

C A S E R E P O R T

Impalement injuries of the shoulder: a case report with literature review

Marco Scaglia, Stefano Negri, Gianmarco Pellizzari*, Andrea Amarossi, Davide Pasquetto, Elena Samaila, Tommaso Maluta, Eugenio Vecchini, Matteo Ricci, Roberto Valentini, Bruno Magnan*

Orthopaedic and Trauma Surgery Unit, Department of Surgery, Dentistry, Paediatrics and Gynaecology of the University of Verona, Verona, Italy. *: These authors contributed equally to this work

Abstract: The management of penetrating skeletal extremity trauma is a clinical challenge even for experienced surgeons. While the treatment of associated vascular injuries should be prioritized, there is still a lack of evidence regarding the management of foreign bodies in case of bone fractures or neurological injuries. Here we present a case of impalement of the right proximal humerus with a construction steel rod. The 54-year-old man was successfully treated without vascular, neurological, and thoracic sequelae. A review of the current literature about the most appropriate extrication sequences and soft tissue reconstruction following massive foreign body injuries was carried out.

Keywords: Shoulder impalement, penetrant trauma, foreign body, surgical management, shoulder function

Introduction

Penetrating traumas are injuries caused by a body piercing the skin and damaging the underlying tissues. (1) The incidence of such traumas has been rising worldwide (1, 2). Extremities are often involved, with an equal distribution of gunshot and non-gunshot injuries (1, 3-6).

The mortality rate is estimated between 0,5% and 29.1% and death is usually due to major vessel bleeding. Arterial damage is associated with injury of veins in 31%, nerves in 27%, and bones in 26% (6-12).

A delayed diagnosis of associated neurovascular and tendon injuries is not rare, especially in the upper limb and in unconscious patients (2, 13, 14).

The application of advanced trauma life support (ATLS) principles is mandatory to diagnose and treat on-time life and limb-threatening conditions. After airways management, cardiovascular functions should be preserved with manual compression of bleedings or

by using a tourniquet. Patients with signs of major arterial bleeding need surgical repair within 6-12 hours, while patients more stable can be further studied. Neurological injuries such as brachial plexus or axillary nerve are uncommon, but a careful neurological exam should be carried out. In penetrating traumas, copious wound irrigation is essential, and appropriate antibiotic prophylaxis helps to prevent deep infections. Close clinical monitoring is required for the early detection of compartment syndrome signs (2, 10).

Few studies are present about the most appropriate management and timing of surgery on bone penetrating trauma.

Here we report a case of impalement of the right proximal humerus with a construction steel rod. Written consent was taken from the patient for publication.

A review of the current literature about the most appropriate extrication sequences and soft tissue reconstruction following massive foreign body injuries was carried out.

Case report

A 54-year-old male patient was transported to the Emergency Department after falling from 1.5 meters on an iron rod that resulted embedded in his right shoulder.

The patient had a history of glomerulonephritis after an allergic reaction to the tetanus vaccine; no other pathologies were reported.

At the first medical examination, the patient was conscious, hemodynamically stable with a normal body temperature. The ATLS protocol was followed, and no signs of life-threatening conditions were found.

The wound with the protruding rod had no significant bleeding (Fig. 1), normal peripheral pulses, and no alteration of the peripheral neurovascular status.

The patient immediately started antibiotic prophylaxis with Amoxicillin/Clavulanic acid 2g q8 for 72 hours, according to guidelines for contaminated wounds (15).

At shoulder x-rays and CT scan with contrast, the foreign body was trespassing the proximal humeral epiphysis, leaving a minor intraarticular bony fragment but avoiding any neurovascular structure (Fig. 2). No signs of bleeding from major vessels and no sign of pneumothorax were found. A complete panel of blood tests (Table 1) was performed. No abnormalities were present.

