incidence; Physical distancing
INTRODUCTION

Coronavirus disease 2019 (COVID-19) is caused by severe acute respiratory syndrome coronavirus-2, which was first reported in December 2019 in Wuhan, China [1]. The disease spread rapidly around the world and was declared a pandemic by the World Health Organization on March 11, 2020 [2]. The first case in Korea was reported on January 20, 2020 [3]. Currently, almost 270,000 people have been infected in Korea [4]. The spread of the disease has severely altered people's daily lives, as well as the economy and healthcare system.

The incidence of traumatic injuries is influenced by several factors, including the environment and outbreaks of contagious diseases [5–7]. To control the spread of COVID-19, many countries implemented lockdown and/or social distancing policies. In Korea, the government restricted private gatherings according to the number of people with time limitations. In addition, sports facilities and restaurants were closed after designated hours. Social distancing in Korea was divided into three levels and was revised to four levels from July 1, 2020. Level 4 is defined as a pandemic, when the national quarantine system has reached its limit; people are advised to stay home as much as possible, and only private meetings of up to two people are allowed after 6 PM [4].

The effects of COVID-19 on the volume of trauma patients in several countries have been reported [8–10]. The pandemic has altered the needs and provision of health care throughout the world. As a result of restrictive social measures, such as lockdown or social distancing, the incidence of crimes and traffic accidents (TAs) decreased sharply [11]. The aim of this study was to determine the impact of the pandemic and social distancing policies on the volume of trauma patients at our trauma center. We hypothesized that the COVID-19 pandemic reduced the volume of trauma patients and that taking restrictive actions affected the number of patients who presented to the emergency department due to traumatic injuries.

METHODS

Ethical statements

The protocol of the study was reviewed and permission to use data from the Korea Trauma Data Bank (KTDB) and patients’ medical charts was obtained from the Institutional Review Board of Korea University Guro Hospital (No. 2021GR0430). The Institutional Review Board waived the requirement for obtaining informed consent because the study was designed to review existing records.

Study design and setting

An observational retrospective analysis using the KTDB and our hospital’s trauma registry was conducted. Our hospital is located in the southwest region of the capital of Korea, with a population of over 9.5 million people. The hospital is a regional emergency center and is designated as a focused training center for trauma with 1,053 beds. It receives around 2,000 trauma patients per year and about 1,500 patients are admitted. In March 2014, our hospital established an urgent treatment processing system to promote quick and effective trauma management. Patients presenting to the emergency department at our institution from January to April in 2017 to 2021 were included in the analysis. The COVID-19 group included patients who arrived at the emergency department from January 1 to April 30 of 2020 and 2021, and the control group included patients who arrived at the emergency department during the same months in 2017 to 2019.

Data collection

The collected variables included the age and sex of patients, mechanism of injury, time of arrival at the emergency department, Injury Severity Score (ISS), treatment with orthopedic surgery, and mortality. Orthopedic trauma operations were performed by orthopedic trauma surgeons affiliated with our hospital’s trauma center. To analyze the effects of social distancing, periods of 14 consecutive days starting from August 2, 2020 to November 23, 2020 were compared. In these periods, the level of social distancing was elevated, lowered, or remained the same. The total number of patients, the number of TA patients, the number of orthopedic trauma operations, the number of patients with an ISS above 15, and mortality were compared.

Statistical analysis

The chi-square test was used to compare variables between the COVID-19 group and the control cohort. Poisson regression analysis was used to compare trauma incidence and other variables among different social distancing levels. SAS ver. 9.4 (SAS Institute, Cary, NC, USA) was used to analyze the data. A P-value less than 0.05 was considered to indicate statistical significance.

RESULTS

The demographic characteristics of the patients are shown in Table 1. The total number of patients was 3,032, including 1,752 male patients (51.8%) and 1,280 female patients (42.2%). The distribution of patients by sex was not statistically different (P = 0.356). The average numbers of patients per year in the con-
The average number of patients decreased by 15.6% in the COVID-19 group compared with the number of patients in the control group. The mean age of the patients was 54.9 ± 21.9 years.

A comparison of injury mechanisms between the two groups is shown in Table 2. The percentage of patients with TAs decreased from 25.0% in the control group to 18.2% in the COVID-19 group (P < 0.0001). The proportions of patients with in-car TAs and pedestrian TAs decreased from 6.7% to 3.5% and 10.8% to 6.0%, respectively (P = 0.0002 and P < 0.0001). In contrast, the percentage of patients injured in bicycle TAs increased from 2.4% in the control group to 4.0% in the COVID-group (P = 0.0128). The percentage of motorcycle accidents did not differ significantly between the two groups (5.2% and 4.8%, respectively, P = 0.6343). Injuries from slips, falls, or injuries by machines at the workplace did not show statistically significant differences between the two groups.

Table 3 presents a comparison of the percentage of patients with an ISS above 15 and mortality. The percentage of patients with an ISS score above 15 (9.6% and 9.6% in the control and COVID-19 groups, respectively) and the mortality rate (2.0% and 2.6% in the control and COVID-19 groups, respectively) did not change significantly.

Table 4, 5 and Fig. 1 show the effects of social distancing on the number of trauma patients, TA, ISS, mortality, and orthopedic trauma operations. Table 6 summarizes the social distancing levels. When the social distancing level increased from self-distancing to level 2, the number of patients presenting to the emergency department per day decreased from 4.71 to 2.93, and when the social distancing level decreased from level 2 to level 1, the number of patients per day increased from 4.82 to 6.24. Overall, as the level of social distancing increased, the average number of patients decreased, and as the level of social distancing decreased, the number of patients increased. A similar pattern was observed in the number of patients who were injured by TAs, but not at all levels. When the social distancing level decreased from level 2.5 to level 2, the daily average number of TAs increased from 0.29 to 1.21. The number of orthopedic trauma operations changed in the same direction. Neither the number of patients with ISS above 15 nor the mortality rate was affected by social distancing levels. The correlation between the social distancing level and the number of patients was statistically significant in three comparison groups; the number of TA patients was statistically significant in one comparison group, and the number of orthopedic trauma operations was statistically significant in two comparison groups. The number of patients with an ISS > 15 and the mortality rate did not show significant correlations in any comparison groups.

**DISCUSSION**

This study evaluated the impact of the COVID-19 pandemic on...
the volume of trauma patients and orthopedic trauma operations at a single trauma center in Korea. A significant decline in trauma patients has been reported worldwide during the COVID-19 period. Our study also showed that the number of patients with traumatic injuries decreased during the COVID-19 era compared to the control group from before the COVID-19 pandemic (Table 1). We postulate that overall movement in our region declined after the outbreak of COVID-19 due to modifications of people’s behavior, including decreased time spent at work and social activities. Behavioral change in patients seeking medical assistance may also be a reason for the decline in patients presenting to the emergency department [12]. The COVID-19 pandemic resulted in a redistribution of public health resources; thus, restricted access to the emergency department due to COVID-19 patients may have also been responsible for the overall decline in trauma patients. However, our trauma center remained open during the pandemic period.

The proportion of patients experiencing TAs decreased during the COVID-19 period (Table 2). The percentages of patients injured in in-car TAs and pedestrian TAs decreased, whereas that of patients who experienced bicycle TAs increased significantly. The increased proportion of bicycle accidents may have been caused by the increased use of bicycles rather than public transportation or the use of bicycles for exercising rather than working out in public gyms. Although the number of patients was small, the incidence of motorcycle TAs did not differ between the two groups. Other injury mechanisms did not change significantly.

Some studies have highlighted psychological changes due to quarantine or isolation; an investigation exploring the effects of these psychological changes on self-inflicted injuries would be interesting [13].

Injury severity and mortality were not significantly different between the two patient groups (Table 3). In other words, during the COVID-19 period, patients had injuries comparable to those of patients before the COVID-19 period.

Many countries are taking social actions to slow down or stop the spread of COVID-19. These measures may also prevent accidents. Staying home and limiting social activities may reduce the

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**Table 4. Correlations of social distancing levels with the number of patients, TAs, severity of injury, and orthopedic trauma operations**

<table>
<thead>
<tr>
<th>Level</th>
<th>Date</th>
<th>Total patients</th>
<th>Patients/day</th>
<th>TA/day</th>
<th>ISS &gt;15/day</th>
<th>Mortality/day</th>
<th>OS operation/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-isolation</td>
<td>2020. 08. 02–2020. 08. 15</td>
<td>66</td>
<td>4.71</td>
<td>0.57</td>
<td>0.36</td>
<td>0.14</td>
<td>1.57</td>
</tr>
<tr>
<td>Level 2</td>
<td>2020. 08. 16–2020. 08. 29</td>
<td>41</td>
<td>2.93</td>
<td>0.64</td>
<td>0.07</td>
<td>0</td>
<td>0.79</td>
</tr>
<tr>
<td>Level 2.5</td>
<td>2020. 08. 30–2020. 09. 13</td>
<td>28</td>
<td>2.21</td>
<td>0.29</td>
<td>0.14</td>
<td>0.07</td>
<td>0.21</td>
</tr>
<tr>
<td>Level 2</td>
<td>2020. 09. 14–2020. 10. 11</td>
<td>134</td>
<td>4.82</td>
<td>1.21</td>
<td>0.39</td>
<td>0.07</td>
<td>1.64</td>
</tr>
<tr>
<td>Level 1</td>
<td>2020. 10. 12–2020. 11. 23</td>
<td>258</td>
<td>6.24</td>
<td>1.07</td>
<td>0.62</td>
<td>0.19</td>
<td>1.76</td>
</tr>
</tbody>
</table>

TA, traffic accident; ISS, Injury Severity Score; OS, orthopedic surgery.

**Table 5. Poisson regression analysis of differences due to changes in social distancing levels**

<table>
<thead>
<tr>
<th>Difference of level</th>
<th>P-value</th>
<th>No. of patients</th>
<th>TA</th>
<th>OS operation</th>
<th>No. of patients of ISS &gt;15</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>S vs. 2</td>
<td>0.016</td>
<td>0.808</td>
<td>0.056</td>
<td>0.103</td>
<td>0.157</td>
<td></td>
</tr>
<tr>
<td>2 vs. 2.5</td>
<td>0.118</td>
<td>0.166</td>
<td>0.033</td>
<td>0.564</td>
<td>0.317</td>
<td></td>
</tr>
<tr>
<td>2.5 vs. 2</td>
<td>&lt;0.001</td>
<td>&lt;0.001&lt;sup&gt;a&lt;/sup&gt;</td>
<td>&lt;0.001</td>
<td>0.157</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>2 vs. 1</td>
<td>0.016</td>
<td>0.524</td>
<td>0.878</td>
<td>0.147</td>
<td>0.157</td>
<td></td>
</tr>
</tbody>
</table>

TA, traffic accident; OS, orthopedic surgery; ISS, Injury Severity Score; S, self-isolation.

