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Original Article

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Radiological Findings in Pediatric Firearm Extremity Injuries

Pediatrik Ateşli Silah Ekstremite Yaralanmalarında Radyolojik Bulgular

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ABSTRACT

Objective: To evaluate the damage to soft tissue and bone, the presence of foreign bodies within the tissue, and associated injuries in firearm-related extremity injuries in children with different weapons, based on radiological findings.

Material and Methods: Patients who were admitted to the pediatric emergency department of University of Health Sciences Türkiye, Adana City Training and Research Hospital between January 1, 2018, and December 31, 2021, with firearm-related extremity injuries were included. Data on age, gender, weapon type, radiological examinations, hospitalization, intervention status, and clinical outcomes were collected. Radiological images were evaluated to determine soft tissue and bone damage, the presence of foreign bodies, and associated injuries.

Results: Among the 72 cases, 80% were male, with a median age of 164.6 months. Injuries were caused by shotguns in 51% and by handguns in 36%. Among those injured by handguns, 18 cases had isolated soft tissue injuries, 1 had vascular injury, and 7 had bone fractures. In six of the cases with isolated soft tissue injuries, the bullet core was surgically removed under local anesthesia. Five patients with bone fractures and one with vascular injury were hospitalized and underwent surgical treatment. Among those injured by shotguns, 33 cases had isolated soft tissue injuries, 2 sustained bone fractures, 1 sustained both a bone fracture and vascular injury, and 1 sustained nerve damage. All cases, except those with isolated soft tissue injuries, were hospitalized and received surgical treatment.

Conclusion: When a bullet core impacts bone, it tends to cause more severe damage compared to when it only passes through soft tissue. Bullet cores and shotgun pellets, that hit soft tissue can cause vascular injuries, and computed tomography angiography should be considered when vascular damage is suspected. Soft tissue injuries caused by bullet cores or buckshots can lead to nerve damage, making it essential to perform a thorough neurological examination of the injured extremity.

Keywords: Child, gunshot wounds, extremity, vascular injury, nerve damage

ÖZ

Amaç: Çocuklarda ateşli silahlar ile gerçekleşen ekstremite yaralanmalarında silah türüne göre farklılık gösteren yumuşak doku ve kemikte meydana gelen hasarı, dokuda yabancı cisim varlığını, eşlik eden yaralanmaları radyolojik bulgular eşliğinde incelemektir.

Gereç ve Yöntemler: Türkiye Sağlık Bilimleri Üniversitesi, Adana Şehir Eğitim ve Araştırma Hastanesi çocuk acil servisine 01.01.2018-31.12.2021 tarihleri arasında getirilmiş olan ve ateşli silahlar ile ekstremite yaralanması gerçekleşen olgular dahil edilmiştir. Olguların yaş, cinsiyet, silah çeşidi, radyolojik tetkikleri, hastaneye yatış, müdahale durumu ve klinik sonuçları kayıt edilmiştir. Radyolojik görüntüler yumuşak doku, kemik hasarı, dokuda yabancı cisim varlığı ve eşlik eden damar yaralanması açısından değerlendirilmiştir.

Bulgular: Çalışmaya dahil edilen 72 olgunun %80'i erkek, yaş median 164,6 (127-189) aydı. Yaralanma %51 tüfek, %36 tabanca aracılığı ile gerçekleşmişti. Tabanca ile yaralanan 18 olguda izole yumuşak doku yaralanması, 1 olguda damar yaralanması, 7 olguda kemikte kırık saptanmıştır. İzole yumuşak doku yaralanması olan 6 olguda mermi çekirdeği lokal anestezi eşliğinde cerrahi olarak çıkartılmıştır. Kemik kırığı saptanan 5 olgu ve damar yaralanması saptanan 1 olgu cerrahi olarak tedavi edilmiştir. Av tüfeği ile yaralanan 33 olguda izole yumuşak doku yaralanması, 2 olguda kemikte kırık, 1 olguda kemikte kırık ve damar yaralanması, 1 olguda sinir hasarı saptanmıştır. İzole yumuşak doku yaralanması dışındaki tüm olgular hastaneye yatırılarak cerrahi olarak tedavi edilmiştir.