The patient was taken to the operating room; under general anesthesia, after irrigation with saline

mixed with povidone-iodine (50:50 ratio), the iron rod was removed conjunctly with a T-Shirt fragment using a self-locking orthopedic plier. A series of samples for microbiological analysis was carried out. Finally, the wound was irrigated with a total of 6 liters of saline solution. An intraarticular drain was placed, and the wound was left open for a secondary intention healing.

The postoperative CT scan did not show additional fragments (Fig. 3).

The days after the patient was constantly afebrile, with a minimum increase of C-reactive protein (CRP, maximum 36 mg/L). The microbiological analysis of intraoperative samples was negative for bacteria and fungi. At the third postoperative day, pendular exercises were started.

The patient was then discharged at home with an arm sling for fifteen days, with weekly appointments for wound medication.

Two weeks after the patient, presented a satisfactory range of motion (ROM), with a Constant Shoulder Score (CSS) of 60 and an Oxford Shoulder Score (OSS) of 32. There was no alteration in the peripheral neurovascular functions.

After 3 months the ROM significantly improved, reaching a flexion of 180°, abduction of 90°, a complete internal rotation and external rotation. However, moderate pain was present at maximal external rotation and abduction, with a CSS of 85 and OSS of 39. The magnetic resonance (MRI) showed supraspinatus and sub-

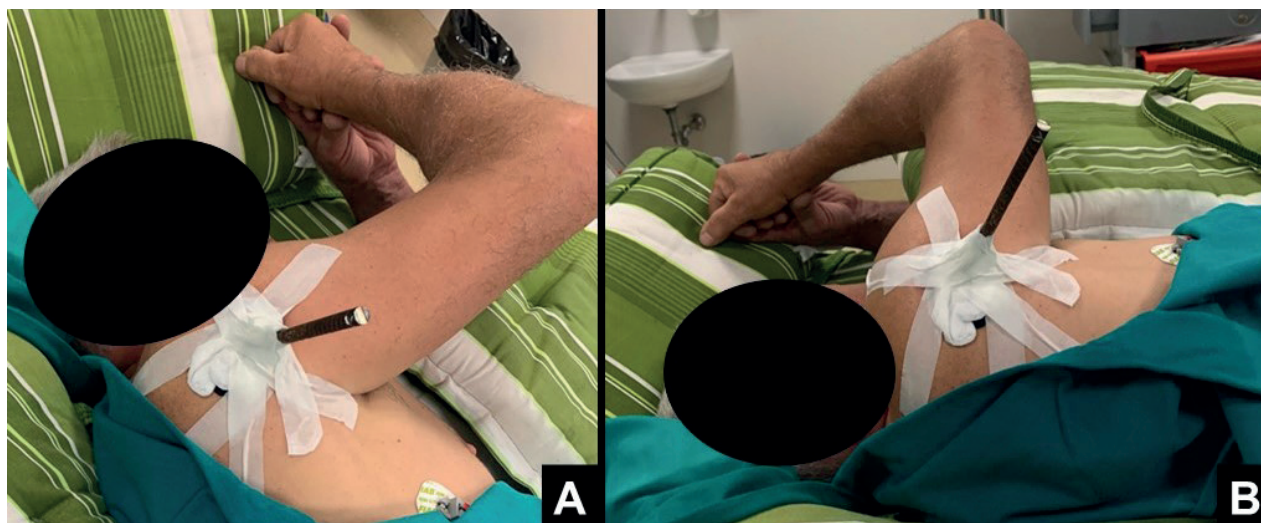


Figure 1. Clinical appearance at admission (A-B)