<sup>a</sup>0.0002.

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**Fig. 1. Patterns of the daily average number of patients, traffic accident (TA) incidents, orthopedic surgery (OS) operations, patients with Injury Severity Score (ISS) >15, and mortality depending on social distancing levels.**

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number of trauma incidents, including TAs. We evaluated the adjacent social distancing levels to see the effect of changing the social distancing level on the volume of trauma patients. The volume of trauma patients and orthopedic trauma operations decreased when the level of social distancing increased and vice versa (Tables 4, 5). This may have been due to decreased movement and social activities in response to strengthened social distancing. Although not all the results showed statistical significance, the social distancing level was inversely related to the number of trauma patients, TA incidents, and the number of orthopedic trauma operations. These results are in agreement with studies from other countries [8,10,14,15]. Neither the number of patients with an ISS > 15 nor mortality was significantly different in the control group compared with the COVID-19 group. The lack of differences may be explained in two ways. First, the number of cases may have been too small to see the correlation. Second, trauma injuries can be severe regardless of whether the number of patients declines. Even during social distancing, an increase in trauma patients can be anticipated as people become familiar with the restrictive measures.

The COVID-19 pandemic caused major challenges in managing trauma patients [14,16,17]. Even in this challenging situation, health care providers and trauma specialists should pay particular attention and be prepared for an increase in patients as social distancing levels decrease. Trauma care specialists should also be aware that severe traumatic injuries can happen at any time and they should be ready to provide support at all times. The protocols that existed before the outbreak of COVID-19 may be difficult to maintain. Protective measures for health care workers might lead to delays in the rapid treatment of critical trauma patients, surgery can be postponed due to protection against COVID-19 or detection of COVID-19 in a patient, and shortages of blood products can lead to insufficient treatment of critical patients. Therefore, many changes are necessary and improvisations based on previous management strategies must be taken [18,19]. Appropriate allocation of resources such as space, equipment, and healthcare personnel should take place. Strict use of personal protective equipment should be mandated, along with minimizing the required staff in the trauma bay and operating rooms.

One of the limitations of this study is that it was conducted at a single trauma center located in a specific region. The results of this study do not reflect the situation of all trauma centers, and inconsistent results may be observed across different institutions. To validate the effects of COVID-19 on trauma patients, a nationwide multi-center study with more patients is necessary. A second limitation of this study is that patients were selected in certain periods. To determine the effects of COVID-19, we compared the volume of patients between January and April in 2020 and 2021 to the volume in the corresponding months from 2017 to 2019. The volume of patients can be affected by weather and

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**Table 6. Goals and guidelines of social distancing levels**

<table>
<thead>
<tr>
<th>Social distancing level</th>
<th>Description</th>
</tr>
</thead>
</table>
| Self-isolation          | Goal: allow daily social and economic activities under prevention regulations while managing incidence levels under the capacity of healthcare system  
  - Social meetings and admissions to sporting events are allowed  
  - School attendance and online sessions are jointly implemented  
  - Public institutions operate under the condition of reduced density |
| 1                       | Additional enhanced epidemic control measures are carried out to implement self-isolation level  
  - Unnecessary visits, meetings, and social events are advised to be avoided  
  - 1 m distance between the tables or setting up partitions between the tables at restaurants with no time limits  
  - One person per 6 m² area at entertainment facilities  
  - Limiting the number of audience up to 50% at sporting events |
| 2                       | Goal: limiting gathering of people to control the spread of the disease in the local region  
  - Private gatherings with more than nine people are prohibited  
  - Restaurants and entertainment facilities closed after midnight  
  - Limiting the number of audience up to 30% at sporting events |
| 2.5                     | Goal: stop the rapid spread of disease and recover quarantine controls  
  - All meetings and events with five or more people are prohibited  
  - Restaurants and entertainment facilities closed after 10 PM  
  - No school attendance is allowed  
  - Public institutions are enforced with work-from-home with exceptions |
season, which was the main reason why we excluded patients treated from May to December 2020. To overcome selection bias, we compared the same periods in 3 years before COVID-19. A comparison of patients treated throughout the entire year might provide more accurate insights on the effects of COVID-19 on the volume of trauma patients, but using data from the same period in 2 years for comparison may provide correlations over a longer period. Furthermore, to evaluate the effect of social distancing, the period from August 2, 2020 to November 23, 2020 was analyzed. The level of social distancing remained the same for longer times in other periods. Thus, this period was chosen to determine the effects of changes in social distancing measures on the volume and severity of trauma patients.

In conclusion, the volume of trauma patients and orthopedic trauma operations decreased during the COVID-19 period at our institution. Taking restrictive actions and self-isolation had several trauma-related effects, including a reduction in the number of injuries. A nationwide study is needed for a more conclusive assessment of the correlation between COVID-19 and trauma incidence.

NOTES

Ethical statements
The study was obtained from the Institutional Review Board of Korea University Guro Hospital (No. 2021GR0430). The Institutional Review Board waived the requirement for obtaining informed consent because the study was designed to review existing records.

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

Funding
None.

Author contributions
Conceptualization: JKO; Data curation: WSS, JMC; Formal analysis: WC; Methodology: HK, TWN; Project administration: JKO, NK; Visualization: SS, NJC; Writing–original draft: WC; Writing–review & editing: HK, WSS, SS, JMC, NJC, TWN, NK, JWC, JKO.
All authors read and approved the final manuscript.

REFERENCES

The effect of neuropathic pain on quality of life, depression levels, and sleep quality in patients with combat-related extremity injuries

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Purpose: There is limited research on the effects of neuropathic pain (NP) on quality of life, depression levels, and sleep quality in patients with combat-related extremity injuries. This study evaluated whether patients with combat-related extremity injuries with and without NP had differences in quality of life, sleep quality, and depression levels.

Methods: A total of 98 patients with combat-related extremity injuries, 52 with NP and 46 without, were included in this cross-sectional study. The presence of NP was determined using the Leeds Assessment of Neuropathic Symptoms and Signs questionnaire. The outcome measures were a visual analogue scale (VAS), the 36-Item Short Form Survey, the Beck Depression Inventory, and the Pittsburgh Sleep Quality Index (PSQI).

Results: The VAS subparameter scores for pain (all \( P < 0.05 \)), PSQI sleep duration subscale scores (\( P = 0.025 \)), PSQI sleep disturbance subscale scores (\( P = 0.016 \)), and PSQI total scores (\( P = 0.020 \)) were significantly higher in patients with NP than those without. Logistic regression analysis showed that VAS scores of 5 and above for average pain during the previous 4 weeks contributed independently to the prediction of NP.

Conclusions: Patients with combat-related extremity injuries with NP had more pain and poorer sleep quality than those without NP. Sleep quality should be evaluated as part of the diagnostic work-up in patients with combat-related extremity injury with NP, and interventions to improve sleep quality may help manage NP in this patient group.

Keywords: Combat; Extremity injury; Neuropathic pain; Quality of life; Sleep quality

INTRODUCTION

Modern combat body armor is designed to protect the abdomen and chest, but provides limited protection for the limbs. Fragmentation and blast injuries cause multidimensional and complex wounding patterns. Multiple injuries involving neural destruction, extensive soft tissue defects and bone destruction are common in the extremities [1–3].

Chronic pain is common among military veterans and is associated with lower quality of life (QoL), functional disability, and psychological symptoms [4,5]. It has also been suggested that veterans with chronic pain might have increased risks for...
posttraumatic stress disorder, depression, and anxiety [6,7]. However, most of the previous studies have considered chronic pain as a whole, and limited research exists on the association of neuropathic pain (NP) with QoL and psychological comorbidity [8].

NP is a direct result of a disease or lesion affecting the somatosensory system [9]. Typical clinical features of NP include spontaneous pain, paroxysmal pain, burning, ice-cold sensations, electrical shocks, or abnormally intense responses to nonpainful (allodynia) or painful (hyperalgesia) stimuli [10].

Studies with civilian subjects have shown that patients with NP symptoms have higher levels of depression and anxiety, and worse health-related QoL than the general population [11–13]. There is, however, limited research on the extent to which NP influences QoL, levels of depression, and sleep quality in patients with combat-related extremity injuries. Therefore, this study investigated differences in QoL, depression level, and sleep quality among such patients with and without NP.

METHODS

Participants and study design
This was a cross-sectional study conducted in the Orthopedic Rehabilitation Unit of Gaziler Physical Medicine and Rehabilitation, Training and Research Hospital (Ankara, Turkey), a tertiary hospital, from July 2020 to November 2021. A sample size calculation was performed using G*Power ver. 3.1 (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany; http://www.gpower.hhu.de/). In order to detect a difference at 5% type 1 error level with 90% power for an effect size of 0.62 [14], a minimum of 46 patients was required for each group. A total of 98 patients with combat-related extremity injuries, 52 with NP and 46 without, were included. The inclusion criteria were previous history of combat-related extremity injury, age of 18 to 65 years, and time after injury ≥ 3 months. Exclusion criteria were known rheumatic disease, neurologic, or endocrine disorders; previous history of cervical or lumbosacral radiculopathy; excessive alcohol consumption; and vitamin B12 deficiency. The study was approved by the Ethics Committee of Ankara City Hospital (No. E1-20-838). The study was also registered with the ClinicalTrials.gov database (No. NCT04674631). Written informed consent was obtained from all patients.

Demographic and clinical variables
The subjects’ demographic and clinical features including age, weight, height, education, occupation, side of injury, type of injury, and duration of pain were noted. A 10-cm visual analogue scale (VAS) was used to measure the severity of pain [15]. The presence of NP was established using the Leeds Assessment of Neuropathic Symptoms and Signs (LANSS) questionnaire [16]. The Turkish adaptation of LANSS was developed by Yucel et al. [17] and has been shown to be a valid scale. The 98 patients were divided into two groups based on the absence or presence of NP. The NP group included 52 patients with scores of 12 or more on the LANSS, while the 46 patients with scores less than 12 were the group without NP.