Sonuç: Tüm olgulara uygun yöntemle X-ray grafi çekilmesi gerektiği, mermi çekirdeğinin kemiğe isabet etmesi durumunda sadece yumuşak dokudan geçen mermi çekirdeğine göre daha şiddetli hasar yaratacağı, yumuşak dokuya isabet eden mermi çekirdeği ve saçma tanelerinin damar yaralanmasına yol açabileceği, damar yaralanması düşünülen olgularda bilgisayarlı tomografi-anjiografi istenmesinin gerekli olduğu, aynı şekilde yumuşak dokuya isabet eden mermi çekirdeği ve saçma tanelerinin sinir hasarına neden olabileceği, yaralanan ekstemitenin ayrıntılı nörolojik muayenesinin yapılması gerektiği düşünülmektedir.

Anahtar Kelimeler: Çocuk, ateşli silah yaralanması, ekstremite, vasküler yaralanma, sinir hasarı

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INTRODUCTION

Every day, an increasing number of children are injured or killed by firearms, due to factors such as the ease of obtaining weapons, inadequate security measures during possession, negligence, and lack of education. While the extremities are the most frequently affected areas in firearm injuries (FI), the mortality rate in these cases is lower than in injuries to the head, neck, chest, and other critical regions (1-3).

Essentially, injury results from energy transfer, which depends on the ability of the bullet core or buckshot to transfer energy to the tissue. Deformation develops in the bullet core when a 9 × 19 mm handgun, a low energy weapon commonly used, strikes bone tissue. Deformation refers to the change in shape and contours of the bullet core upon impacting a hard surface. In such instances, the increased energy of the bullet core is transferred more rapidly to the surrounding tissue via the friction surface. When a bullet core hits thick bones such as the pelvis, vertebrae, femur, or humerus, the resulting fragmentation of the bullet core is referred to as primary fragmentation, while the fracturing and fragmentation of the bone itself is termed secondary fragmentation. The significance of fragmentation lies in the fact that each fragment behaves like a bullet core, increasing the extent of damage by transferring energy to the surrounding tissues, thereby further exacerbating tissue damage (4-8). Injuries caused by shotgun buckshots exhibit different characteristics from those caused by handgun bullet cores. Buckshots, fired in a cluster from a shotgun, disperse based on the shooting distance, transfer kinetic energy to the tissue, and cause tissue damage (9-11).

Based on radiological findings, the aim of this study was to evaluate the damage to soft tissue and bone, the presence of foreign bodies within the tissue, and associated injuries in firearm-related extremity injuries in children.

MATERIALS and METHODS

This cross-sectional study was conducted on patients who were admitted to the pediatric emergency department of the tertiary Adana Training and Research Hospital between January 1, 2018, and December 31, 2021, with firearm-related extremity injuries. Data on age, gender, weapon type, radiological examinations [(X-ray and/or tomography and computed tomography (CT) angiography)], hospitalization, intervention status (medical or surgery), and clinical outcomes (death or discharged) were collected. Radiological images from the hospital information management system were independently evaluated by two researchers, who were blinded to each other's assessments, to determine soft tissue and bone damage, the presence of foreign bodies, and associated injuries.

Ethical approval for the study was obtained from the Clinical Research Ethics Committee of University of Health Sciences Türkiye, Adana City Training and Research Hospital on March 14, 2024 (decision no: 3223).

Statistical Analysis

The Statistical Package for Social Sciences (SPSS 21.0; Chicago, IL) was used for data analysis. Continuous variables were expressed as the median (interquartile range: 25-75), while categorical variables were expressed as the number and percentages. A cross-tabulation was generated to examine the distribution of two different categorical variables.

