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Stratification of Musculoskeletal Injuries Caused by Tree Stand Falls During Deer Hunting: A Single Health System Retrospective Study

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Abstract

Background/Objectives: Tree stand falls have become one of the leading causes of hunting-related injuries in the United States, surpassing firearm incidents. These injuries often result in significant morbidity, particularly musculoskeletal trauma, yet detailed anatomical stratification of fractures remains underreported. The purpose of this study is to classify and analyze the anatomical distribution of musculoskeletal injuries sustained from tree stand falls during deer hunting and to describe associated demographics, injury severity, and resource utilization in a rural health system. **Methods**: A retrospective review was conducted on patients aged ≥18 years who presented to a Level I or II trauma center in central Pennsylvania between 2005 and 2020 following a tree stand fall. Data were extracted from electronic medical records and trauma registry, including demographics, mechanism of injury, fracture location, Injury Severity Score (ISS), Intensive Care Unit (ICU) admission, and discharge disposition. Two orthopedic surgeons independently reviewed radiographs for accuracy. **Results:** A total of 144 patients were included (mean age was 53.0 ± 14.6 years; 143 of 144 were male). Falls had a median height of 15 ft (range, 2–45 ft), with harness use documented in only 2 patients. The mean ISS was 11.97 (range 2–36). Twenty patients required ICU admission (mean stay 4.8 days), and seven required mechanical ventilation. Most injuries occurred between October and December. Fractures most frequently involved the spine (36.3%), followed by the thorax (ribs and sternum; 36.1%), the hip and lower extremity (9.0%), the pelvis (9.0%), the shoulder and upper extremity (6.0%), and the skull and facial bones (3.5%). No fatalities were recorded. **Conclusions:** Tree stand falls during deer hunting result in complex, multi-system injuries with high resource utilization but low mortality. Spine and thorax fractures predominate, underscoring the need for trauma centers serving hunting communities to maintain subspecialty capabilities in orthopedic, spine, thoracic, and multidisciplinary trauma care. Preventive strategies, including targeted safety education during peak hunting months, may be implemented to potentially reduce injury burden.

Keywords: accidental falls; hunting; orthopedic injuries; spinal fractures; deer; retrospective studies

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1. Introduction

In the United States, hunting is a popular sport and recreational activity. It is generally a regulated activity depending on the state in which it is practiced, and everyone wishing to engage in this practice must have a license. According to the National Research Department's 2021 National Hunting License Report, there were approximately 15.2 million license holders in the U.S. [1]. In the state of Pennsylvania, the percentage of residents with paid hunting licenses is 7.3%. This corresponds to an estimated 930,000 paid license holders, making it the second-most-licensed state in the country. The 2019–2020 season was particularly successful for hunters in the state of Pennsylvania, with the most significant growth in deer hunting in the last 15 years [2]. Overall, among the big game species, deer are the most popular game species pursued by hunters, and Pennsylvania deer hunters have harvested more deer per square mile than any other state in the nation [3].

Tree stand falls have emerged as one of the leading causes of hunting-related injuries, surpassing firearm incidents in recent decades, according to a national analysis of US emergency department visits [4]. This national finding is further corroborated by regional studies indicating that these injuries predominantly affect middle-aged male hunters, with low mortality but significant morbidity. Data from a statewide trauma registry revealed that fall rates increased markedly over time, while shooting incidents declined, with falls becoming the most common mechanism by 1999; although fatality rates were low, most victims sustained multiple injuries and functional limitations [5]. Recent case reviews further highlight that falls often involve severe orthopedic trauma, sometimes requiring surgical intervention, underscoring the need for strict adherence to tree stand safety guidelines [6]. Several additional retrospective series corroborate these findings: across cohorts ranging from 22 to 54 patients, spinal fractures were the most frequent injury (54–59%), with neurologic deficits in up to two-thirds of affected patients, and reported risk factors included falls from heights exceeding 10–11 feet, infrequent or absent safety harness use (documented in only 2–11% of cases), and alcohol intoxication in a minority of patients (4–10%) [7–10]. In addition to alcohol, recreational and prescription drug use has been reported as a contributing risk factor in hunting-related falls, and substance use is recognized as a particular public health concern in rural communities, where access to hunting grounds is widespread [11].