The impact of pain on health-related QoL was assessed using the 36-Item Short Form Survey (SF-36). SF-36 is a common tool for evaluating QoL, and includes 36 items in eight separate scales (physical role, physical functioning, general health, bodily pain, social functioning, vitality, mental health, and emotional role). The subscales are scored between 0 and 100, and better QoL is indicated by higher scores [18]. The Turkish version of the SF-36 has been found to be valid and reliable [18].

The Beck Depression Inventory (BDI) was used to evaluate the depression status of the patients. BDI measures symptoms and attitudes characteristic of depression [19]. The 21-item scale is scored between 0 and 63. The Turkish version of BDI has been shown to be valid and reliable [20]. Scores over 17 indicate clinically significant depression. The full depression scale for this test is minimal, 0 to 9; mild, 10 to 16; moderate, 17 to 29; and severe, 30 to 63 [21].

The patients’ self-reported sleep quality during the previous month was assessed using the Pittsburgh Sleep Quality Index (PSQI) [22]. The index includes 19 items and evaluates seven components of sleep quality (subjective quality of sleep, sleep duration, sleep latency, sleep disturbances, sleep efficiency, daytime dysfunction, and drug use for sleep). The total PSQI score is the sum of scores from the seven components, and ranges from 0 to 21. Scores of 6 or higher indicate poor quality of sleep [23]. The Turkish version of PSQI has been validated [24].

Statistical analysis
The study data were analyzed using IBM SPSS ver. 23.0 (IBM Corp., Armonk, NY, USA). Nonsignificant results from the Kolmogorov-Smirnov test were used to show the normality of data distribution. Continuous variables were presented as mean ± standard deviation and categorical variables as percentages (%). The Pearson chi-square test, independent-samples t-test, and Mann-Whitney U-test were used to compare the two groups. Pearson and Spearman correlation analyses were used to evaluate the relationships between LANSS scores and demo-
graphic and clinical parameters in patients with NP. A P-value less than 0.05 was considered to indicate statistical significance.

Logistic regression analysis was performed using possible factors identified in previous analyses to predict NP. The independent factors included in the model were age, duration of pain (months), SF-36 pain subscale scores, the PSQI sleep disturbance and sleep duration subscale scores, PSQI total scores, the percentage of the patients with poor sleep quality (PSQI total score, < 6 vs. ≥ 6), VAS during movement scores (< 5 vs. ≥ 5), VAS average pain during the past 4 weeks scores (< 5 vs. ≥ 5), and VAS night pain scores (< 5 vs. ≥ 5). The Hosmer-Lemeshow test was used for model fit. For each variable, 95% confidence intervals and odds ratios were calculated, and the Wald test was performed to test significance.

RESULTS

This study included 98 male subjects; 3 to 312 months had elapsed since their injuries in patients with NP and 3 to 264 months in patients without NP. The most common type of injury was gunshot wounds, accounting for 50% of the patients with NP. The frequency of peripheral nerve injuries was higher in the NP group (P < 0.001). Demographic variables of the patients are shown in Table 1, and the etiology of NP is presented in Table 2.

The VAS subparameter scores for pain (all P < 0.05), PSQI sleep duration subscale scores (P = 0.025), PSQI sleep disturbance subscale scores (P = 0.016), and PSQI total scores (P = 0.020) were significantly higher in patients with NP than in those without NP (Table 3). Moderate or severe depression was found in 40.4% of the patients with NP and in 32.6% of those without NP. There was no statistically significant difference between the two groups in terms of depression severity (P = 0.523). Poor sleep quality was found in 76.0% of the patients with NP and 59.0% of those without NP (P = 0.066).

In patients with NP, LANSS scores correlated significantly with VAS during movement (r = 0.376, P = 0.006), the SF-36 general health subscale (r = -0.326, P = 0.022), and the PSQI sleep disturbances subscale (r = 0.374, P = 0.007) (Table 4). Logistic regression analysis showed that VAS scores of 5 and above for average pain during the previous 4 weeks contributed independently to the prediction of NP (Table 5).

DISCUSSION

Our results showed that patients with combat-related extremity injuries with NP had more pain and poorer sleep quality than those without NP. LANSS scores were also significantly associated with VAS during movement, the SF-36 general health subscale, and the PSQI sleep disturbances subscale in patients with NP.

The release of inflammatory mediators following tissue trauma can lead to primary or secondary peripheral sensitization of nociceptors, making them more sensitive to stimulation and causing a “wind-up” of spinal cord activity. This can cause the continuation of pain and if left untreated, central sensitization can occur, leading to chronic NP with persistent perceptions that last after tissue repair is complete [1].

Our findings showed that all VAS subparameter scores for pain were significantly higher in patients with NP than in those without NP. This finding is broadly consistent with studies showing that patients with mostly neuropathic chronic pain often report more severe pain [13,25]. Moreover, VAS scores of 5 and above for average pain during the previous 4 weeks were shown to independently contribute to the prediction of NP in our study.

A nationwide epidemiological study of the general population in France demonstrated that participants with NP exhibited lower QoL, poorer sleep quality, and more depression and anxiety symptoms than those without NP [11]. In our study, in contrast, no difference was found between the two groups (with and without NP) in terms of QoL and depression, except for sleep quality.

Besides NP, other factors can affect the QoL and depression status of patients with combat-related injuries. Woodruff et al. [26] showed that health-related QoL among service members injured in combat was associated with demographic factors, injury and service experience, and most strongly with present mental health status. Griefer et al. [27] demonstrated that the clinical characteristics of injuries (e.g., mechanism and severity) in battle-injured soldiers were related to the risk of developing depression and postinjury posttraumatic stress disorder, as well as acute and chronic pain. In our study, the etiology of injury was similar in both groups, and we interpret the similarity of the SF-36 scores as reflecting the broad similarity of the demographic variables and severity of depression in the two patient groups.

To the best of the authors’ knowledge, only one previous study compared patients with combat-related extremity injuries with and without NP [8]. That study of combat-injured Danish soldiers showed that NP was associated with deterioration of self-rated health and increased psychological distress. The sample size in that study, in which the presence of NP was evaluated with the PainDETECT questionnaire, was smaller than our study and
Table 1. Demographic features of the subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n=98)</th>
<th>Patients with NP (n=52)</th>
<th>Patients without NP (n=46)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>29.73±6.26</td>
<td>29.53±6.53</td>
<td>29.95±6.00</td>
<td>0.438</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>24.95±3.10</td>
<td>24.92±0.42</td>
<td>24.98±0.47</td>
<td>0.921</td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
<td></td>
<td>0.926</td>
</tr>
<tr>
<td>Single</td>
<td>58 (59.2)</td>
<td>31 (59.6)</td>
<td>27 (58.7)</td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>40 (40.8)</td>
<td>21 (40.4)</td>
<td>19 (41.3)</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td>0.565</td>
</tr>
<tr>
<td>&lt;High school</td>
<td>75 (76.5)</td>
<td>41 (78.8)</td>
<td>34 (26.1)</td>
<td></td>
</tr>
<tr>
<td>≥High school</td>
<td>23 (23.5)</td>
<td>11 (21.2)</td>
<td>12 (73.9)</td>
<td></td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
<td></td>
<td>0.546</td>
</tr>
<tr>
<td>Smoker</td>
<td>63 (64.3)</td>
<td>32 (61.5)</td>
<td>31 (67.4)</td>
<td></td>
</tr>
<tr>
<td>Nonsmoker</td>
<td>35 (35.7)</td>
<td>20 (38.5)</td>
<td>15 (32.6)</td>
<td></td>
</tr>
<tr>
<td>Alcohol consumption</td>
<td></td>
<td></td>
<td></td>
<td>0.239</td>
</tr>
<tr>
<td>Drinker</td>
<td>11 (11.2)</td>
<td>4 (7.7)</td>
<td>7 (15.2)</td>
<td></td>
</tr>
<tr>
<td>Nondrinker</td>
<td>87 (88.8)</td>
<td>48 (92.3)</td>
<td>39 (84.8)</td>
<td></td>
</tr>
<tr>
<td>Time since injury (mo)</td>
<td>43.56±72.48</td>
<td>46.36±77.39</td>
<td>40.39±67.22</td>
<td>0.492</td>
</tr>
<tr>
<td>Etiology</td>
<td></td>
<td></td>
<td></td>
<td>0.129</td>
</tr>
<tr>
<td>Mine</td>
<td>12 (12.2)</td>
<td>6 (11.5)</td>
<td>6 (13)</td>
<td></td>
</tr>
<tr>
<td>Explosives</td>
<td>19 (19.4)</td>
<td>8 (15.4)</td>
<td>11 (23.9)</td>
<td></td>
</tr>
<tr>
<td>Gunshot</td>
<td>43 (43.9)</td>
<td>26 (50.0)</td>
<td>17 (37.0)</td>
<td></td>
</tr>
<tr>
<td>Rocket</td>
<td>10 (10.2)</td>
<td>8 (15.4)</td>
<td>2 (4.4)</td>
<td></td>
</tr>
<tr>
<td>Other (e.g., car accident)</td>
<td>14 (14.3)</td>
<td>4 (7.7)</td>
<td>10 (21.7)</td>
<td></td>
</tr>
<tr>
<td>Injury site</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right upper extremity</td>
<td>20 (20.4)</td>
<td>13 (25.0)</td>
<td>7 (15.2)</td>
<td>0.230</td>
</tr>
<tr>
<td>Left upper extremity</td>
<td>22 (22.4)</td>
<td>13 (25.0)</td>
<td>9 (19.6)</td>
<td>0.520</td>
</tr>
<tr>
<td>Right lower extremity</td>
<td>49 (50.0)</td>
<td>28 (53.8)</td>
<td>21 (45.7)</td>
<td>0.418</td>
</tr>
<tr>
<td>Left lower extremity</td>
<td>44 (44.9)</td>
<td>24 (46.2)</td>
<td>20 (43.5)</td>
<td>0.790</td>
</tr>
<tr>
<td>Injury type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peripheral nerve injury</td>
<td>58 (59.2)</td>
<td>40 (76.9)</td>
<td>18 (39.1)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Fracture</td>
<td>50 (51.0)</td>
<td>27 (51.9)</td>
<td>23 (50.0)</td>
<td>0.849</td>
</tr>
<tr>
<td>Amputation</td>
<td>25 (25.5)</td>
<td>11 (21.2)</td>
<td>14 (30.4)</td>
<td>0.293</td>
</tr>
<tr>
<td>Duration of pain (mo)</td>
<td>23.27±44.04</td>
<td>20.03±25.07</td>
<td>26.93±58.67</td>
<td>0.065</td>
</tr>
<tr>
<td>Current medical treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pregabalin</td>
<td>21 (21.4)</td>
<td>21 (40.4)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Gabapentin</td>
<td>3 (3.1)</td>
<td>3 (5.8)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Narcotic analgesics</td>
<td>5 (5.1)</td>
<td>3 (5.8)</td>
<td>2 (4.3)</td>
<td>0.750</td>
</tr>
<tr>
<td>Paracetamol</td>
<td>10 (10.2)</td>
<td>4 (7.7)</td>
<td>6 (13.0)</td>
<td>0.382</td>
</tr>
<tr>
<td>NSAIDs</td>
<td>14 (14.3)</td>
<td>5 (9.6)</td>
<td>9 (19.6)</td>
<td>0.160</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation or number (%). NP, neuropathic pain; NSAID, nonsteroidal anti-inflammatory drug. *P<0.05.