RESULTS

Among the 72 cases included in the study, 80% (58/72) were male, and the median age was 164.6 (127-189) months. The injury location was the lower extremity in 67% (48/72), the upper extremity in 22% (16/72), and both upper and lower extremities in 11% (8/72). The most frequent consultations were requested from the orthopedics and cardiovascular surgery departments. Injuries were caused by shotguns in 51% (37/72) and by handguns in 36% (26/72). No information about the weapon type could be obtained for 9 cases; these patients were treated as outpatients, and no foreign body was detected in their radiographs (Table 1).

Of the 26 cases injured by handguns, 18 had isolated soft tissue injuries, 1 had vascular injury, and 7 had bone fractures. In 6 of the cases with isolated soft tissue injuries, the bullet core was surgically removed under local anesthesia. Five cases with bone fractures and 1 with vascular injury were hospitalized and underwent surgical treatment. Of the 37 cases injured by shotguns, 33 had isolated soft tissue injuries, 2 had bone fractures, 1 had both bone fracture and vascular injury, and 1 had nerve damage. All cases, except those with isolated soft tissue injuries, were hospitalized and received surgical treatment. There were no fatalities among the cases included in this study.

Bullet cores, and their related soft tissue deformation, bone fractures and vascular damage resulting from handgun injuries are shown in Figures 1-3. Buckshots and their related soft tissue deformation and bone fractures resulting from shotgun injuries are shown in Figures 4-6.

Table 1. Patients' demographic and injury findings according to weapon type				
	Total (n: 72)	**Shotgun (n: 37)**	**Handgun (n: 26)**	**Unknown (n: 9)**
Age	164.6 (127-189)	180 (157-192)	191 (158-204)	122 (69-174)
Gender				
Female	14 (19.6%)	7 (9.8%)	4 (5.6%)	3 (4.2%)
Male	58 (80.4%)	30 (41.5%)	22 (30.5%)	6 (8.4%)
Injury location				
Upper extremity	48 (66.4%)	18 (25%)	23 (31.6%)	7 (9.8%)
Lower extremity	16 (22.4%)	11 (15.4%)	3 (4.2%)	2 (2.8%)
Upper + lower extremity	8 (11.2%)	8 (11.2%)	-	-
Injured tissue				
Isolated soft tissue injury	60 (83.2%)	33 (45.6%)	18 (25%)	9 (12.6%)
Bone fracture	9 (12.6%)	2 (2.8%)	7 (9.8%)	-
Vascular injury	1 (1.4%)	-	1 (1.4%)	-
Nerve injury	1 (1.4%)	1 (1.4%)	-	-
Bone fracture + vascular injury	1 (1.4%)	1 (1.4%)	-	-
Treatment				
Medical	56 (77.8%)	33 (45.8%)	14 (19.4%)	9 (12.6%)
Surgery	16 (22.2%)	4 (4.2%)	12 (18%)	-

DISCUSSION

In our study, similar to findings in the literature, 80% of the cases were male and the median age was 164.6 months. Although the weapon type is influenced by factors such as geographical region and social and cultural differences, research in Türkiye, has shown that firearm related injuries and fatalities are more common than those caused by handguns. For instance, the weapon distribution was reported as 66% shotgun and 34% handgun in Konya; 65.8% shotgun and 34.2% handgun in İzmir; 59.4% shotgun and 40.6% handgun in Muğla; 65.8% shotgun and 34.2% handgun in Manisa, and 51% shotgun and 36% handgun in our study. The higher frequency of firearm-related injuries and deaths is attributed to their easy availability and widespread presence in homes, often stored unsafely, especially in rural areas where agriculture and animal husbandry are common (12-18).