Despite the insights provided by previous studies, none have delineated the precise anatomical distribution of musculoskeletal fractures, which could prove critical for optimizing resource allocation and subspecialty care in rural hospitals managing these injuries. Accordingly, the objective of this retrospective study was to systematically classify and categorize the exact locations of musculoskeletal injuries sustained in tree stand falls among hunters presenting to level I and II trauma centers in north Appalachia, while also characterizing patient demographics, injury mechanisms, morbidity, and mortality associated with these orthopedic injuries.

2. Materials and Methods

An Institutional Review Board (IRB)-approved (GIRB 2022-0575 on 13 March 2024) retrospective review and analysis was conducted in all patients 18 years or older, treated in a single health system in north Appalachia (central Pennsylvania) between 2005 and 2020, who presented to the institution because of a fall from a tree stand while hunting. The study period was selected because the institution's trauma registry and electronic medical record system began reliably capturing searchable, codified data for tree stand/hunting-related mechanisms of injury starting in 2005, and the period was closed at 2020 to limit confounding from the COVID-19 pandemic, which was associated with substantial disruptions in trauma center volumes, hunting patterns, and healthcare-seeking behavior nationally.

The data for this study were obtained from the electronic medical records and trauma registry records that matched the terms "deer stand", "hunting stand", "tree stand", "deer", "hunting", and "hunt". After filtering, charts were individually reviewed to confirm the cause of injury and to collect data on patient demographics, injuries sustained, severity scores, length of stay, transfer status from other trauma institutions, need for intensive care unit admission, date of injury, incidence of alcohol and recreational drug use, and mortality. The study data were stored in a secure database on a password-protected system, with server access restricted to the study team. Study ID numbers were randomly assigned, and analyses were conducted using the codified data to protect patient identity. Only group-level data without protected health information were used to present results.

For the purposes of this study, a tree stand fall was defined as an unintentional descent from an elevated hunting platform (commercial or homemade, fixed or climbing) affixed to or positioned against a tree, occurring during ascent, descent, occupancy, installation, or removal of the stand while performing a deer hunting activity, resulting in a presentation for medical evaluation. We included patients who sustained a fall from a tree stand during deer hunting or related activities and presented to the hospital via the emergency department or the outpatient clinic. Patients with mechanical falls that were hunting-unrelated, patients with only non-orthopedic injuries, patients younger than 18 years, and patients with isolated soft-tissue injuries (abrasions, lacerations, sprains or muscle injuries) were excluded. For all included cases, clinical documentation, including admission records, operative notes, and follow-up visits, was thoroughly reviewed. Additionally, radiographic images were independently assessed by two orthopedic surgeons to ensure accuracy and consistency in data extraction. Collected variables included patient demographics, mechanism of injury, fracture type and anatomical location, intensive care unit (ICU) admission data, and details of clinical management. Surgical management was defined as documented fixation, operative reduction, repair, debridement, fusion, amputation, or another comparable therapeutic operation. Patients without a documented qualifying operation were classified as conservatively managed.

Injury severity was quantified using the Injury Severity Score (ISS), an anatomically based score derived from the Abbreviated Injury Scale (AIS). Injuries were assigned AIS severity values from 1 (minor) to 6 (maximal) within six body regions: head/neck, face, chest, abdomen/pelvic contents, extremities/pelvic girdle, and external injuries. The ISS is calculated as the sum of the squares of the highest AIS scores in the three most severely injured body regions. ISS values were obtained from the institutional trauma registry. No separate face- or internal-validity assessment of the ISS was performed in this retrospective cohort.