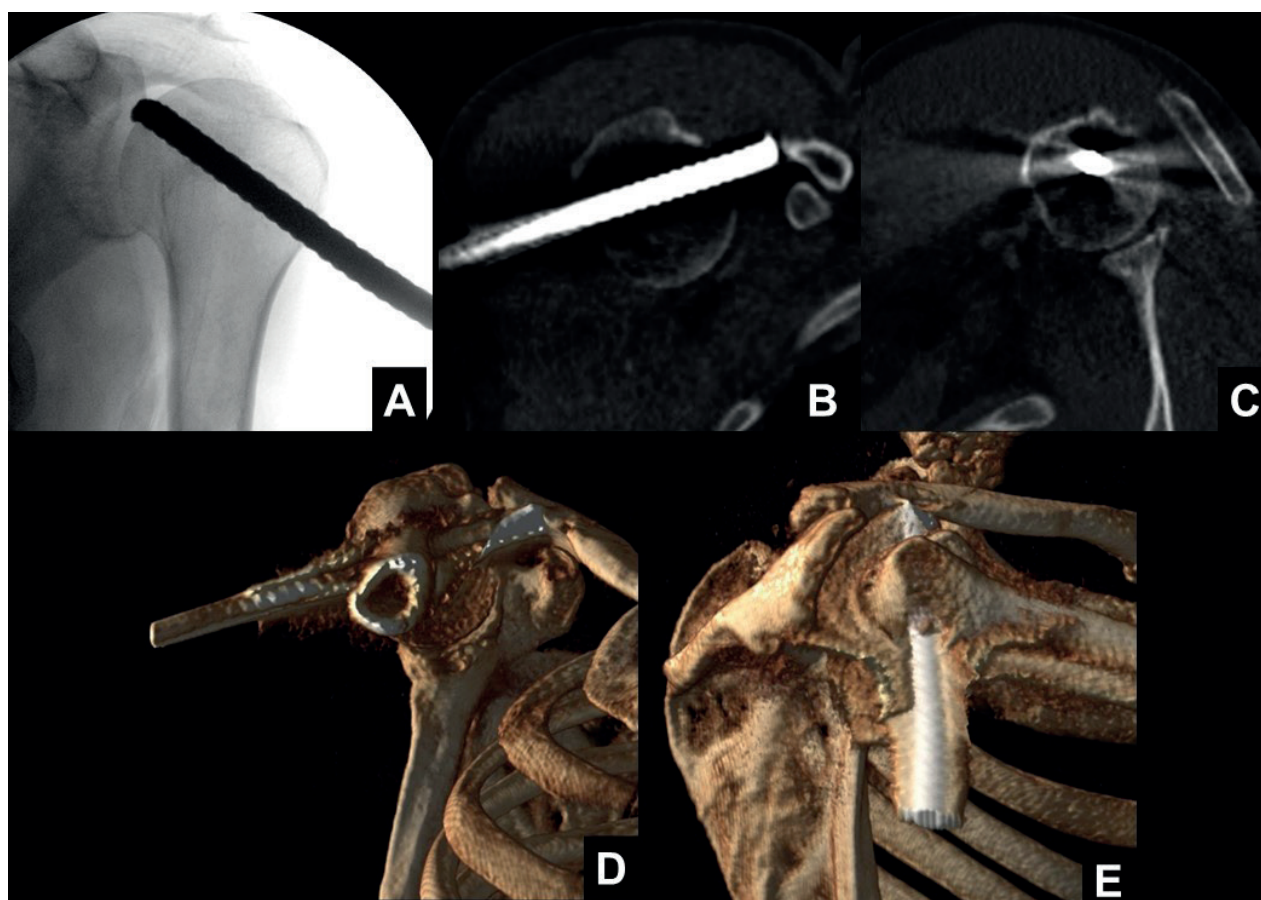


Figure 2. Radiographic imaging: X-rays (A), CT scan (B-C), 3D reconstruction (D-E)

Table 1: Summary of arterial blood test analysis performed at the emergency room admission.