In cases involving handguns, isolated soft tissue injuries were observed in 18 cases, vascular injury in 1 case, and bone fractures in 7 cases. In 6 cases with isolated soft tissue injuries, the bullet core was surgically removed using local anesthesia. Five cases with bone fractures and one with vascular injury required hospitalization and surgical treatment. According to our findings, cases with isolated soft tissue injuries caused by low energy weapons that do not involve vascular, nerve, or bone damage can be managed on an outpatient basis. However, when the bullet core impacts bone and causes fragmentation due to deformation, surgical treatment may be necessary. Cases with vascular injuries must be hospitalized and treated surgically.

In shotgun injuries, buckshot enter the body in clusters and disperses depending on the shooting distance, causing damage by transferring energy to the affected tissues. At close range, shotgun injuries can cause more severe damage than handgun injuries (7,11). In our study, 33 cases had isolated soft tissue injuries, 2 cases had bone fractures, 1 case had both a bone fracture and vascular damage, and 1 case had nerve damage. All cases, except those with isolated soft tissue injuries, were hospitalized and treated surgically. In one case, where an injury to the left arm was sustained, the buckshot caused significant tissue loss and ulnar nerve damage. Our findings indicate that shotguns are associated with fewer bone fractures but more vascular and nerve damage compared to handguns. Therefore, except for cases with isolated soft tissue injuries, surgical treatment, and hospitalization should be considered.

Although the severity of FI depends on the type of weapon and the area hit, extremity injuries can affect peripheral vessels, nerves, and the spinal cord, in addition to bones and soft tissues. It is important to remember that even small entry wounds may be accompanied by serious internal bleeding, a risk of compartment syndrome, and damage to major vessels as the bullet travels through the body. It is recommended that X-rays be taken after initial treatment and stabilization, ensuring that images are bidirectional and include both the proximal and distal parts of the injury site. X-rays should be evaluated for bullet core residue, fragmented bullet cores, bone fractures, displaced bone fragments, and soft tissue injuries. Air densities in areas outside the injury zone could indicate cavitation (19,20).