Table 2. Etiology of neuropathic pain (n=52)

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Patients with neuropathic pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peripheral nerve injury</td>
<td>40 (76.9)</td>
</tr>
<tr>
<td>Complex regional pain syndrome</td>
<td>1 (1.9)</td>
</tr>
<tr>
<td>Neuroma</td>
<td>8 (15.4)</td>
</tr>
<tr>
<td>Phantom limb pain</td>
<td>3 (5.8)</td>
</tr>
</tbody>
</table>

The prevalence of sleep disturbances ranges from 50% to 80% in patients with chronic pain, and the severity of sleep disturbances is associated with pain intensity [28]. Melikoglu et al. [23] showed that 80% of patients with NP had poor sleep quality regardless of the cause of NP. The detected rate of poor sleep quality of 76% in this study for patients with NP is comparable to pre-
vious findings in the literature. To our knowledge, no previous studies have compared sleep quality in patients with combat-related extremity injuries with and without NP. As in the related civilian studies [11, 23], sleep quality in patients with NP was found to be poorer than in those without NP in our study. Moreover, a correlation was found between LANSS scores and the PSQI sleep disturbances subscale in patients with NP. Although the difference in the percentage of the patients with poor sleep quality between the two groups did not reach statistical significance, the P-value was close to 0.05.

This study has some limitations. The study population and time after injury were heterogeneous. The results of the study cannot be generalized since all the participants were male and from a single center. The uneven number of patients between the two groups is another limitation. Detailed information on injury-related features was not obtained using specific scales such as the Injury Severity Score or Abbreviated Injury Scale. In this cross-sectional study, we also could not evaluate changes in and effects of NP in patients over time. A prospective cohort study is needed to obtain a more complete evaluation of the NP in patients with combat-related extremity injuries. Lastly, the number of patients with amputation in our study was small. We could not compare patients with NP with and without amputation in terms of QoL, depression level, and sleep quality because we did not track amputations. Further studies with more patients with amputation are required to compare patients with NP with and without amputation in terms of QoL, depression level, and sleep quality.

Patients with combat-related extremity injuries with NP had more pain and poorer sleep quality than those without NP. Sleep quality should be evaluated as part of the diagnostic work-up in patients with combat-related extremity injuries with NP, and ap-

<table>
<thead>
<tr>
<th>Clinical feature</th>
<th>Patients with NP (n=52)</th>
<th>Patients without NP (n=46)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual analogue scale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average pain during the past 4 wk</td>
<td>5.80±1.45</td>
<td>4.50±2.42</td>
<td>0.005*</td>
</tr>
<tr>
<td>Worst pain within the past 4 wk</td>
<td>8.50±1.42</td>
<td>6.89±2.84</td>
<td>0.005*</td>
</tr>
<tr>
<td>At rest</td>
<td>4.32±2.47</td>
<td>2.52±2.82</td>
<td>0.001*</td>
</tr>
<tr>
<td>At movement</td>
<td>5.96±2.05</td>
<td>4.86±2.69</td>
<td>0.042*</td>
</tr>
<tr>
<td>Night pain</td>
<td>5.03±2.67</td>
<td>2.80±3.00</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>LANSS</td>
<td>18.05±3.65</td>
<td>3.80±3.73</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>36-Item Short Form Survey</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical functioning</td>
<td>49.51±25.19</td>
<td>55.69±27.85</td>
<td>0.217</td>
</tr>
<tr>
<td>Role limitation due to physical health</td>
<td>29.08±38.30</td>
<td>29.01±36.57</td>
<td>0.740</td>
</tr>
<tr>
<td>Pain</td>
<td>36.83±25.83</td>
<td>48.72±27.75</td>
<td>0.070</td>
</tr>
<tr>
<td>General health status</td>
<td>51.22±20.72</td>
<td>54.88±21.05</td>
<td>0.368</td>
</tr>
<tr>
<td>Vitality</td>
<td>47.65±25.16</td>
<td>53.72±22.30</td>
<td>0.219</td>
</tr>
<tr>
<td>Role limitation due to emotional problems</td>
<td>49.48±29.86</td>
<td>52.03±26.99</td>
<td>0.831</td>
</tr>
<tr>
<td>Social relations</td>
<td>38.83±43.21</td>
<td>39.53±43.19</td>
<td>0.906</td>
</tr>
<tr>
<td>Mental health</td>
<td>53.61±22.59</td>
<td>58.51±24.54</td>
<td>0.308</td>
</tr>
<tr>
<td>Beck Depression Inventory (total)</td>
<td>15.32±9.60</td>
<td>14.39±11.08</td>
<td>0.423</td>
</tr>
<tr>
<td>Pittsburgh Sleep Quality Index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep quality</td>
<td>1.64±0.74</td>
<td>1.34±0.91</td>
<td>0.087</td>
</tr>
<tr>
<td>Sleep latency</td>
<td>1.86±1.01</td>
<td>1.56±0.97</td>
<td>0.127</td>
</tr>
<tr>
<td>Sleep duration</td>
<td>1.48±0.99</td>
<td>1.04±1.03</td>
<td>0.025*</td>
</tr>
<tr>
<td>Sleep efficiency</td>
<td>0.50±0.73</td>
<td>0.36±0.74</td>
<td>0.164</td>
</tr>
<tr>
<td>Sleep disturbance</td>
<td>1.80±0.67</td>
<td>1.43±0.69</td>
<td>0.016*</td>
</tr>
<tr>
<td>Use of sleep medication</td>
<td>0.66±1.17</td>
<td>0.40±0.99</td>
<td>0.182</td>
</tr>
<tr>
<td>Daytime dysfunction</td>
<td>1.12±0.93</td>
<td>1.02±0.92</td>
<td>0.642</td>
</tr>
<tr>
<td>Total</td>
<td>9.06±3.70</td>
<td>7.18±4.00</td>
<td>0.020*</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.
NP, neuropathic pain; LANSS, Leeds Assessment of Neuropathic Symptoms and Signs.
*P<0.05.
Table 4. Correlations between LANSS scores and demographic and clinical variables in patients with neuropathic pain

<table>
<thead>
<tr>
<th>Variable</th>
<th>r</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time since injury (mo)</td>
<td>–0.009</td>
<td>0.951</td>
</tr>
<tr>
<td>Duration of pain (mo)</td>
<td>–0.075</td>
<td>0.598</td>
</tr>
<tr>
<td>Visual analogue scale</td>
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<td></td>
</tr>
<tr>
<td>Average pain during the past 4 wk</td>
<td>0.169</td>
<td>0.231</td>
</tr>
<tr>
<td>Worst pain within the past 4 wk</td>
<td>0.211</td>
<td>0.134</td>
</tr>
<tr>
<td>At rest</td>
<td>0.226</td>
<td>0.025</td>
</tr>
<tr>
<td>At movement</td>
<td>0.376*</td>
<td>0.006*</td>
</tr>
<tr>
<td>Night pain</td>
<td>0.21</td>
<td>0.136</td>
</tr>
<tr>
<td>36-Item Short Form Survey</td>
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<td></td>
</tr>
<tr>
<td>Physical functioning</td>
<td>–0.100</td>
<td>0.493</td>
</tr>
<tr>
<td>Role limitation due to physical health</td>
<td>–0.048</td>
<td>0.745</td>
</tr>
<tr>
<td>Pain</td>
<td>–0.066</td>
<td>0.654</td>
</tr>
<tr>
<td>General health status</td>
<td>–0.326*</td>
<td>0.022*</td>
</tr>
<tr>
<td>Vitality</td>
<td>–0.111</td>
<td>0.450</td>
</tr>
<tr>
<td>Role limitation due to emotional problems</td>
<td>–0.207</td>
<td>0.154</td>
</tr>
<tr>
<td>Social relations</td>
<td>–0.049</td>
<td>0.738</td>
</tr>
<tr>
<td>Mental health</td>
<td>–0.118</td>
<td>0.421</td>
</tr>
<tr>
<td>Beck Depression Inventory (total)</td>
<td>–0.027</td>
<td>0.848</td>
</tr>
<tr>
<td>Pittsburgh Sleep Quality Index</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep quality</td>
<td>0.214</td>
<td>0.136</td>
</tr>
<tr>
<td>Sleep latency</td>
<td>0.249</td>
<td>0.081</td>
</tr>
<tr>
<td>Sleep duration</td>
<td>–0.014</td>
<td>0.922</td>
</tr>
<tr>
<td>Sleep efficiency</td>
<td>0.066</td>
<td>0.651</td>
</tr>
<tr>
<td>Sleep disturbance</td>
<td>0.374*</td>
<td>0.007*</td>
</tr>
<tr>
<td>Use of sleep medication</td>
<td>0.007</td>
<td>0.964</td>
</tr>
<tr>
<td>Daytime dysfunction</td>
<td>0.032</td>
<td>0.824</td>
</tr>
<tr>
<td>Total</td>
<td>0.181</td>
<td>0.208</td>
</tr>
</tbody>
</table>

LANSS, Leeds Assessment of Neuropathic Symptoms and Signs.
*P<0.05.