Statistical Analysis

Exploratory analyses were performed to examine associations among age, ISS, fracture location, ICU admission, and discharge disposition. Where applicable, Pearson correlation coefficients were used for continuous-variable associations, and group means were compared using two-sided Welch t tests. Fracture-region distributions were summarized according to ICU admission and discharge disposition. These secondary analyses were hypothesis-generating, and a two-sided p value < 0.05 was considered statistically significant. Statistical analysis was performed using Microsoft Excel software, version 2507 (Microsoft Corporation, Redmond, WA, USA), and MedCalc Statistical Software, version 24.0.3 (MedCalc Software Ltd., Ostend, Belgium).

3. Results

A total of 163 patients were screened from the electronic medical record and trauma registry using the search terms described above. Of these, 19 were excluded following application of the selection criteria, resulting in 144 patients included in the final analysis. The median fall height was 15 ft (range, 2–45 ft, recorded for 126 patients) during hunting-related activities. There was no documentation on the use of harnesses during the activity in all but 2 patients.

The mean age of patients was 53.0 ± 14.6 years (range, 19–87 years), and 143 of 144 patients were male. Serum alcohol testing was performed in 98 patients, of whom 7 (7.1%) tested positive. Drug screening was performed in 95 patients (66.0% of the cohort), of whom 61 (64.2%) tested positive for at least one recorded substance and 34 (35.8%) were negative for all substances. Opioids or narcotics were detected in 55 patients (57.9% of those screened), benzodiazepines in 11 (11.6%), cannabis (tetrahydrocannabinol [THC]) in 4 (4.2%), and amphetamines in 3 (3.2%), with some patients having overlapped narcotic findings. Twelve patients had two or more recorded drug classes, representing 19.7% of positive screens. Because the timing and source of these substances could not be determined, positive results were considered evidence of exposure rather than evidence that substance use contributed to the fall.

The Injury Severity Score (ISS) had a mean value of 11.97, with a minimum of 2 and a maximum of 36. Twenty of 144 patients required admission to the Intensive Care Unit for a mean of 4.8 days, and 7 patients required mechanical ventilation for 1–12 days. For patients who did not require ICU admission, the average length of stay was 3.8 days. One hundred of 144 patients were discharged home, while 11 of 144 were discharged to a skilled nursing facility, 28 of 144 to a rehabilitation center, and 5 of 144 patients were referred to another trauma center or transitional care unit.

We identified injuries occurring between 2005 and 2020, with an increase during the years 2011 to 2016 and a decrease in injuries in 2020. Additionally, we found that the most common months for patients presenting with this type of injury were October, with 48 cases; November, with 50 cases; and December, with 14 cases. The month with the fewest injuries was April, with no cases (Figure 1).

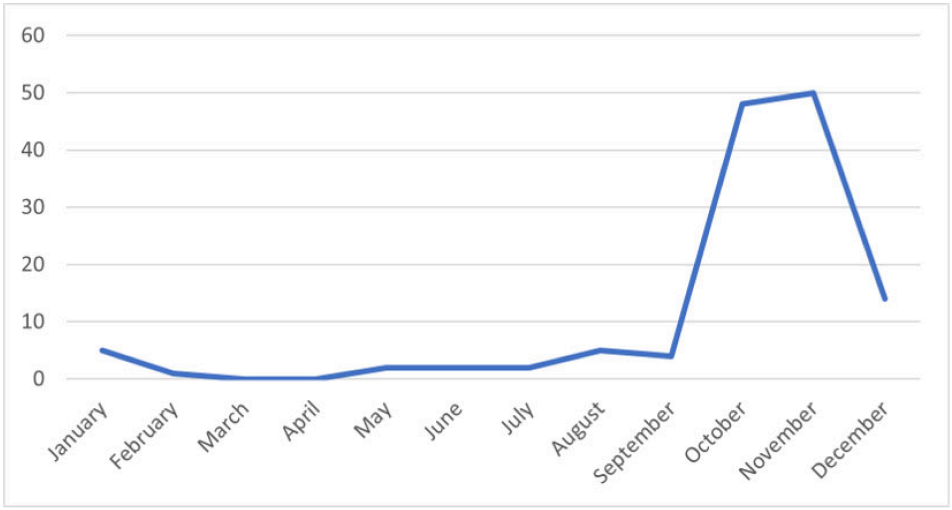


Figure 1. Illustration of the injury numbers by month.