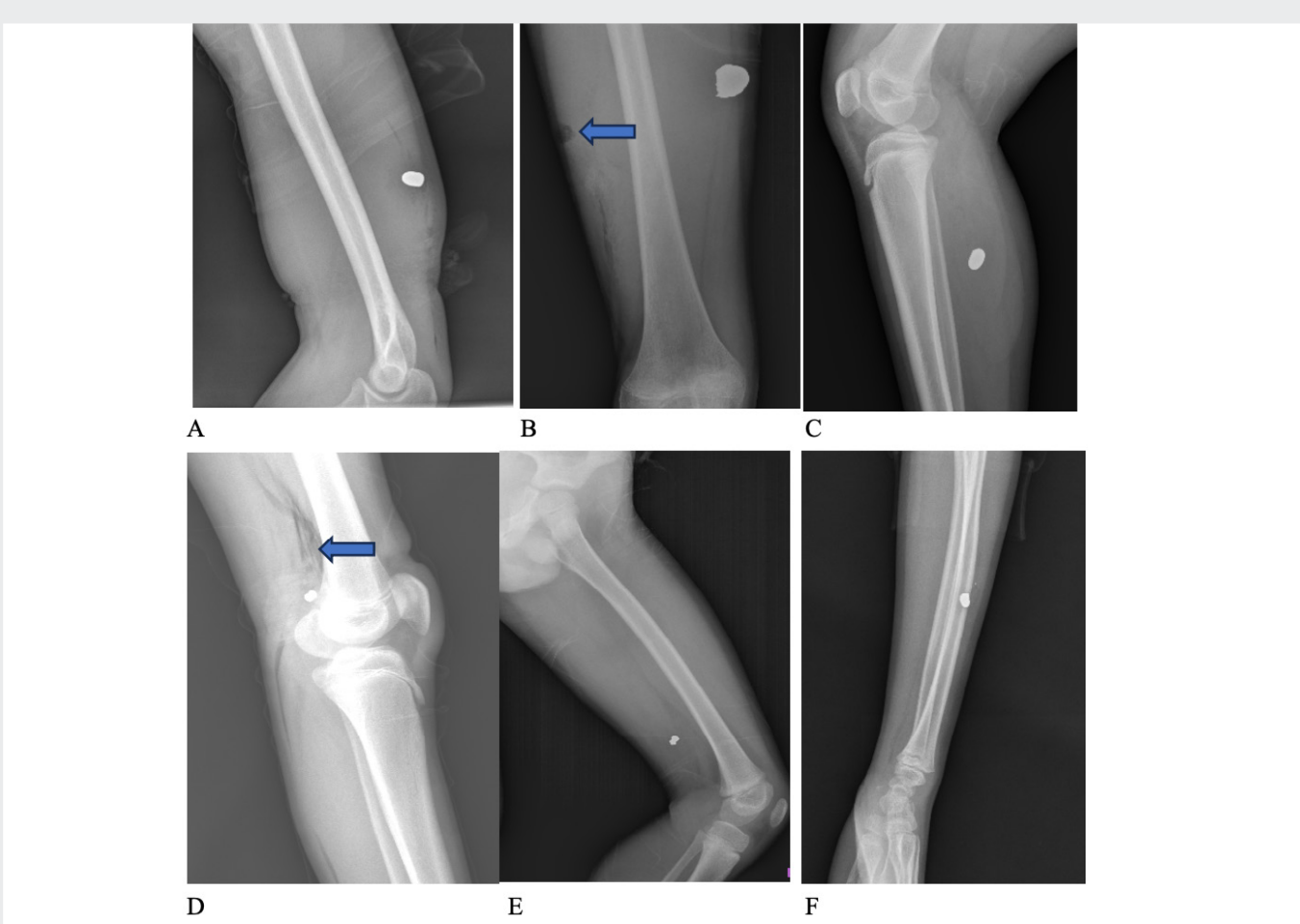

Figure 1. Isolated soft tissue injury with handgun (A) Bullet core lodged in soft tissue of right arm. (B) Bullet core and entry wound in soft tissue of right thigh (blue arrow) (C) Bullet core in soft tissue of left leg (D) Bullet core and cavitation in the soft tissue behind the left knee (blue arrow) (E) Bullet core in the soft tissue of the left distal thigh (F) Bullet core in soft tissue of left forearm

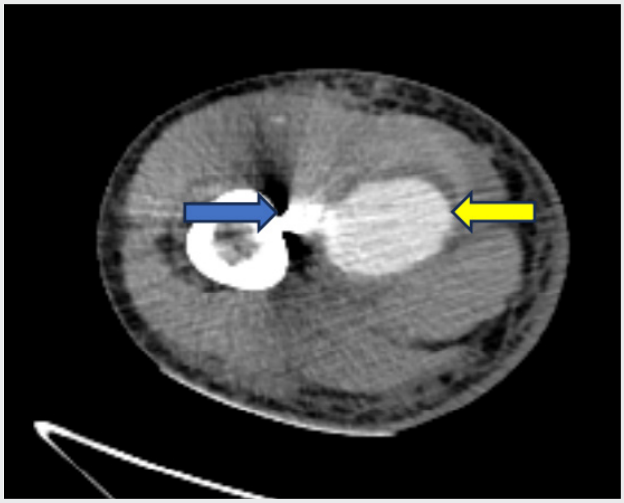

Figure 2. Handgun injury, bullet core (blue arrow) and vascular injury (yellow arrow) in soft tissue

In children, FI is one of the most common causes of vascular damage. Even if a blood vessel supplying an organ is not directly hit, it may be injured if it is within the temporary cavity created by the bullet. While the media and adventitia layers of the vessel are composed of strong elastic fibers and can withstand sudden stretching and compression, the single-layer epithelial structure of the intima may tear, leading to coagulation and subsequent clot formation, which can result in necrosis in the affected organ. Signs of vascular injury include abnormal pulse in the injured extremity, expanding hematomas, pulsatile bleeding, entry and exit wounds near vascular regions, and abnormal vascular Doppler examination findings. Mortality is higher in cases of suspected vascular damage in firearm-related extremity injuries, making it crucial to perform CT angiography promptly and plan appropriate surgical intervention (21-23). In our study, CT angiography was performed on 20 cases, with vascular damage detected in 4 of them. These cases were admitted to the cardiovascular surgery department and underwent surgical intervention.