Table 5. Logistic regression analysis of the variables predictive of neuropathic pain

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio</th>
<th>95% Confidence interval</th>
<th>P-valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.984</td>
<td>0.907–1.068</td>
<td>0.698</td>
</tr>
<tr>
<td>Duration of pain (mo)</td>
<td>1.009</td>
<td>0.997–1.021</td>
<td>0.150</td>
</tr>
<tr>
<td>36-Item Short Form Survey (pain)</td>
<td>1.002</td>
<td>0.977–1.027</td>
<td>0.887</td>
</tr>
<tr>
<td>Pittsburgh Sleep Quality Index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sleep duration</td>
<td>0.606</td>
<td>0.293–1.252</td>
<td>0.176</td>
</tr>
<tr>
<td>Sleep disturbance</td>
<td>0.626</td>
<td>0.230–1.708</td>
<td>0.361</td>
</tr>
<tr>
<td>Total</td>
<td>1.178</td>
<td>0.877–1.582</td>
<td>0.278</td>
</tr>
<tr>
<td>Poor sleep quality (≥6)</td>
<td>0.955</td>
<td>0.205–4.455</td>
<td>0.953</td>
</tr>
<tr>
<td>Visual analogue scale</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At movement (≥5)</td>
<td>0.805</td>
<td>0.219–2.956</td>
<td>0.744</td>
</tr>
<tr>
<td>Average pain during the past 4 wk (≥5)</td>
<td>6.711</td>
<td>1.772–25.412</td>
<td>0.005*</td>
</tr>
<tr>
<td>Night pain (≥5)</td>
<td>2.785</td>
<td>0.967–8.020</td>
<td>0.058</td>
</tr>
</tbody>
</table>

*aWald test.
*P<0.05.

Approaches to boost sleep quality may contribute to the overall management of NP in this patient group. Future studies addressing the limitations of this study are warranted.

NOTES

Ethical statements
The study was approved by the Ethics Committee of Ankara City Hospital (No. E1-20-838). The study was also registered with the ClinicalTrials.gov database (No. NCT04674631). Written informed consent was obtained from all patients.

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

Funding
None.

Author contributions
Conceptualization: MÖA, GKK, KA; Data curation: MÖA, GKK, FÖ, YD; Formal analysis: MÖA, GKK, FÖ, YD; Methodology: MÖA, GKK, KA; Writing–original draft: MÖA, YD; Writing–review & editing: all authors.
All authors read and approved the final manuscript.

REFERENCES

INTRODUCTION

Crush injuries of the hand have become a relatively common phenomenon due to modern lifestyle habits and are a common cause of amputation or historically poor outcomes in non-specialized services [1]. Usually caused by a high-energy mechanism, a compressive force crushes and leads to a rise in tissue pressure and damage of varying severity to multiple tissue types [1]. Crush injuries of the hand pose a challenge to the hand surgeon, whether it is a minor fingertip injury sustained by the hand being squashed or a high-pressure compression injury involving the palm or wrist [2,3].

We describe a case of hyperbaric oxygen therapy (HBOt) as an adjunct to treatment of a crush injury to the hand. A 34-year-old male paramedic was involved in a motor vehicle accident and admitted for diagnosis and surgical treatment. He sustained a crush injury to his right hand and presented with significant muscle damage, including multiple fractures and dislocations, an avulsion injury of the flexor tendons, and amputation of the distal phalanx of the little finger. He underwent reconstructive surgery and received HBOt over the following days. In the following 2 months, he lost the distal and middle phalanges of the little finger and recovered hand function. Posttraumatic compartment syndrome responds well to HBOt, which reduces edema and contributes to angiogenesis, as well as promoting the cascade of healing events. High-energy trauma causes massive cell destruction, and the blood supply is usually not sufficient to meet the oxygen demands of viable tissues. Hyperbaric oxygenation by diffusion through interstitial and cellular fluids increases tissue oxygenation to levels sufficient for the host’s responses to injury to work and helps control the delayed inflammatory reaction. HBOt used as an adjunct to surgical treatment resulted in early healing and rehabilitation, accelerating functional recovery. The results suggest that adjunctive HBOt can be beneficial for the treatment of crush injuries of the hand, resulting in better functional outcomes and helping to avoid unnecessary amputations.

Keywords: Hyperbaric oxygenation; Crush injuries; Surgical flaps; Compartment syndrome; Case reports
A crush injury of the hand is defined as compression of the distal extremities of the upper limbs causing muscular, neurological, vascular, and bone disturbance and producing damage to tissues. The degree of damage is proportional to the amount of force applied and the duration of compression.

A wide zone of injury results from a delayed inflammatory reaction involving the bordering zone, which may initially belie the severity of the damage. Profuse edema and inflammation increase the volume within the fascial compartments, decreasing perfusion to soft tissues and nerves and progressively reducing tissue viability [1].

Debridement is the cornerstone of surgical treatment of open traumatic injuries. All devitalized tissue and foreign bodies should be removed, and all viable, well-vascularized tissue should be preserved. However, it is not always possible to assess tissue viability intraoperatively and sometimes, depending on the surgeon’s experience, an inappropriate decision may be made.

Notwithstanding this observation, experience and knowledge of the beneficial effects of hyperbaric oxygen therapy (HBOt) in the rescue of hypoxic tissue can contribute substantially not only to saving the limb, but also to earlier healing. Thus, a well-trained and experienced team of surgeons, as well as physicians with knowledge of hyperbaric medicine, can provide a successful alternative for salvaging tissues and body segments when compared to services that do not offer hyperbaric facilities.

CASE REPORT

A 34-year-old male paramedic was involved in a motor vehicle accident and admitted for diagnosis and surgical treatment. He sustained a crush injury to his right hand with significant muscle damage, including multiple fractures and dislocations, an avulsion injury of the flexor tendons, and amputation of the distal phalanx of the little finger (Fig. 1).

Emergency reconstructive surgery was performed. The distal phalanx of the fifth finger did not satisfy the minimum conditions for replantation, and the presence of debris in the wound and an unviable aspect of the thenar musculature were also noted. The wound was then abundantly washed with saline, and debridement was performed to clean the wound from unviable tissue. The interphalangeal joint dislocations of the middle and little fingers were reduced and fixed using Kirschner wires under image intensifier guidance. Tenorrhaphy of the distal flexor digitorum profundus stumps and proximal flexor digitorum superficialis (FDS) stumps of the middle and ring fingers was performed, followed by transosseous suturing of the distal FDS stump to the middle phalanx of the avulsed little finger. Grafting of the distal FDS stump of the little finger to the proximal FDS stump of the ring finger was achieved with tendon transfer. The wound was closed using a plane suture as satisfactorily as technically possible (Fig. 2).

Volume replacement therapy, pain medication, broad-spectrum antibiotics, and nutritional support were initiated as per the service’s routine. The wound showed progressive tissue damage, manifesting mainly as a change in the color of the skin associated with progressive edema (Fig. 3).

Despite the delayed start of HBOt, the color in some of the ischemic and hypoxic superficial tissues improved within the first days of adjunct treatment (day 6), after only three HBOt sessions.

Fig. 1. Right hand on day 1 in the emergency box.

Fig. 2. Right hand on day 1, on the immediate postoperative period.
In addition, the posttraumatic edema also improved markedly with HBOt (Fig. 4). The lesion progressed to soft tissue necrosis in the thenar region with superficial spreading towards the base of the fingers (Fig. 5).

Over the ensuing days, occlusive dressings were changed daily and unviable tissue was removed, eventually revealing wet necrosis and infection in the middle phalanx of the little finger (Fig. 6). The patient was taken to the operating room for amputation of the distal phalanx of the little finger, and a thenar skin flap was taken from the right forearm (Fig. 7).

Concurrently, an early rehabilitation program was initiated with an excellent functional outcome and full restoration of hand function at the end of treatment, despite the loss of the distal and
middle phalanges of the little finger (Fig. 8).

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

DISCUSSION

Skeletal muscle-compartment syndrome (SMCS) is a consequence of trauma, but in this situation the affected tissues are muscles and nerves. Edema and/or bleeding within the confines of the fascial envelope can increase the pressure within the skeletal muscle compartment. When the tissue fluid pressure within the compartment exceeds the capillary perfusion pressure to these tissues, they are rendered ischemic and manifest the signs and symptoms of SMCS. No means to arrest the progression of SMCS, especially in its stages before fasciotomy is required, exist other than HBOt [4].

Unfortunately, HBOt is neglected as an adjunct for managing crush injuries and SMCS. Arguments exist for its use based on evidence-based information and how HBOt mitigates the pathology of these conditions [4].

The literature regarding the use of HBOt in patients with SMCS is limited, mainly because this condition does not occur as a standalone event and is most frequently associated with hypovolemic shock, crush injuries, and polytrauma. Despite the paucity of research, the beneficial effects of HBOt as an adjunctive therapy have been demonstrated in both experimental and human studies, even though one study with a low level of evidence has reported that tissue necrosis progressed with HBOt. Bouachour et al. [5] conducted a randomized clinical trial with a high level of evidence and reported complete healing in 94% of patients receiving HBOt versus 34% in the control group (P < 0.05). These findings are consistent with several reported clinical cases.

The underlying pathophysiology of crush injuries and SMCS is trauma with tissue hypoxia, which may lead to the continued evolution of the injury to an irreversible state or a self-perpetuating progression of edema, forming a vicious circle. The consequences of trauma include visible tissue damage, injury at the cellular level, and biochemical alterations. Immediate necrosis occurs in high-energy trauma cases and the only options in these circumstances are debridement or amputation.

Trauma to the vasculature at the microcirculation level leads to transudation of fluid with increasing edema, interstitial bleeding, slowed blood flow, venous stasis, clot formation, and vascular obstruction. The consequences are ischemia and hypoxia to the tissues perfused by the damaged vasculature. When this occurs, cells are no longer able to maintain their metabolic functions such as retaining intracellular water, which contributes to edema and third-spacing of fluid. If the edema occurs in a closed space, the increased pressure will collapse the microcirculation, eliminate oxygen transfer across the capillary endothelium, and contribute to the hypoxic tissue insult [4]. Considering that oxygen is required for all metabolic functions, the low oxygen tension from trauma and its consequences thwart the cascade of events involving wound healing, angiogenesis, bacterial killing by neutrophils, and the action of fibroblasts.

Events at the biochemical level, the ultimate determinants of outcomes, are manifested in two ways. First, oxygen is required for all cellular metabolic functions. If oxygen tension is insufficient, cell signaling factors, wound healing and angiogenesis responses as elaborated through fibroblasts, and bacterial killing by neutrophils are thwarted. A partial pressure of oxygen in the tissue fluids greater than 30 mmHg is required for these responses to occur.