Of the 144 patients, 142 patients had at least one fracture: 33 (23.2%) had a single fracture and 109 (76.8%) had multiple fractures while two patients had no counted fractures. The most common injuries were spine fractures, accounting for 229 of 631 fractures (36.29%): lumbar (124, 19.65%), thoracic (73, 11.57%), and cervical (32, 5.07%). The thorax was the sec-

ond most commonly involved region (ribs and sternum; 228/631, 36.13%) (Tables 1 and 2). Forty-four patients (30.6%) underwent surgical management, whereas 100 (69.4%) were managed conservatively without a documented qualifying operation. The overall hospital length of stay was 4.8 ± 4.3 days (median, 4 days; range, 1–26 days). No deaths occurred (mortality, 0%).

Table 1. Locations of the fractures according to the body parts.

Fracture Location	Number of Fractures	Percent (%)
Spine (cervical, thoracic, lumbar)	229	36.29
Thorax (ribs and sternum)	228	36.13
Shoulder and upper extremity	38	6.02
Hip and lower extremity	57	9.03
Pelvis (pubic rami, pelvic ring, acetabulum)	57	9.03
Skull and facial bones (associated)	22	3.49
Total	631	100

Table 2. Anatomical locations of the fractures.

Fracture Location	No.	%
Spine subtotal *	229	36.29
Lumbar spine	124	19.65
Thoracic spine	73	11.57
Cervical spine	32	5.07
Ribs	218	34.55
Pubic rami	27	4.28
Skull and facial bones	22	3.49
Pelvic ring (incl. sacrum)	21	3.33
Ankle	18	2.85
Proximal tibia/tibial plateau	12	1.90
Radius	10	1.58
Sternum	10	1.58
Acetabulum	9	1.43
Humerus	7	1.11
Proximal fibula	6	0.95
Scapula	6	0.95
Clavicle	6	0.95
Fibula diaphysis	6	0.95
Femur diaphysis	5	0.79
Ulna	5	0.79
Carpi and metacarpi	4	0.63
Tarsal and metatarsal bones	4	0.63
Hip	2	0.32
Tibia diaphysis	2	0.32
Patella	2	0.32
Shoulder dislocation **	11	–
Ankle dislocation **	2	–

* Spine subtotal is the sum of cervical, thoracic, and lumbar fractures and is not included separately in the overall percentage total. ** Shoulder and ankle dislocations are excluded from the fracture-percentage calculations.

Exploratory Comparative Analysis

Age was not associated with ISS ($r = -0.05$, $p = 0.524$). Patients admitted to the ICU had a higher mean ISS than those not admitted to the ICU (19.6 vs. 10.7; $p < 0.001$). Age did

not differ according to ICU admission. Patients discharged to destinations other than home were older than those discharged home (58.2 vs. 50.7 years; $p = 0.007$). Pelvic fractures had the highest proportion of non-home discharge (60.0%), while skull/facial fractures had the highest ICU-admission proportion (25.0%); these fracture-location comparisons were descriptive because patients could have injuries in multiple regions. Fall height was frequently documented as approximate ranges, precluding reliable assessment of its association with injury severity.

4. Discussion

This study reviewed the types and locations of tree stand-related fractures during deer hunting at Level I and II trauma centers in central Pennsylvania. The most common fracture region was the spine (36.3%), followed closely by the thorax (36.1%). Pelvic and hip/lower-extremity fractures were tied at 9.0% each.

