

Experience in Managing War Trauma with a Damage Control Approach in the Hospital for Patients with Femur or Tibia Fractures

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ABSTRACT

Introduction: The Central Military Hospital of Bogotá, Colombia has a specialized team for treating war trauma patients. They conduct an initial assessment of patients and promptly manage potentially fatal injuries using a damage control approach that aims to save the patient's life, save the limb, and preserve its function. **Materials and Methods:** An observational, descriptive, cross-sectional study was conducted on patients from the Colombian armed forces who, between 2012 and 2020, had femur or tibia fractures as a result of war trauma; these patients were treated using external fixation by the orthopedics and traumatology service of the Central Military Hospital in Bogotá, Colombia. **Objectives:** To describe the complications associated with war trauma following a year of treatment for femur and/or tibia fractures under a damage control protocol at the Central Military Hospital, the nation's reference facility for this kind of trauma. **Results:** A retrospective review of war trauma patients between 2012 and 2020 with femoral or tibial fractures treated with DCO was performed. Fisher's Exact tests were used for comparisons. Seventy-two soldiers were selected, 96% of fractures were open, 91% (66 cases) had some type of complication such as nerve injury, vascular injury, coverage defect, infection, and nonunion. **Conclusions:** In our country, war trauma persists as one of the causes of polytrauma in young patients, which has significant clinical and financial implications. Bone injuries of severely affected extremities require staged management based on external fixation according to damage control principles.

Keywords: Trauma; damage control; fracture; tibia; femur.

Level of Evidence: IV

Experiencia en el manejo del trauma de guerra con un enfoque de control de daños en el hospital para pacientes con fracturas de fémur o tibia

RESUMEN

Introducción: El Hospital Militar Central cuenta con un grupo especial para la atención de pacientes con trauma de guerra que incluye una evaluación inicial y manejo urgente de las lesiones que amenacen la vida, mediante un enfoque de control de daños que busca preservar la vida del paciente, salvar la extremidad y conservar su función. **Materiales y Métodos:** Estudio observacional, descriptivo, transversal de pacientes de las fuerzas militares de Colombia, que sufrieron fracturas de fémur o tibia por trauma de guerra entre 2012 y 2020; y tratados mediante fijación externa en este Hospital. **Objetivos:** Describir las complicaciones del trauma de guerra tras un año de manejo de pacientes con fracturas de fémur o tibia utilizando un protocolo de control de daños en el Hospital Militar Central centro de referencia para este tipo de trauma en el país. **Resultados:** Se realizó una revisión retrospectiva de pacientes con fracturas femorales o tibiales por traumas de guerra entre 2012 y 2020, manejados con un protocolo de control de daños. Se seleccionaron 72 soldados, el 96% de las fracturas eran abiertas, el 91% (66 casos) sufrió alguna complicación, como lesión nerviosa, lesión vascular, defecto de cobertura, infección, falta de consolidación. **Conclusiones:** El trauma de guerra continúa representando una de las etiologías de politraumatismo en pacientes jóvenes de nuestro país que, a su vez, sigue teniendo grandes implicaciones clínicas y económicas. Las lesiones óseas de las extremidades requieren un manejo por etapas basado en la fijación externa según los principios de control de daños.

Palabras clave: Trauma; control de daños; fractura; tibia; fémur.

Nivel de Evidencia: IV

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INTRODUCTION

The conflict between political parties during the *La Violencia* period, the failed agrarian reform, and the actions of some strongholds that refused to surrender their weapons after General Gustavo Rojas Pinilla granted amnesty were fertile ground for the formation of guerrilla and paramilitary groups that sought to mitigate their actions. This armed confrontation, whose main sources of financing have been drug trafficking, illegal mining, extortion, kidnapping and selective homicides, has lasted for more than 50 years¹ and has affected more than 9,099,358 people through serious violations of International Humanitarian Law and international human rights norms, mainly through behaviors such as forced disappearance, forced displacement and homicide.² In short, it is a conflict characterized by periods of escalation that has sought to sow fear in the population through episodes of extreme cruelty, brutality and torture, especially in members of the security forces.¹