The second biochemical event is that of ischemia-reperfusion injury (IRI) [6]. Once perfusion is temporarily interrupted, which occurs in varying degrees with crush injuries and compartment syndrome, the endothelium becomes sensitized to the hypoxic insult, resulting in the activation of adhesion molecules, which in turn leads to the attachment of neutrophils to the endothelium and the release of reactive oxygen species (ROS). The consequence is a cascade of biochemical events, whereby these ROS damage tissue further and cause severe vasoconstriction, defining the IRI and the no-reflow phenomenon associated with it.

The immediate justification for using HBOt in crush injuries and compartment syndromes is twofold. First, HBOt supplements oxygen availability to hypoxic tissues during the early

Fig. 8. Right hand (A) on the day of crush injury and (B) after recovery.
postinjury period, when perfusion is most likely to be inadequate and the oxygen requirement is greater. Second, HBOt increases tissue oxygen tension to sufficient levels for the host responses to function. Hyperbaric oxygen exposure at a pressure of two atmospheres absolute (202.65 kPa) increases the oxygen content (the combination of hemoglobin and oxygen) by 125%. The oxygen tension in plasma and tissue fluids is thus increased 10-fold—that is, by 1,000% [7,8]. Increased tissue oxygen tension results in a threefold driving force (mass effect), which compensates for the hypoxia resulting from the increased oxygen diffusion distance from the capillary to the cell through the edema fluids.

Edema reduction is a secondary effect of tissue hyperoxygenation. Hyperbaric oxygen induces precapillary vasoconstriction, which reduces blood flow by 20% [9,10]. Because inflow is decreased while outflow is maintained, the net effect is edema reduction of roughly 20% [10–12]. Edema reduction occurs because of decreased filtration of fluid from the capillary to the extracellular space as a consequence of vasoconstriction, resulting in decreased perfusion pressure in the capillary bed, while resorption of fluid at the capillary level is maintained by the oncotic pressure inside the capillary. Hyperoxygenation of the plasma maintains oxygen delivery to tissues in the presence of HBOt-induced vasoconstriction [9,13]. Another consequence of decreasing the interstitial fluid pressure through edema reduction is improved blood flow through the microcirculation. The reason for this is that, once the interstitial fluid pressure is reduced below the capillary perfusion pressure, the collapsed microcirculation can again open up and allow perfusion to resume. By reducing edema while supplementing tissue oxygenation, HBOt interrupts the self-perpetuating edema/ischemia vicious circle to prevent progression of the injury; therefore, SMCS and crush injuries are particularly amenable to HBOt.

Mitigation of IRI is another effect of HBOt for crush injuries and SMCS [13]. HBOt interrupts the interactions between oxygen free radicals and cell membrane lipids, perturbing lipid peroxidation of the cell membrane and inhibiting the sequestration of neutrophils on postcapillary venules [14,15]. The latter effect occurs because HBO interferes with the adherence of neutrophils elaborated through the beta-2 integrin (cluster designation-11) on the sensitized capillary endothelium. The result is interruption of the interaction of superoxide anion with nitric oxide, which produces the highly reactive peroxynitrite radical [15]. Another benefit of HBOt for IRI is the generation, in an oxygenated environment, of enzymes such as superoxide dismutase, catalase, peroxidase, and glutathione reductase that detoxify ROS, improving patients' prognosis.

The correlation of the pathophysiology of crush injuries with the physiological effects of adjunctive HBOt and the course of events in this case indicates that HBOt may be beneficial for arresting progressive tissue damage, reducing edema, and improving oxygenation and tissue perfusion. However, more well-designed studies with larger sample sizes are needed to establish high-level evidence to support its use. HBOt used as an adjunct to surgical treatment resulted in early healing and rehabilitation, accelerating functional recovery. The results suggest that adjunctive HBOt can be beneficial in the treatment of crush injuries of the hand, resulting in better functional outcomes and helping to avoid unnecessary amputations (Fig. 9).

NOTES

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

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

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

REFERENCES
Management of a traumatic anorectal full-thickness laceration: a case report

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1Department of General Surgery, AOU Careggi University Hospital, Florence, Italy
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The rectum is the least frequently injured organ in trauma, with an incidence of about 1% to 3% in trauma cases involving civilians. Most rectal injuries are caused by gunshot wounds, blunt force trauma, and stab wounds. A 46-year-old male patient was crushed between two vehicles while he was working. He was hemodynamically unstable, and the Focused Assessment with Sonography for Trauma showed hemoperitoneum and hemoretroperitoneum; therefore, damage control surgery with pelvic packing was performed. A subsequent whole-body computed tomography scan showed a displaced pelvic bone and sacrum fracture. There was evidence of an anorectal full-thickness laceration and urethral laceration. In second-look surgery performed 48 hours later, the pelvis was stabilized with external fixators, and it was decided to proceed with loop sigmoid colostomy. A tractioned rectal probe with an internal balloon was positioned in order to approach the flaps of the rectal wall laceration. On postoperative day 13, a radiological examination with endoluminal contrast injected from the stoma after removal of the balloon was performed and showed no evidence of extraluminal leak. Rectosigmoidoscopy, rectal manometry, anal sphincter electromyography, and trans-stomic transit examinations showed normal findings, indicating that it was appropriate to proceed with the closure of the colostomy. The postoperative course was uneventful. The optimal management for extraperitoneal penetrating rectal injuries continues to evolve. Primary repair with fecal diversion is the mainstay of treatment, and a conservative approach to rectal lacerations with an internal balloon in a rectal probe could provide a possibility for healing with a lower risk of complications.

Keywords: Emergency surgery; Rectal trauma; Hip fractures; Crush injuries; Case reports

INTRODUCTION

The rectum is the least frequently injured organ in trauma, with an incidence of about 1% to 3% of trauma cases involving civilians, while 5.1% of rectal trauma cases result from war trauma. Of these, about 23% of cases are due to explosives. In civilians, most injuries are caused by gunshot wounds (approximately 70%–85%), while blunt force trauma (5%–10%) and stab wounds (3%–5%) account for the remaining cases [1]. Of these, extraperitoneal rectal injuries from blunt trauma are very rare in civilians.
and are usually accompanied by sacral or pelvic fractures associated with intraperitoneal injury [2]. In addition to being relatively rare given the protected position of the rectum within the pelvis, rectal injuries can be difficult to diagnose and are often overlooked [3].

Intraperitoneal rectal lesions are managed in the same way as colonic lesions—that is, they are often treated with direct repair without diversion. In contrast, extraperitoneal rectal lesions are difficult to access and the transabdominal approach only allows the creation of a stoma for fecal diversion [4]. Extraperitoneal rectal lesions can be managed conservatively or surgically, depending on the extent of the lesion. There is currently no standardization of the management of minor injuries, but closure of the defect, when possible, seems to be beneficial [2]. In such cases, the optimization of access to extraperitoneal rectal lesions can allow effective primary repair and avoid the need for diversion. In this context, transanal minimally invasive surgery could increase the likelihood of successful primary repair of extraperitoneal rectal lesions [4]. Mortality rates have declined in recent decades, but despite advances in the management of trauma patients, mortality rates range from 3% to 10%, and the risk of further complications is 18% to 21%. Moreover, lesions of the rectum are rarely observed alone, given the close proximity to other organs and major pelvic vessels, damage to which can worsen the patient’s outcome and make the management more complex. Considerable disagreement persists about the optimal management of such injuries [1,3].

**CASE REPORT**

A 46-year-old male patient was crushed between two vehicles at work. He arrived in the emergency room in a hemodynamically unstable condition, so he underwent damage control surgery with pelvic packing. Subsequently, a whole-body computed tomography scan performed after hemodynamic stabilization showed a displaced fracture of the right hemi-basin, which was superomedially displaced with partial overlapping of the ilium with the pubic ischium and the branches of the symphysis (Fig. 1). Furthermore, fractures of both alae of the sacrum with diastasis of the stumps to the right and involvement of the foramina were noticed, with detachment and ascent of the cranial portion associated with fracture of the left iliac wing in the posterior aspect. There was also evidence of inhomogeneity of the periprostatic and membranous urethra, indicative of traumatic lesions. A rectal examination identified an extensive 270° extraperitoneal laceration on the anterior rectal wall. We performed second-look surgery 48 hours after the first operation, during which we stabilized the pelvic bone fracture with external fixators and performed cystostomy and loop sigmoidostomy. We decided not to proceed with primary closure of the rectal laceration given the high risk of stenosis that would have been posed by primary-intention healing with an extensive wound defect close to the anal sphincter. We then placed a Foley balloon in traction proximal to the tear to promote secondary intention healing for two purposes: to facilitate approximation between the proximal and distal flaps of the tear and to allow effective washing of the wound. After positioning the probe, several rectal washouts were carried out until satisfactory progress in rectal cleaning was observed. A methylene blue test was performed and showed no abdominal dye shedding. The postoperative course was uneventful. On postoperative day (POD) 13, a radiological examination with endoluminal contrast injected from the stoma after removal of the balloon showed no evidence of extraluminal leak. Rectosigmoidoscopy, rectal manometry, anal sphincter electromyography, and trans-stomic transit control showed normal findings, indicating that it was appropriate to proceed with the subsequent closure of the colostomy, which was performed 1 year later. The postoperative course was uneventful; the patient was regularly canalized on.

**Fig. 1.** Contrast-enhanced CT scan of the abdomen shows (A) a rectal injury (arrow) that occurred during trauma with (B) pelvic fractures.
POD 3, showing good continence. The patient was then discharged on POD 5.