Variable	Arterial Blood Sample (range)
<i>Hemoglobin</i>	148 g/L (135-170)
<i>Hematocrit</i>	0.42 L/L (0.38 - 0.49)
<i>White blood cells</i>	$8.91 \times 10^9/L$ (4.30 - 10.00)
<i>Platets</i>	$146 \times 10^9/L$ (150 - 400)
<i>Prothrombin time</i>	0.95 INR (0.80 - 1.17)
<i>Activated partial thromboplastin time</i>	0.77 Ratio (0.8 - 1.20)
<i>Ph</i>	7.39 (7.35- 7.45)
<i>Partial pressure of carbon dioxide</i>	38 mmHg (35 - 45)
<i>Partial pressure of oxygen</i>	96 mmHg (80 - 100)
<i>Bicarbonate</i>	26 mmol/L (22 - 26)
<i>Oxygen saturation</i>	97%
<i>Lactate</i>	1.0 mmol/L (0.6 - 2.2)
<i>Sodium</i>	138 mmol/L (135 - 145)
<i>Potassium</i>	3.8 mmol/L (3.5 - 5.0)
<i>Chloride</i>	104 mmol/L (95 - 107)
<i>Ionized calcium</i>	1.16 mmol/L (1.1 - 1.35)
<i>Glucose</i>	108 mg/dl (60 - 99)