Although the State has attempted to reclaim territorial control, its efforts have been thwarted by reprisals against the population and security forces, which have resulted in the use of non-conventional weapons with greater destructive potential, such as cylinder bombs, incendiary bombs, Molotov bombs, gasoline-filled pots, fragmentation grenades, handmade tanks, *tatucos*, anti-personnel mines, and vehicle bombs.^{1,3,4} The usage of war materials explains why Colombia ranks second only to Afghanistan in the number of casualties of anti-personnel mines and explosive remnants of war, and first in the number of victims of security forces; it is the only country in America where these weapons are still utilized.⁴

Thus, when the course of the conflict required the State to reclaim territory controlled by terrorist groups, the Central Military Hospital served as a strategic reserve for the care of all wounded military personnel (Figure 1), where medical care strategies were developed that reduced deaths and increased the survival of all the wounded, an example of which was the implementation of the model of care for the war wounded through the “*Plan pantera*”.⁵ Thus, it is evident how the oldest conflict in Latin America has shaped the casuistry of all professionals responsible for the care of the wounded admitted to the Central Military Hospital.



Figure 1. The sculpture “Wounded Soldier” by José Eduardo Ordoñez was donated to the Central Military Hospital in 2003 and represents all the pride and invaluable effort of the medical and paramedical personnel of the Colombian Armed Forces during more than 60 years of conflict. Photo taken from HOMIL social network, 82nd anniversary. Date: April 18, 2021.

Regarding war trauma, it is well documented that the extremities are the main target;⁶⁻¹⁰ in some descriptions, such as that of Koržinek et al.,⁷ they account for 75% with respect to other parts of the body, and up to one third of them have bone involvement.

The initial approach to the combat wounded by an interdisciplinary group at the Central Military Hospital deserves special mention.^{5,11} As part of this approach, the orthopedics and traumatology group, which receives up to 40% of the combat wounded,⁸ is responsible for the initial evaluation of the affected extremity using some classifications, such as that of Gustilo and Anderson, 1976, with its subsequent modifications^{12,13} and the Mangled Extremity Severity Score,¹⁴ which are useful tools when used cautiously for decision making,^{15,16} to avoid permanent disability from amputation or increased mortality from a prolonged course of interventions in failed limb salvage.¹⁶ These high-energy injuries cause significant involvement of soft tissue, neurovascular structures and bone tissue.^{5,17,18} Therefore, rapid physiological restoration is critical, a premise based on *damage control surgery*, a term coined in 1940 in the navy and later applied to surgery. It has recently been extended to the field of orthopedics under the name of *damage control orthopedics*, aimed at preserving the patient's life, saving the limb, and preserving function¹⁹ with the use of external fixators. In particular, the use of external fixators constitutes a valuable measure in the easy and rapid stabilization of fractures, avoids complications associated with prolonged and definitive orthopedic treatments, a phenomenon known as *second hit* and under the premise of *do no further harm*,¹⁹⁻²¹ thus creating a favorable environment for bleeding control, pain management and for limiting further damage to soft tissues and neurovascular structures by free bone fragments.

Among the actions contemplated in this management approach is the damage inventory which includes a surgical exploration of the wound and its various planes, the removal of devitalized tissues and any foreign body, and abundant irrigation with saline solution and hydrogen peroxide for the subsequent taking of samples for cultures. This is due to the high potential of infection by materials such as soil, vegetation, clothing, tissues of other victims, and intentional contamination of war material with fecal matter by the enemy and the frequent presence of microorganisms such as *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Staphylococcus epidermidis*, *Pseudomonas aeruginosa*, *Proteus mirabilis*, *Enterococcus faecalis*, *Candida albicans*, *Enterobacter cloacae* and *Serratia marcescens*.^{17,18} All of these microorganisms have significant resistance patterns and, in most cases, the infections are polymicrobial.

In this sense, although there are several publications on war trauma in multiple war confrontations throughout history, femur and tibia fractures are an area that lacks publications in Colombia and Latin America, so efforts to elucidate the lessons of the Colombian armed conflict in this area are valuable.

The purpose of this study was to describe the complications and outcomes observed during one year of management of combat-wounded patients of the Colombian military forces, aged 18 to 40 years, treated by external fixation and damage control protocols, at the Central Military Hospital, between 2012 and 2020.