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

**DISCUSSION**

Guidelines for rectal injuries continue to evolve, and an emphasis is now placed on more conservative approaches [5]. Historically, the first studies were conducted on rectal trauma that occurred during wars. During World War I, direct repair of rectal injuries associated with the occasional use of diversion reduced mortality from about 90% to 67%, while in World War II, the use of deviation in addition to presacral drainage brought mortality to 30%. Finally, during the Vietnam War, with the progress of anesthetic techniques and the spread of antibiotic prophylaxis, direct repair associated with distal rectal lavage further reduced the mortality rate to 15% [3]. The preliminary evaluation of trauma patients must follow the principles of advanced trauma life support; anorectal lesions are evaluated secondarily, with digital rectal exploration, which has poor sensitivity for the identification of rectal lesions. Traumatic injuries of the rectum are classified in terms of their location (intraperitoneal vs. extraperitoneal) and according to the American Association for the Surgery of Trauma rectum injury scale in grades from I to V [6]. However, the choice of treatment depends mainly on other factors such as hemodynamic instability, level of contamination, and other concomitant injuries [5]. As described in the literature, intraperitoneal rectal lesions are often treated with proximal diversion, although these patients showed a higher rate of abdominal complications (22% vs. 10%). However, extraperitoneal lesions can be much more challenging due to their deep location in the pelvis and their close relationships with surrounding structures. Extraperitoneal rectal lesions could be approached either transabdominally or transanally for proximal or distal injuries, respectively [7]. Patients with extraperitoneal lesions received proximal deviation in approximately 76% of cases, in 75% of which this was the only treatment. In the remaining cases, approximately 20% of patients underwent presacral drainage with or without distal rectal washout; both of these treatments have been associated with a 3-fold higher risk of abdominal complications. However, most of the lesions involved the extraperitoneal rectum, and 75% of these lesions were classified as grades I and II, with a high incidence of associated pelvic and abdominal lesions [8]. The causes for morbidity and mortality due to traumatic injuries of the extraperitoneal rectum include the difficulty in obtaining adequate exposure of the intervention field and the delay in diagnosis [5]. While surgeons initially shared the “4 Ds” strategy, given the good results since the Vietnam War, when it was proposed as the standard of care, the literature has subsequently begun to review the role of some of the “4Ds.” In particular, debates have focused on the need for repair, presacral drainage, distal rectal washout, and up to proximal diversion for extraperitoneal lesions [8,9]. Currently, guidelines recommend proximal diversion, without routinely proceeding with presacral drainage and distal rectal washout. Steele et al. [10] in 2011 found that there is no evidence for or against any treatment. Each treatment should be tailored for the individual patient. Chow et al. [11] stated that the literature supports stoma closure at any time between hospitalization and up to more than 3 months post-trauma. However, further studies are needed to establish a consensus on the timing of colostomy closure, given the high rate of associated complications (5% to 25%). The correct timing should be individualized based on individual factors, including nutritional status and clinical course [11]. Gash et al. [3] found that direct repair of the isolated lesion alone without diversion was comparable in terms of complications and mortality to suture repair of intraperitoneal lesions. Furthermore, patients treated with diversion associated with direct repair showed significantly longer hospital stays and a higher rate of postoperative complications than those who received direct repair without ostomy. Therefore, direct repair not associated with ostomy diversion may represent a viable strategy for the surgical management of isolated extraperitoneal lesions [3]. However, Brown et al. [8] suggested that extensive mobilization of the rectum should not be performed just to repair a rectal injury. Some authors observed, in appropriately selected patients, that secondary intention healing of extraperitoneal traumatic lesions of the rectum was possible. The conservative management of this type of full-thickness lesion has already been described in the literature after resection of rectal cancer and iatrogenic retroflexion rectal lesions during colonoscopy [12–14]. Associated urological injuries are common, with an incidence of approximately 25% in some studies, and although they are more frequent when the trauma is due to penetrating wounds, while approximately 40% of these injuries occurred following blunt trauma. Therefore, this type of accompanying injury should be suspected in patients with urinary symptoms or an abdominal fluid collection associated with poor urine output; in such cases, it is necessary to perform further diagnostic tests such as computed tomography with contrast or cysto-urethrography. According to some authors, patients with associated urological and rectal le-
sions more frequently underwent fecal deviation than those without urological lesions, with equivalent outcomes [3,15].

The optimal management for extraperitoneal penetrating rectal injuries continues to evolve. We now know that every injury is unique, but previously all of these cases were treated with a “one size fits all” approach. In patients with a higher risk of complications who cannot achieve early abdominal closure, fecal diversion should be considered after damage control laparotomy. Primary repair with fecal diversion is the mainstay of treatment for extraperitoneal injuries; moreover, a conservative approach to rectal lacerations with an internal balloon in a rectal probe could provide a possibility for healing with a lower risk of complications.

NOTES

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

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

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Author contributions
Conceptualization: LF, AB, RS; Data curation: LF, AB; Formal analysis: LF; Methodology: RS; Project administration: RS, SG; Supervision: RS, SG; Validation: RS, SG; Writing–original draft: LF, AB; Writing–review & editing: all authors.

All authors read and approved the final manuscript.

REFERENCES


Exercise-induced traumatic muscle injuries with active bleeding successfully treated by embolization: three case reports

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INTRODUCTION

Muscle injuries are common, accounting for 10% to 55% of all injuries that occur during exercise. Traumatic muscle injuries can be classified into four groups: strain due to indirect stretching, contusion after a direct impact, laceration caused by penetrating trauma, and compartment syndrome due to increased pressure [1,2]. Strains or tears are the most common type of muscle injuries caused by an indirect mechanism in noncontact activities [1].

Traumatic muscle injuries are generally managed conservatively with rest, ice compression, immobilization, or medication. However, more aggressive treatments, such as surgery or percutaneous transcatheter arterial embolization (TAE), may be required in the following situations: hypovolemia with a large hematoma or active bleeding, complete rupture of the muscle belly or musculotendinous junction, or failure of nonoperative management [2–6].

Herein, we report the first case series of exercise-induced traumatic muscle ruptures (the rectus abdominis, adductor longus, and iliopsoas muscles) with active bleeding from indirect trauma that were successfully managed using TAE. Based on these cases, we would like to discuss the role of TAE in bleeding control of such injuries.

The Institutional Review Board and the Ethics Committee of Dankook University Hospital approved the study (No. DKUH 2022-01-019). The Institutional Review Board waived the need for informed consents because the study was conducted as a secondary review of the charts.
CASE REPORTS

Case 1
A 55-year-old female patient was admitted to the emergency room (ER) with abdominal pain that had occurred while she was performing a sit-up exercise. She had received successful curative treatment for gastric cancer and megaloblastic anemia. Her initial vital signs were stable, with a blood pressure (BP) of 138/86 mmHg and a heart rate (HR) of 87 beats per minute (bpm). A physical examination revealed tenderness in the right lower quadrant (RLQ) of the abdomen without definite signs of peritoneal irritation. The initial hemoglobin level was 13.3 g/dL. Abdominopelvic computed tomography (APCT) showed an organized hematoma in the right rectus abdominis muscle (RAM) with active bleeding (Fig. 1A, B). The patient underwent angiography, and focal active contrast leakage was found in the branch of the right inferior epigastric artery (Fig. 1C). TAE was then performed at the proximal site of bleeding using n-butyl cyanoacrylate and gel-foam (350–560 μm), and the distal part was also embolized with microcoils (Fig. 1D). Since collateral vessels to the inferior epigastric artery arise from the superior epigastric artery, both proximal and distal protection was necessary. On hospital day 5, the patient was discharged without any complications.

Case 2
A 50-year-old male patient was transferred to the ER with swelling and pain in the right inguinal area after kicking a ball while playing soccer. He had a history of hypertension and dyslipidemia. His initial vital signs were stable (BP, 138/86 mmHg; HR, 87 bpm) with a hemoglobin level of 13.5 g/dL. Despite the patient’s hemodynamic stability, APCT showed a large and non-liquefied hematoma in the right adductor longus muscle with focal contrast extravasation (Fig. 2). Contrast leakage on angiography was not obvious, despite a thorough inspection of the right profunda femoris, obturator, and medial circumflex arteries. Therefore, nonselective embolization with gel-foam was performed on the corresponding vessels in the CT. On hospital day 4, the patient was discharged with a full recovery.

Case 3
A 66-year-old male patient with a history of diabetes was admitted to the ER complaining of abdominal pain in the RLQ caused by kicking straw in a barn. The patient’s BP was 145/67 mmHg and HR was 88 bpm on arrival. A physical examination showed RLQ tenderness but no rebound tenderness. Initially, the hemoglobin level was 9.0 g/dL, but it dropped to 7.6 g/dL an hour later. APCT showed intramuscular hematoma with contrast leakage in the right iliopsoas muscle (Fig. 3). On subsequent angiography, no contrast leakage was visible in the right iliolumbar, obturator, and deep circumflex iliac arteries. However, systematic TAE of the corresponding vascular areas based on the CT scan was performed using gel-foam, and the postprocedural hemoglobin level increased to 8.5 g/dL. There were no immediate complications, and the patient was transferred to another hospital according to his request.

DISCUSSION

In indirect trauma of muscles, the main cause of injury is an eccentric contraction beyond tolerable forces of the affected muscles. Therefore, biarticular muscles containing fast-twitch type II fibers with a pennate structure are frequently involved [1,3,7]. Likewise, the injuries in all three of these cases occurred in the eccentric phase of muscle contraction after an indirect insult. In

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Fig. 1. Case 1. (A) Axial and (B) coronal views of computed tomography, showing a hematoma in the right rectus abdominis muscle with extravasation (arrows). (C) Angiography showing contrast leakage in the right inferior epigastric artery branch (arrow). (D) Disappeared extravasation (arrow) after successful embolization (asterisks).
case 1, an abdominal wall injury occurred after overuse of the torso by repetitive activities. In cases 2 and 3, the thigh muscles were ruptured, corresponding to the most common location of injuries in professional kickers [8].

Although CT is the gold-standard diagnostic tool for blunt trauma, ultrasonography and magnetic resonance imaging are prioritized in acute muscle injuries due to their excellent spatial and soft-tissue contrast resolution [1,9]. Nonetheless, CT was used to establish the definitive diagnosis in the current cases, for two reasons. First, common intraabdominal pathologies should be ruled out, especially if pain is present in the RLQ and inguinal region. Second, a traumatic hemorrhage was suspected in the case 3 due to dropped hemoglobin level. A jet of contrast material within the hematoma on CT is a sign of active bleeding [6]. This radiologic finding is associated with unsuccessful conservative management, and therefore can serve as an indication of

Fig. 2. Case 2. (A) Axial and (B) coronal views of computed tomography showing a hematoma with extravasation in the right adductor longus muscle (arrows).

Fig. 3. Case 3. (A) Axial and (B) coronal views of computed tomography showing an intramuscular hematoma with extravasation in the right iliopsoas muscle (arrows).
TAE [6]. Although TAE has been extensively utilized for various types of traumatic hemorrhage (e.g., solid organ injuries or pelvic fractures), with its advantages of being selective and relatively noninvasive, it has been suggested less frequently for hemostasis in muscles due to the scarcity of available data [6].