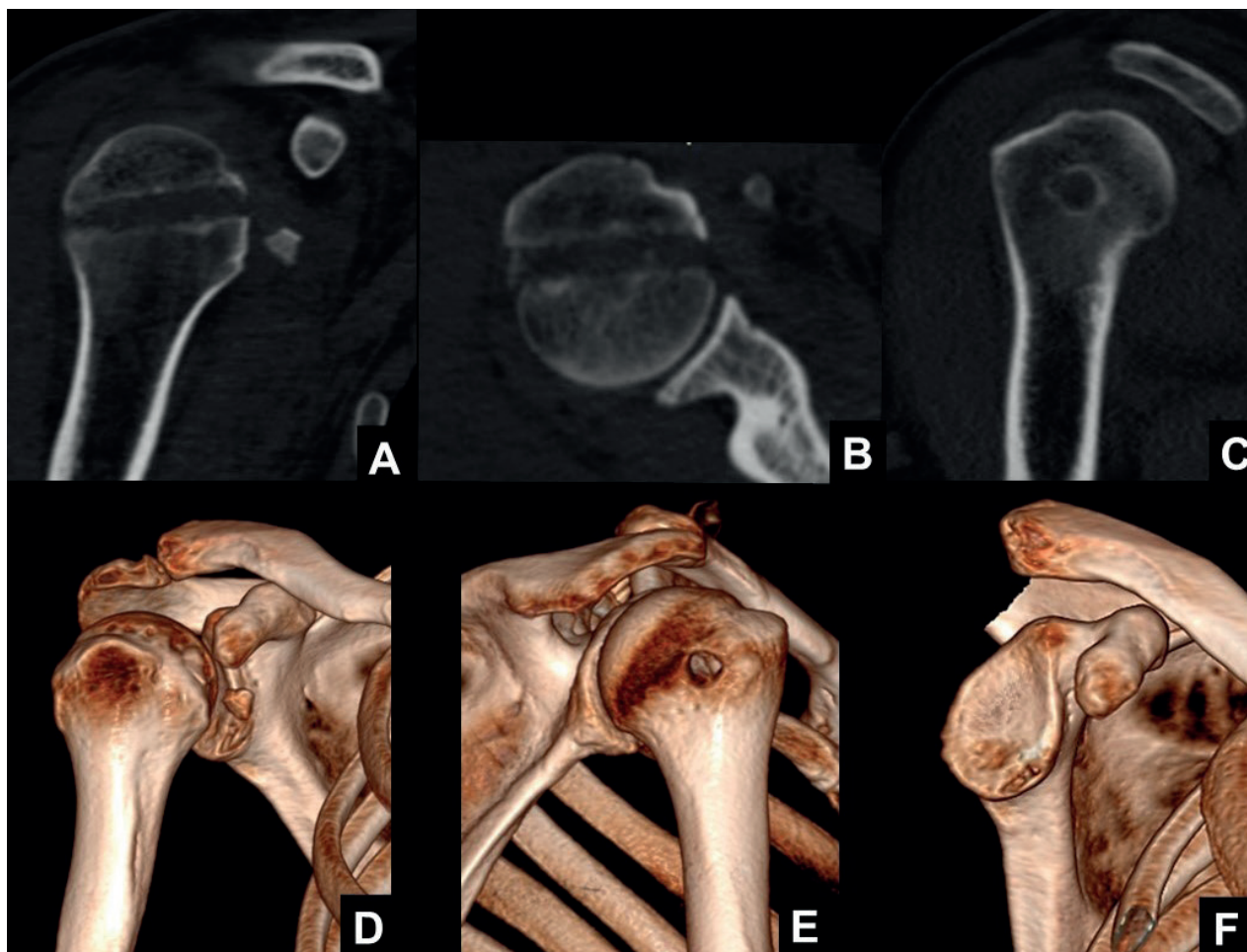


Figure 3. CT scan imaging after foreign body removal: CT scan sections (A-C) and 3D reconstruction (D-F)

scapularis tendinopathy without full-thickness breaches. Non-steroidal anti-inflammatory drugs (NSAIDs) and physiotherapy for the rotator cuff were recommended.

Discussion

A correct approach to penetrant trauma (PET) can significantly reduce the mortality and associated morbidity associated to these events. The key steps are represented by triage, primary evaluation on the field, transfer in a trauma hub, secondary evaluation, and definitive care (4). The ATLS precepts guide the emergency evaluation and treatment throughout all these steps (16).

The orthopedic consultant is often involved in the secondary assessment and definitive care of extremities PET.

Vascular assessment

The evaluation of the vascular damage should be primarily performed. Hard signs of arterial injury include pulsatile bleeding, expanding hematomas, palpable tremor, audible noise, and the “5 Ps” of distal ischemia (pulselessness, pallor, pain, paresthesia/paralysis, poikilothermia). Patients with PET and hard signs often need a surgical repair (2, 17). Soft signs such as diminished pulse, delayed capillary refill and stable hematomas, indicate conditions that often do not require surgical treatment, and 24 hours-observation is recommended in these scenarios (2, 14, 18-21).

However, many studies have shown that peripheral pulses often do not correlate with arterial injury (14, 22, 23, 24). Interestingly, while distal pulses can be maintained in 24% of arterial injuries, pulseless limbs

can have no arterial injury in 27% of cases (14, 22, 23, 24). In addition, arteries with partial-wall lesions are unable to contract and control the bleeding (10).

Angiograms and CT Angiography (CTA) are the gold standards for the diagnosis of PET-associated vascular injuries. However, their universal use in PET has still debated because their cost-effectiveness (2, 25). API (Arterial Pressure Index) and ABI (Ankle Brachial Index) are two clinical available methods to screen arterial injuries and they have a high predictive value with a range between 0.8 and 0.9 (23). In the clinical case shown here, in absence of hard signs of vascular injury, we decided to perform a CT angiography.

Neurological assessment

Neurological injuries following shoulder traumas are relatively uncommon (26). BPI (Brachial Plexus injuries) occur in 6% of PET and are often associated with vascular damage (27). The nerve injury of the plexus is usually complete (53% of cases) or supraclavicular (39% of cases). Infraclavicular BPI is uncommon and less frequently require surgery (17% vs 52% of the complete and supraclavicular) (27, 28). The axillary nerve is the most common nerve trunk involved but it recovers spontaneously in 80% of the cases (26, 29).

Deep infection prevention

The infection risk in the context of soft tissue damage is mainly related to three major aspects: contamination, tissues vitality, and time from the index trauma.

Systemic antibiotics should be initiated as early as possible following the current protocols for bone and soft tissue open traumas since the risk of infection increases dramatically after 8 hours from the index trauma (1, 3).