Tree stand-related injuries are more common than gun-related hunting injuries [4–6]. According to a study on the epidemiology of hunting stand injuries, it is estimated that there are more injuries from falls from tree stands than from gunshots. These injuries occurred predominantly in white males with an average age of 40 years and were associated with a low mortality rate but significant morbidity [4]. In another study that utilized a statewide trauma registry from 1990 to 2017, researchers found that tree stand falls were the most common cause of injuries during deer hunting, and that fall rates increased significantly from 1.5 to 10.4 per million hunting days, while hunting-related shooting incident rates decreased from 4.9 to 1.2, with falls surpassing shooting incidents in 1999 and becoming most common among hunters aged 50 to 59 years. Although the case fatality rate was low (0.8%), 77% of victims sustained multiple injuries, and 26% had functional limitations at discharge. The authors emphasized the need for ongoing surveillance and improved tree stand safety education [5].

In another recent study, Lachance et al. (2025) reviewed 38 cases of tree stand falls over 10 years and found that most victims were male (94.7%) with an average fall height of 13.8 ft (4.22 m) [6]. Nearly half sustained orthopedic injuries involving the extremities, spine, or pelvis, and 18% required surgical intervention. Although nonoperative management was most common, injuries were often severe and potentially fatal. The authors emphasized that multiple factors contribute to these falls and highlighted the importance of strict adherence to tree stand safety guidelines [6].

Other studies also highlighted the significant morbidity associated with tree stand falls among hunters. Lazzara et al. reported that at a Level II trauma center, 33 patients sustained injuries between 2015 and 2019, with spinal (33%) and lower extremity fractures (15%) being the most common; notably, one-third of cases were nonadmitted yet required specialist care [12]. Crockett et al. analyzed 130 hunting-related injuries over 10 years and found that falls, 92% from tree stands, accounted for 50% of cases, often resulting in severe trauma such as spinal fractures (59%) and lower extremity fractures (47%), with 81% requiring surgery [13]. Similarly, Carroll et al. reviewed 193 cases at a Level I trauma center and observed that falls from heights greater than 20 feet were linked to higher injury severity, while safety harness use was alarmingly low (<3%), emphasizing the need for preventive measures [14]. Major debilitating consequences of tree stand injuries include neurological damage and the need for longer hospital stays or admission to rehabilitation centers [15–17].

The Tree Stand Manufacturers Association has made significant efforts to actively reduce accidents related to the use of stands. Studies have demonstrated that younger patients are at higher risk of tree stand injury, likely related to incorrect use of stands and lack of safety equipment. Older patients, however, may present with more debilitating

injuries, and the potential for long-term effects can create both physical and economic consequences for patients and their families [16]. In the present study, harness use was documented in only 2 of 144 patients, but it should be noted that proper use of a harness would prevent a fall of more than 3–4 feet [18]. Some available studies suggest that the average fall height is 18 feet [19]. In our study, the median fall height was 15 feet (range, 2–45 feet).

Several factors have been identified as risk factors for tree stand falls, such as structural failure, slips while entering or exiting the stand, alcohol use, and falling asleep [19]. In our study, we identified 7 patients with a positive alcohol test, but of the 144 patients included, only 98 were tested. Additionally, 61 of 95 patients tested positive for substances, including THC, benzodiazepines, amphetamines, and other narcotics; however, the specific substance, timing, and relationship to the fall could not be determined in most cases, as only 21 of the 144 patients overall had a positive alcohol test or an identifiable, named substance (THC, benzodiazepine, or amphetamine) on screening, while the remainder of positive drug screens reflected nonspecific opioid/narcotic detection of uncertain source. Given the increased burden of substance use in Appalachian communities and its impact on hunting-related injuries [11], toxicology screening at the time of injury may warrant consideration to better characterize this potential risk factor in future studies.