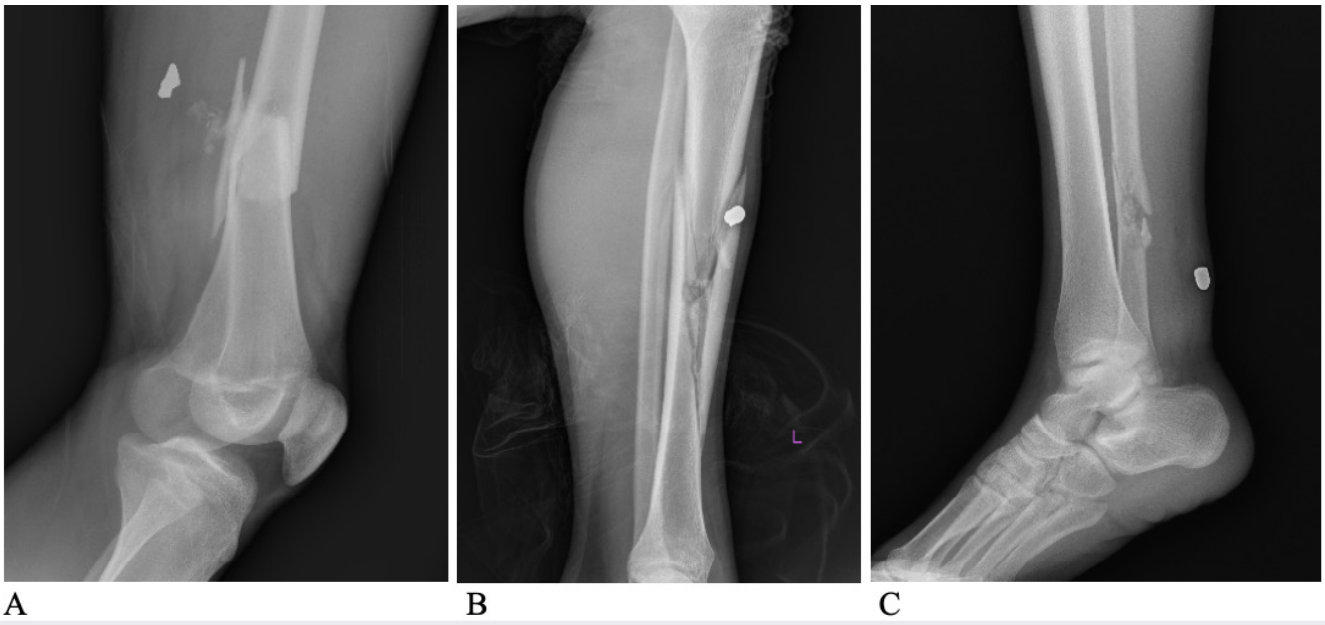

Figure 3. Handgun injury (A) Left distal femur fracture and soft tissue deformation (B) Left tibial shaft fracture and bullet core in the bone (C) Right distal tibia fracture and bullet core in soft tissue