The protocol in our Trauma Center includes a beta-lactamase inhibitor in combination with a beta-lactam drug (Amoxicillin/Clavulanic acid 2g q8) (15). With bone or joint injuries or mammalian bites, antibiotics should be continued for 24–72 hours (2, 30, 31).

Fractures near wounds should be considered open fractures and antibiotics should be started as early as

possible, while debridement, irrigation, and reduction of the fracture are completed within 24 hours (14, 32, 33).

The immunization for tetanus should be checked and in case the patient is not immunized, immunoglobulin (Ig) administration is highly recommended.

Surgical treatment: foreign body removal, irrigation, and debridement

Foreign body removal and the treatment of bony associated lesions should be performed avoiding iatrogenic injuries (2). A second-level of diagnostics such as a CT scan can help the surgeon to plan the surgical procedure. Although a foreign body should be preferably removed in many cases, this is contraindicated if the procedure is likely to be excessively traumatic (16). In our case, the benefits from the removal of the construction rod were clearly higher than the risk associated with its permanence in the shoulder.

After extraction of visible debris, irrigation should be performed with a high volume of saline under pressure, using a pulsatile lavage or a syringe (2); soap or topical antibiotics are not beneficial (2, 34–36).

There are no guidelines for the surgical management of penetrant intraosseous trauma (1, 12, 37). It is good practice to perform a proper exposition if the foreign body is not visible. An osteotomy could be necessary if a major skeletal segment is involved. Arthroscopy seems to be a safe alternative for intraarticular foreign bodies (1, 38, 39).

In our case, given the absence of neurovascular injuries, the rod was removed by retrograde beating, without further tissues damages.

For skin closure, clean wounds with vital tissues can be primarily closed. In case of treatment after 8 hours from the trauma (5 hours for the hand and 3 hours for the foot), or in case of grossly contamination, delayed closure or secondary intention healing should be considered, packing the wound with saline-soaked gauze, or using negative pressure drainage devices (2, 3, 40). In our case, although we were able to take the patient to the operating room within 4 hours from the trauma, the contamination of the foreign body (soil and rust) required a second intention healing of the wound.

Post-operative care and discharge

In the post-operative time, if the patients are not in critical condition, close monitoring should be performed (2, 4, 10, 38, 41). Compartment syndrome can occur in case of long ischemia times, high energy traumas, and tourniquet usage. Fat embolism with pulmonary failure can occur in patients with long bone involvement. Renal failure could occur for massive myoglobin release secondary to muscular damage. Finally, residual fragments of the foreign body could lead to late-onset infection or metal poisoning.

Patients should be instructed to check for signs such as growing hematomas, increased unexplained pain, hyperthermia, and secreting wounds (2, 10).

A close follow-up of at least 1-2 weeks is suggested to early detect any complications.

Our patient stayed in the Orthopedic department for a week. After discharge, he had an outpatient visit after 2 weeks, 1, 2, and 3 months.

Conclusion

The case shown here suggests that early diagnosis and proper preparation for surgery are required for penetrating trauma. The most important condition to diagnose and treat are vascular injuries since they are the leading cause of death and limb loss.

There is no consensus on modalities of foreign body removal, but wound irrigation and surgical debridement of non-vital tissue should be performed. The patient should be closely followed up at least 2 weeks to detect early complications.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article.