The superiority of surgery over TAE in muscle injuries, or vice versa, has not yet been proven by a well-designed study. The surgical ligation of bleeders within the muscle is limited due to the inability to localize the vascular pedicles, while an advantage of surgery is the ability to remove the entire hematoma or necrotic tissue [1,2,5]. According to Rimola et al. [5], who described the use of TAE to treat 12 patients with spontaneous RAM hematoma, a 100% hemostasis rate with no recurrence or complications was obtained. Although these results were confined to patients who underwent anticoagulation therapy, the study was the largest series demonstrating that TAE could be an effective and safe option for persistent RAM bleeding. Moreover, a lack of contrast leakage on angiography cannot guarantee the cessation of active bleeding in 10% to 20% of cases [10]. Therefore, TAE can be performed at suspicious vessels based on CT scans, as in our cases 2 and 3. Gel-foam is an excellent agent for prophylactic embolization, which promotes temporary vascular occlusion, allowing reperfusion within 2 weeks [10].

Hence, we propose reserving surgery for the following situations in traumatic muscle bleeding: TAE failure, the need to evacuate a very large hematoma or area of necrotic tissue, hemodynamic instability, and the development of compartment syndrome in any extremity. An earlier diagnosis and TAE may produce better clinical outcomes in traumatic muscle hemorrhage, if the candidates are properly selected. This suggestion must be adopted with caution, since future studies with larger samples are needed to establish detailed selection criteria for performing TAE in trauma patients.

NOTES

Ethical statements
The Institutional Review Board and the Ethics Committee of Dankook University Hospital approved the study (No. DKUH 2022-01-019). The Institutional Review Board waived the need for informed consents because the study was conducted as a secondary review of the charts.

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

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Author contributions
Conceptualization: YH, DHK; Data curation: YH, HLK; Formal analysis: YH, DHK; Methodology: DHK; Project administration: DHK; Visualization: YH, HLK; Writing–original draft: HLK; Writing–review & editing: YH, DHK.

All authors read and approved the final manuscript.

REFERENCES
INTRODUCTION

The increased utilization and accessibility of nail guns have been accompanied by a parallel increase in the number of emergency department visits resulting from nail gun-related accidents in both consumers and construction workers [1]. Primary injuries tend to be located in the upper extremities, particularly the hands and digits, although numerous case reports have described facial, cranial, and low cervical injuries. However, a paucity of literature exists regarding high cervical spine injuries with vertebral artery involvement [1–6]. Here, we report a rare case of a high cervical spine nail gun injury with unilateral vertebral artery involvement treated with vertebral artery embolization and subsequent removal of the nail projectile.

CASE REPORT

History and presentation

The patient was a 50-year-old right-handed man with no significant past medical history. He was transported to the emergency department by family after an alleged accidental nail gun discharge when he dropped the nail gun while framing a home, embedding a nail in his right upper neck below the ear (Fig. 1A). The patient reported neck pain and a decreased range of motion when looking right. He had no headaches, nausea, vomiting, changes in vision, weakness, paresthesia, or bowel/bladder incontinence. Examination revealed that he was neurologically intact and his head was rotated slightly to the left. The nail head was visible above the skin with notable indentation of the surrounding tissue. No signs were present of acute blood loss or hemato-
ma formation in the area. The patient reported occasionally taking 325 mg of aspirin.

The initial history and physical assessment were immediately followed by diagnostic imaging to better understand the extent of the injury and potential neurovascular structure involvement. Computed tomography (CT) of the head and CT/CT angiography of the neck were performed, revealing an approximately 3-inch-long nonbarbed nail entering the right C2 transverse process and penetrating the right transverse foramen, producing a grade IV vertebral artery injury. Occlusion of distal flow was seen in the V3 segment of the right vertebral artery, with distal reconstitution just above the nail from collateral supply (Fig. 1B). No notable hematoma was observed surrounding the affected vertebral artery. The nail traversed the C2 vertebral body, left C1–C2 facet, and C1 lateral mass and terminated in the left C1 transverse process (Fig. 1C). Additionally, an acute right C7 transverse process fracture was present. Head CT revealed no acute cranial or intracranial abnormalities including, but not limited to, cranial fractures or intracranial hemorrhage. The patient’s tetanus vaccination status was reviewed, and no antibiotics were given. In this case, the decision was made to remove the projectile to improve range of motion and reduce infection risk.

**Operation**

General anesthesia was induced with propofol, midazolam, fentanyl, rocuronium and succinylcholine, and local anesthesia with lidocaine. Prior to removal of the nail, coiling of the right vertebral artery was performed. First, the femoral artery was catheterized with subsequent diagnostic angiography of the bilateral vertebral arteries and common carotid arteries (Fig. 2A). The right vertebral artery demonstrated good opacification with notable stenosis and dissection at the point of injury; distal flow was noted to be quite slow, but appreciable washout from the occipital artery was present (Fig. 2B). The left common carotid artery was not visualized during the procedure. Complete patency of the left vertebral artery was observed, without discernible vessel wall dissection or impingement. Of note, the right occipital artery was found to anastomose with the posterior circulation.

Coiling of the right vertebral artery was performed both distal and proximal to the nail to prevent hemorrhage (Fig. 2C). Access via the right vertebral artery allowed an SL-10 microcatheter (Stryker Neurovascular, Fremont, CA, USA) to be advanced around the nail and to be coiled from the distal V3 back to the distal V2 segment with detachable platinum coils (Target XL, Stryker Neurovascular). Subsequently, the nail was removed using a vice grip with an attached slap hammer (Fig. 3). The right vertebral artery was then immediately revisualized, demonstrating residual distal flow. This prompted additional coil placement to completely occlude distal flow (Fig. 4A).

**Postoperative course**

The patient tolerated the procedure well and displayed no post-
operative neurologic deficits. Postoperative magnetic resonance imaging (MRI) scans of the brain and cervical spine showed no evidence of stroke or spinal cord injury. After discharge on postoperative day 2, the patient was instructed to take 81 mg of aspirin once daily and follow-up in 4 weeks.

At the follow-up appointment, the patient had no acute complaints other than some slight discomfort with neck rotation to the left. A neurological exam yielded no concerns regarding muscle weakness in any of the extremities. Upright and flexion-extension cervical spine X-rays, as well as cervical CT angiography, indicated no change in vertebral alignment and no altered positioning of the embolization coils in the right vertebral artery (Fig. 4B).

Informed consent for publication of the research details and clinical images were obtained via general treatment consent.
DISCUSSION

Vertebral artery involvement is highly uncommon in patients with penetrating trauma, estimated at 0.5% of all cases [7]. The vertebral artery is relatively more likely to be affected in cases of blunt injury to the cervical spine or hyperextension of the neck with lateral flexion. The anatomic course of the vertebral arteries through the transverse foramina of the cervical vertebrae makes the management of patients with penetrating injuries quite intricate. In such cases, it is crucial to quickly assess the extent of vascular involvement through techniques such as CT angiography. Blind disturbance of the embedded projectile could lead to significant bleeding that would be quite difficult to manage, even surgically, as proximal and distal control of the vertebral arteries is challenging to achieve. Additionally, initial imaging can help assess the type of nail(s) embedded in the tissue, as the presence of a barbed nail or a nail with a washer could alter the treatment approach [8].

Once the initial imaging evaluation has been completed, secondary imaging to be performed includes diagnostic angiography, which allows a more focused assessment of the treatment approach. For a penetrating injury threatening a high cervical portion of the vertebral artery, an endovascular approach is the most appropriate. Numerous articles have highlighted the safety and effectiveness of endovascular embolization in treating grade I to grade V vertebral artery injuries, whether iatrogenic or trauma-induced [9–11]. Embolization proximal and distal to the site of injury is the recommended method, as it minimizes potential bleeding as the foreign object is extracted. This approach is ideal for nail penetration injuries, as the nail can be regarded as a low-velocity projectile. Thus, tissue damage is localized along the trajectory of the nail, unlike with a high-velocity projectile such as a bullet, which causes extensive damage to surrounding tissue due to cavitation [12,13]. Final assessment of vessel embolization also remains important; another case series discussing endovascular treatment of vertebral artery injuries saw only an 89% rate of immediate total occlusion [9]. Notably, the reliance on interventional radiology for treating penetrating vertebral artery injuries requires a facility with the necessary equipment. When a penetrating vertebral artery injury occurs in a rural setting, the extent of the injury must be assessed to determine patient stability for transport to a tertiary care center. Surgical treatment of a penetrating vertebral artery injury is possible and has been documented, but this has generally been reserved for cases involving uncontrolled bleeding, suspected spinal cord injury, or vertebral instability [8,14].

When pursuing endovascular rather than surgical treatment for a penetrating injury, particularly with bony involvement as in the present case, assessing the stability of the cervical spine after removal of the foreign object is also of extreme importance. The cervical spine is much more susceptible to biomechanical instability than the thoracic spine, and extra precautions must therefore be taken in cases of projectile injuries. Thus, we obtained postoperative upright cervical spine X-rays to ensure general spinal stability. If possible, an MRI scan should also be obtained for a more precise examination of the stabilizing ligaments in the cervical spine. In particular, the atlantooccipital junction and atlantoaxial joints should be localized, as these are regions at high risk of injury in cases like the present one.

Finally, when dealing with uncommon mechanisms of purportedly accidental injury, the shape of the penetrating nail can hint at a potential cause, with bent nails suggesting a ricochet. In contrast, injuries involving straight nails, as in the present case, could result from a non-accidental or an accidental discharge. The location of the injury can also suggest a primary mechanism; upper extremity injuries are most likely to be due to accidents, while cranial/intracranial, cervical, or abdominal involvement is much more likely in cases of attempted self-harm [15]. An injury side corresponding with patient handedness may also increase the suspicion of self-harm. Cervical nail gun injuries appear to be quite a rarity in the published literature, and thus, little can be deduced from the location of the injury in the present circumstance. Detailed history taking and, if possible, cross-referencing with witnesses may be the only tools available to discern cause.

Cervical nail gun injuries are uncommon in the literature, particularly cases in which the projectile threatens a vertebral artery. Here, we present a case of such an injury, adding to the evidence suggesting that vertebral artery embolization prior to foreign body removal is a safe approach to treating nail gun-related injuries to the vertebral artery. In addition, we stress the importance of assessing the mechanical stability of the cervical spine via both upright cervical X-ray and cervical MRI postoperatively.

NOTES

Ethical statements
Informed consent for publication of the research details and clinical images were obtained via general treatment consent.

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All authors read and approved the final manuscript.

REFERENCES
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