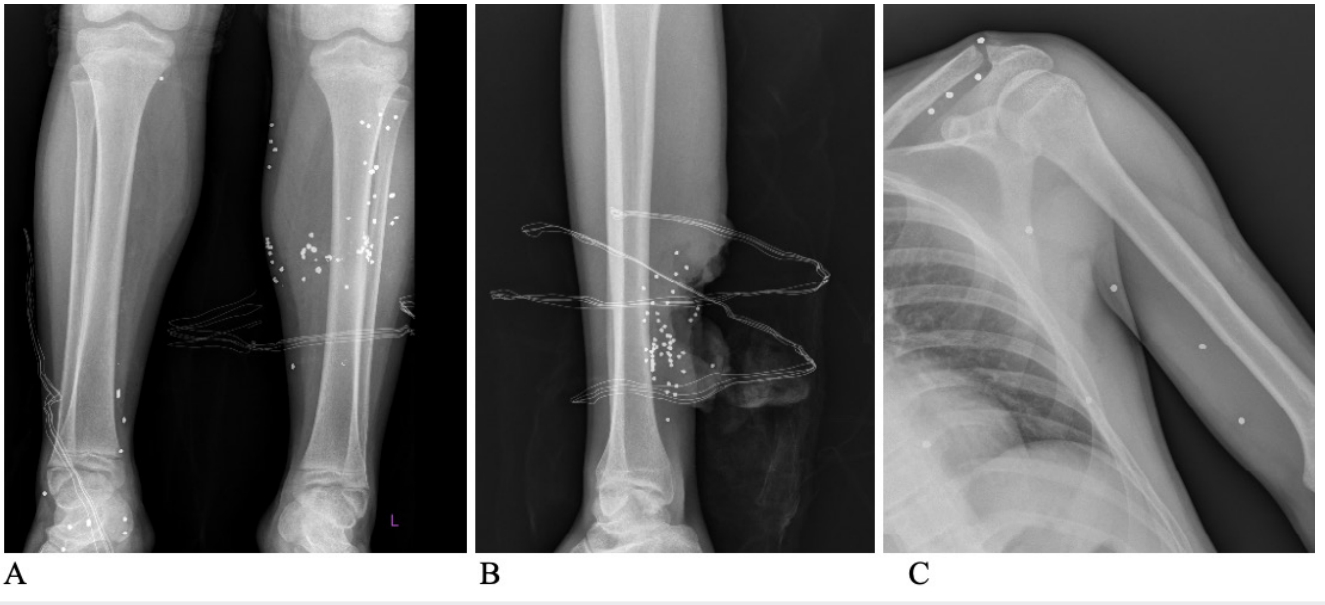

Figure 4. Shotgun injury (A) Soft tissue buckshots in bilateral lower extremities (B) Soft tissue injury and buckshots in the distal right leg (C) Buckshots in soft tissue of left arm and shoulder

Neurological damage is more common in the upper extremity and its associated with morbidity, chronic pain and disfunction (24,25) In one case involving a shotgun injury, extensive tissue damage and ulnar nerve injury were identified, and the patient was hospitalized under the care of the orthopedics department, where surgical intervention was performed.

Study Limitation

A limitation of this study is its retrospective design, which resulted in incomplete information regarding the type of weapon used, the circumstances of the incident, and the shooting distance. However, since the primary objective of the study was to assess injury through radiological findings, we