Taking into account that the Central Military Hospital is a reference institution for this type of trauma in the country, it provides valuable experience in the management of these injuries that have particular characteristics, such as their association with polytrauma, the great comminution and bone contamination resulting from high-energy trauma caused by high-velocity firearms, anti-personnel mines, explosive devices, fragmentation grenades, cylinder bombs and all types of non-conventional weapons, interventions that are not exempt from complications (Figure 2).

In light of the above, this is an effort to share the lessons learned for the training of professionals at the national and international level, laying the groundwork for the development of new studies with a higher level of evidence that will allow the implementation of protocols in the care of other types of trauma.

Armed conflicts in the history of mankind have been the genesis of multiple advances in strategic, technological and scientific terms. Medicine is proof of this, since it has undergone ongoing change and innovation in an effort to handle the vast range of injuries sustained by soldiers as a result of the deployment of increasingly atrocious and ruthless weaponry. These advances have been developed from research and evidence-building processes aimed at identifying interventions that reduce mortality and sequelae, and augur a better prognosis for the victims of the conflict.



Figure 2. Excerpt from Oración patria: “To be your soldier is the greatest of my glories, my greatest ambition is to carry with honor the title of Colombian and, if necessary, die to defend you”. Photo taken from CGFM social network posted on September 30, 2019.

Thus, and taking into account the internal war context, characterized by the use of non-conventional weapons and the generation of injuries with special particularities, there is great interest in producing medical literature on the management of this group of patients and identifying injuries to improve protocols for the care of war trauma or extrapolate such management to other types of more everyday injuries.

Therefore, this study is of great value for the training of health professionals and initial trauma care groups, sowing the seeds for new interventions aimed at saving lives and reducing the social and economic cost of the care, management and rehabilitation of all combat wounded in our country.

MATERIALS AND METHODS

An observational, descriptive, cross-sectional study was carried out at the Central Military Hospital that included military forces personnel (Army, Navy and Air Force) in active service, with the rank of officer, non-commissioned officer, professional soldier or marine, between 18 and 40 years of age, who had suffered a femur or tibia fracture during acts of service, whatever the mechanism, by allied fire or by terrorist groups, treated by external fixation in this hospital.

Sample selection and size

A non-probability convenience sampling was performed. We selected the medical records of patients belonging to the military forces on active duty, aged between 18 and 40 years, with war trauma and who had suffered femur or tibia fractures between 2012 and 2020 during acts of service, whatever the mechanism, by allied fire

or by terrorist groups, and who had been treated with external fixation in the Orthopedics and Traumatology Service of the Central Military Hospital. The initial sample was subjected to inclusion and exclusion criteria, and the resulting sample was variable according to the search performed in the medical records and the evaluation at the time of the cohorts.

The study's descriptive characteristics do not necessitate sample calculation; however, all patients who meet the inclusion criteria between 2012 and 2020 must be included.

The inclusion criteria were:

- Patients admitted to the Central Military Hospital for war trauma between 2012 and 2020.
- Patients managed initially or during recovery at the Central Military Hospital under a damage control approach.
- Men between 18 and 40 years old.
- Patients who, during the study, were part of the military forces (Army, Navy and Air Force) on active duty, with the rank of officer, non-commissioned officer, professional soldier or marine.
- Patients with proximal, diaphyseal or distal closed or open fractures of the femur or tibia due to war trauma caused by conventional or non-conventional weapons in acts of service by allied or enemy fire.

The exclusion criteria were:

- Patients with less than one year of medical management.
- Patients who, during orthopedic treatment of war trauma injuries, would have required amputation at any level of amputation.
- Patients treated with a device other than an external fixator in the initial management of trauma.

Strategies to suppress threats to the validity of results.

- Information bias: to account for information bias, all patients' information was acquired from the unified electronic medical record registry Dinámica® and the Tharsis laboratory.
- Selection bias: patients were found using the Service's database, and patients were also found using the ICD10 code filter in Dinámica®.
- Classification bias: globally accepted definitions were considered for each of the variables, supported by the references of this publication.

Measurements and instruments used

- All variables were loaded into an Excel database, which was parameterized; the database was managed offline to ensure data security.
- Patients will only be accessible to research investigators or national authorities who require it. For security purposes, a unique identifier for the Central Military Hospital is used to guarantee the anonymity of the patients.