References

- Gonzalez-Urquijo M, Zambrano-La M. Broken Knife Blade Completely Penetrating the Humerus: A Case Report and Literature Review. *Bull Emerg Trauma* 2020;8(3):202-204.
- Manthey DE, Nicks BA. Penetrating trauma to the extremity. *J Emerg Med* 2008;34(2):187-93.
- Ronald M. Stewart et al, *Advance Trauma Life Support, Student Manual* tenth edition, 2018.
- Anderson RJ, Hobson RW 2nd, Padberg FT Jr, et al. Penetrating extremity trauma: identification of patients at high-risk requiring arteriography. *J Vasc Surg* 1990;11(4):544-8.
- Sakran JV, Mehta A, Fransman R, et al. Nationwide trends in mortality following penetrating trauma: Are we up for the challenge? *J Trauma Acute Care Surg* 2018;85(1):160-166.
- Whittaker G, Norton J, Densley J, Bew D. Epidemiology of penetrating injuries in the United Kingdom: a systematic review. *Interantion Journal of Surgery* 2017;41:65-69.
- Dorlac WC, DeBaKey ME, Holcomb JB, et al. Mortality from isolated civilian penetrating extremity injury. *J Trauma* 2005;59(1):217-22.
- Kuwahara JT, Kord A, Ray CE jr, Penetrating Extramity Trauma Endovascular versus Open Repair? *Semin Intervent Radi-ol* 2020;37:55-61.
- Chad G. Ball MD. Penetrating nontorso trauma: the extremities, *Can J Surgery* 2015;58(4):286-288.
- Sise MJ, Shackford SR. Peripheral vascular injury. In: *Trauma*, 7th edition. Mattox, Moore & Feliciano. 2014;816-49.
- Abboud JA, Wiesel B, Tomlinson D, Ramsey M. Intraosseous stab wound to the arm. *Am J Orthop (Belle Mead NJ)* 2008;37(3):52-4.
- Khajuria A, Geoghegan L, Solberg Y et al. Selective non-operative management for penetrating extremity trauma: A paradigm shift in management? *J Plast Reconstr Aesthet Surg* 2018;71(9):1239-1244.
- Newton EJ, Love J. Acute complications of extremity trauma. *Emerg Med Clin North Am* 2007;25(3):751-61 .
- Tacconelli E, Carrara E, Mazzaferri F, et al. *Linee Guida di Profilassi Chirurgica e Terapia Antibiotica Empirica in Ortopedia e Traumatologia*, Azienda Ospedaliera Universitaria Integrata Verona, 2019.
- Skinner EJ, Morrison CA. Wound Foreign Body Removal. In: *StatPearls [Internet]*. Treasure Island (FL): StatPearls. 2021
- Gonzalez RP, Falimirski ME. The utility of physical examination in proximity penetrating extremity trauma. *Am Surg* 1999;65: 784-9.
- Frykberg ER, Dennis JW, Bishop K, Laneve L, Alexander RH. The reliability of physical examination in the evaluation of penetrating extremity trauma for vascular injury: results at one year. *J Trauma* 1991;31:502-11.
- Dennis JW, Frykberg ER, Veldenz HC, Huffman S, Menawat SS. Validation of nonoperative management of occult vascular injuries and accuracy of physical examination alone in penetrating extremity trauma: 5- to 10-year follow up. *J Trauma* 1998;44:243-52.