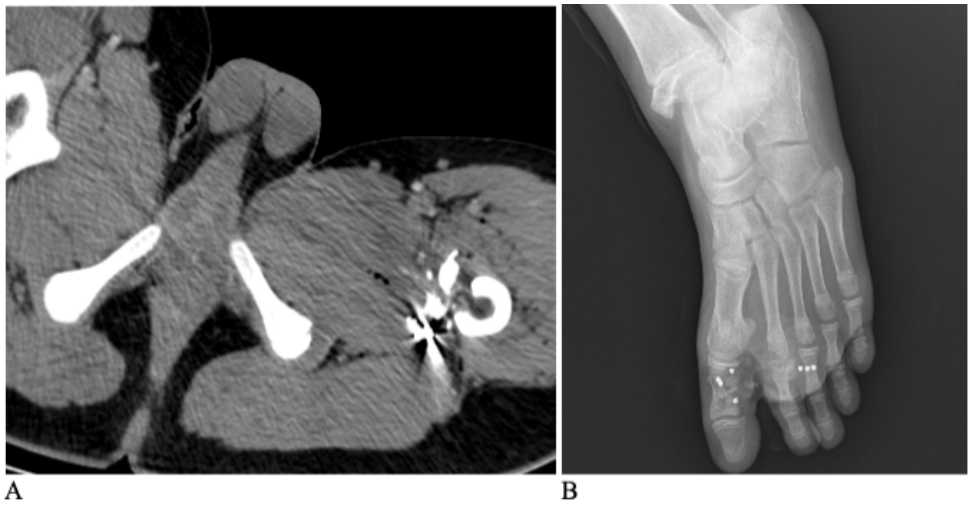

Figure 5. Shotgun injury (A) Fracture and buckshot in the proximal left femur (B) Fractures and buckshots in the right foot

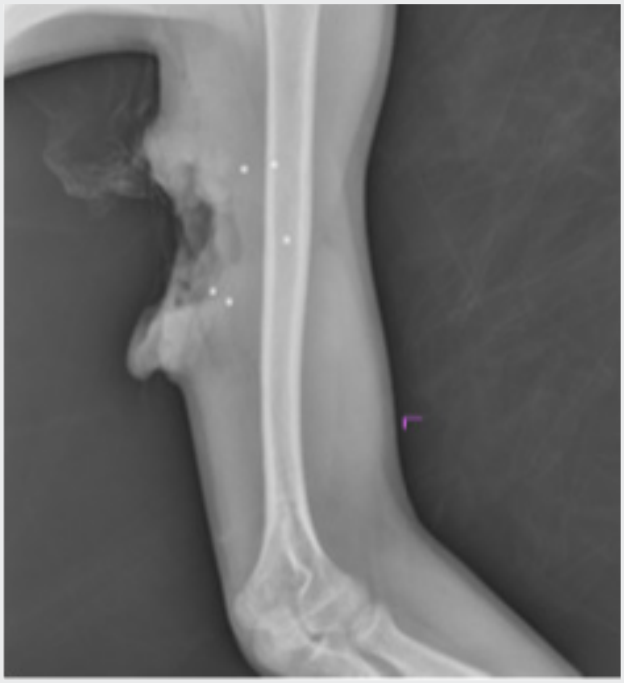

Figure 6. Shotgun injury, soft tissue injury to left arm and buckshots

believe that these historical gaps do not significantly impact the study's results.

CONCLUSION

Although FI encountered in civilian settings typically involves lower energy weapons than those seen in military environments, they can still cause significant trauma and damage. Understanding the structural differences between bullet cores and shotgun pellets, as well as the kinetic energy at the moment of impact, is essential to guiding treatment approaches. Knowledge of weapon mechanisms and their wounding potential is crucial.

According to our study, when a bullet core impacts bone, it tends to cause more severe damage compared with when it only passes through soft tissue. Additionally, bullet cores and shotgun pellets that hit soft tissue can cause vascular injuries, and CT angiography should be considered when vascular damage is suspected. Similarly, soft tissue injuries caused by bullet cores or buckshots can lead to nerve damage, making it essential to perform a thorough neurological examination of the injured extremity.

Ethics

Ethics Committee Approval: Ethical approval for the study was obtained from the Clinical Research Ethics Committee of University of Health Sciences Türkiye, Adana City Training and Research Hospital on March 14, 2024 (decision no: 3223).

Informed Consent: This cross-sectional study was conducted on patients who were admitted to the pediatric emergency department of the tertiary Adana Training and Research Hospital between January 1, 2018, and December 31, 2021, with firearm-related extremity injuries.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.S.K., İ.A., Concept: A.S.K., İ.A., Design: A.Y., A.S.K., İ.A., Data Collection or Processing: A.Y., A.S.K., İ.A., Analysis or Interpretation: A.Y., İ.A., Literature Search: İ.A., Writing: A.Y., S.B., A.S.K., İ.A.

Conflict of Interest: No conflict of interest was declared by the authors.

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