Our study shows that most injuries were not isolated but were associated with other musculoskeletal and systemic injuries. Rib fractures were also common in our cohort, and even isolated rib fractures may result in prolonged pain-related disability [20]. The fall height associated with increased injury severity varied between studies. One study showed that tree stand falls higher than 11 ft were associated with more severe neurologic injuries [7]. Other studies found that falls from 20 ft or taller were associated with a higher ISS [12,14].

Among the patients in our study, 20 required intensive care, reflecting the severity of their injuries, which included not only orthopedic trauma but also cranial and intra-abdominal injuries. Consistent with our findings, a previous study reported that lumbar spine fractures were among the most frequent injuries following tree stand falls and emphasized that the pattern of skeletal injuries is influenced by the site and position of impact. Furthermore, that study identified high-level falls as a predictor of increased Injury Severity Score (ISS), prolonged hospital stay, lower Glasgow Coma Scale (GCS) scores, and greater need for blood transfusions [17].

Regarding the timing of highest incidence, tree stand-related falls in our study occurred most frequently between October and December. This trend aligns with data from the Game Commission, which indicates that hunting season typically begins in mid-September and extends through mid-January of the following year [21]. The overlap between peak hunting activity and increased fall-related injuries underscores the importance of targeted safety interventions during this period.

Study Limitations

Our study has several limitations. Its retrospective design restricts causal inference and relies on the accuracy of existing records. Second, the findings are primarily descriptive and may be most relevant to regions where hunting is common. As a single-health system study, our cohort is also subject to potential selection bias, as it reflects only patients who presented to one regional trauma system, and incomplete documentation resulted in missing data for several variables, including alcohol/drug testing and harness use, which was documented in only 2 of 144 patients. Additionally, this study lacked a non-injured or alternative comparison group, limiting our ability to assess relative risk. Several comparator studies discussed above were conducted in other US regions, including the Midwest

(Michigan, USA) and national emergency department surveillance samples, rather than the Appalachian region of this cohort; regional differences in terrain, deer density, climate, hunting regulations, and tree stand design may limit the direct comparability of injury patterns and incidence estimates across these studies. Moreover, pre-existing musculoskeletal injuries and baseline functional limitations were not systematically captured; therefore, their potential influence on fall risk and outcomes could not be assessed.

Despite these limitations, the study represents one of the largest series of tree stand-related orthopedic injuries to stratify fractures by anatomical location. This level of detail is clinically significant because it highlights the complexity of injuries sustained in these accidents and underscores the need for hospitals serving hunting communities to be equipped with appropriate facilities and subspecialties, particularly spine and orthopedic trauma, to manage these cases effectively.

In summary, this study is among the first to specifically evaluate orthopedic injuries in patients who sustained mechanical falls from deer stands while hunting. Although further research is needed to assess the medium- and long-term impact of these injuries on patients' quality of life, our findings provide emergency and trauma physicians with a practical overview of the injury patterns most commonly encountered in this population. Recognizing these patterns during initial assessment is critical to avoid underdiagnosis and undertreatment, ensuring timely and appropriate management.

5. Conclusions

Our analysis revealed that many patients sustained multiple injuries, with 20 requiring intensive care, yet mortality remained zero, consistent with prior reports of low fatality rates. Although no deaths occurred in this cohort, the injuries were associated with substantial morbidity and resource utilization. Given the low documented rate of harness use observed in this cohort, these findings highlight a potential area for future preventive research. State agencies, such as the Game Commission, have implemented initiatives such as free online archery safety courses to promote tree stand safety. Broader adoption of these measures could reduce injury rates, lower healthcare costs, and minimize the long-term impact on hunters' lives.

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Informed Consent Statement: Waived by the IRB due to the retrospective nature of the study. The study did not involve identifiable personal information.

Data Availability Statement: Data are available from the authors upon reasonable request after fulfilling a formal, institutional data-use agreement.

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Conflicts of Interest: The authors declare no conflicts of interest.

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