19. Espinosa GA, Chiu JC, Sammett EJ. Clinical assessment and arteriography for patients with penetrating extremity injuries: a review of 500 cases with the Veterans Affairs West Side Medical Center. *Mil Med* 1997;162:19–23.
20. Frykberg ER, Schinco MA. Peripheral vascular injury. In: Moore EE, Feliciano DV, Mattox KL, eds. *Trauma*, 5th edn. New York: McGraw-Hill; 2004:969–1002.
21. Fields CF, Latifi R, Ivatury RR. Brachial and forearm vessel injuries. *Surg Clin North Am* 2002;82:105–14.
22. Xu Y, Xu W, Wang A, et al. Diagnosis and treatment of traumatic vascular injury of limbs in military and emergency medicine: A systematic review. *Medicine (Baltimore)* 2019;98(18):e15406.
23. Smith AA, Ochoa JE, Wong S, et al. Prehospital tourniquet use in penetrating extremity trauma: Decreased blood transfusions and limb complications. *J Trauma Acute Care Surg* 2019;86(1):43–51.
24. Pieroni S, Foster BR, Anderson SW, Kertesz JL, Rhea JT, Soto JA. Use of 64-row multidetector CT angiography in blunt and penetrating trauma of the upper and lower extremities. *Radiographics* 2009;29(3):863–76.
25. Zarkadas PC, Throckmorton TW, Steinmann SP. Neurovascular injuries in shoulder trauma. *Orthop Clin North Am* 2008;39(4):483–90.
26. Kaiser R, Waldauf P, Ullas G, Krajcovic A. Epidemiology, etiology, and types of severe adult brachial plexus injuries requiring surgical repair: systematic review and meta-analysis. *Neurosurg Rev* 2020;43(2):443–452.
27. Midha R. Epidemiology of brachial plexus injuries in a multitrauma population. *Neurosurgery* 1997;40(6):1182–8; discussion 1188–9.
28. Domínguez-Páez M, Socolovsky M, Di Masi G, Arráez-Sánchez MÁ. Lesiones traumáticas aisladas del nervio axilar. Experiencia en 4 casos de transferencia nerviosa radial y revisión de la literatura [Isolated traumatic injuries of the axillary nerve. Radial nerve transfer in four cases and literatura review]. *Neurocirugía (Astur)* 2012;23(6):226–33.
29. Zalavras CG, Patzakis MJ, Holtom PG, et al. Management of open fractures. *Infect Dis Clin North Am* 2005;19:915–29.
30. Dellinger EP, Caplan ES, Weaver LD, et al. The necessary duration of antibiotic administration after open fracture. *Arch Surg* 1988;123:333–9.
31. Yang EC, Eisler J. Treatment of isolated type I open fractures: is emergent operative debridement necessary? *Clin Orthop Rel Res* 2003;410:289–94.
32. Skaggs DL, Friend L, Alman B, et al. The effect of surgical delay on acute infection following 554 open fractures in children. *J Bone Joint Surg (Am)* 2005;87:8–12.
33. Barker W, Rodeheaver GT, Edgerton MT, et al. Damage to tissue defenses by a topical anesthetic agent. *Ann Emerg Med* 1982;11: 307–10.
34. Anglen JO. Comparison of soap and antibiotic solutions for irrigation of lower-limb open fracture wounds. A prospective, randomized study. *J Bone Joint Surg Am* 2005;87: 1415–22.
35. Fernandez R, Griffiths R, Ussia C. Water for wound cleansing. *Cochrane Database Syst Rev* 2002;(4).CD003861.
36. Quah C, Whitehouse S, Agrawal Y, Shah N, Phaltankar P. Broken knife blade in proximal humerus: An unusual presentation. *Eur J Orthop Surg Traumatol* 2009: 193–196
37. Cantrell C, Gerlach E, Butler B, Sheth U, Tjong V. The role of arthroscopy in bullet removal: A systematic review of the literature. *J Orthop* 2020;22:442–448.
38. Çatma MF, Ünlü S, Ersan Ö, Öztürk A. Treatment of the Bullet, Traversing Femoral Neck, Lodged in Hip Joint: Initial Arthroscopic Removal and Subsequent Cartilage Repair. *J Orthop Case Rep* 2016;6(4):13–16.
39. Leininger BE, Rasmussen TE, Smith DL. Experience with wound VAC and delayed primary closure of contaminated soft tissue injuries in Iraq. *J Trauma* 2006;61:1207–11.
40. Mabee JR. Compartment syndrome: a complication of acute extremity trauma. *J Emerg Med* 1994;12:651–6.

Received: 15 November 2021

Accepted: 23 December 2021

Correspondence:

Bruno Magnan

Department of Orthopaedics and Trauma Surgery, University of Verona, Azienda Ospedaliera Universitaria, Integrata di Verona (Italy)

Tel. +39 0458123276

Fax +39 0458123578

E-mail: Bruno.magnan@univr.it