Procedures for data collection, instruments to be used and methods for data quality control

After obtaining authorization from the Ethics Committee, data were collected in two stages. In the first stage, data were extracted from databases that included all patients who had an external fixator placed between 2012 and 2020. Patients with femur or tibia trauma corresponding to war trauma and meeting the aforementioned inclusion criteria were selected. The information collected was entered into an Excel spreadsheet and stored under the supervision of the institutional research committee.

In the second stage, the medical records of the patients selected in the first stage were reviewed in order to record the variables to be evaluated in this study, with the values defined for each category to be evaluated, a procedure that was carried out by the principal and secondary investigators. At this stage, the costs for each of the surgical procedures and in-hospital and outpatient controls by orthopedic and traumatology specialists were also requested, as well as the current contract, fees, and modifications between the contracting Central Military Hospital and the contractor HELPEN SAS for "provision of comprehensive services in orthopedics and traumatology, neuromoni-

toring, ultrasound, virtual and 3D planning, supply of osteosynthesis material, medical devices, bone substitutes and custom-made prosthesis, surgical services (orthopedics, maxillofacial, plastic surgery, otorhinolaryngology, neurosurgery)...," which is publicly available in the transactional portal of state entities in the *Compra Eficiente* webpage.

The above information was confirmed under the consideration of another specialist to avoid bias and possible errors arising from this activity given the nature of the study.

After auditing the data for missing information, errors or extreme values and obtaining an error <3%, the data were analyzed. A descriptive analysis of the variables was performed taking into account their nature, measurement scale and categorization by applying measures of central tendency.

The data stored in Excel after the second stage were subjected to statistical analysis with this program. Subsequently, the relevant variables were analyzed together with a methodological advisor to draft the discussion and conclusions of the study.

The development of this study was in accordance with the principles of the Declaration of Helsinki of the World Medical Association, the Belmont Report and the CIOMS guidelines, and Resolution 8430 of 1993, which establishes the scientific, technical and administrative standards for health research and for this particular case, the protection of clinical data derived from the management of the clinical records regulated by Resolution 1995 of 1999 and the Statutory Law of Habeas Data 1581 of 2012 by which the general provisions for the protection of personal data are dictated and regulated by National Decree 1377 of 2013 that regulates the proper handling of sensitive data.

This is a non-risk investigation in accordance with Resolution 8430 of 1993. Non-risk research is defined as a study that uses retrospective documentary research techniques and methods and in which no intervention or intentional modification is made in the physiological, psychological, and social variables of the individuals who participate in it, including questionnaires, interviews, clinical record reviews, and others, in which no sensitive aspects of their behavior are identified or dealt with.

According to their risk profile and the sort of variables to be examined, it was determined that the study did not require informed consent, as specified in article 16 of the Ministry of Health's Resolution 8430 of 1993. This protocol was submitted to and approved by the Research Ethics Committee of the Hospital Militar Central.

RESULTS

From 2012 to 2020, 72 patients were admitted to the Central Military Hospital for trauma associated with combat injuries and met the inclusion criteria for the study analysis. The average age of the patients evaluated was 24 years (mode 19 years; min. 18, max. 37).

In no case did fracture fixation with external tutor exceed four days (2 cases) (average 0.9 days). The average hospital stay was 37 days and the average cost derived exclusively from the room for four people was 10,461,400 Colombian pesos; however, the duration of the stays was very different among the patients in the sample, with minimum periods of 2 days and maximum periods of 147 days, typical of the great variety of injuries.

Regarding outpatient follow-ups by orthopedic outpatient clinic, there was an average of five consultations (range 0-15). However, the three patients with 0 consultations were admitted multiple times to the emergency department for care, the same occurred with the nine patients with two outpatient consultations and five with one outpatient consultation, this may be due to limited economic resources for transportation from their cities of origin or due to follow-up in medical clinics of lower complexity (Table).

The most frequent type of weapon causing trauma were high-velocity projectiles (59 patients, 81%), followed by antipersonnel mines (7 patients, 9.7%) and explosive devices (6 patients, 9.2%).

Fifty-eight percent of the lesions (42 cases) were located on the left extremity and 41% (30 cases) on the right. Among the 39 cases of femoral fractures, distal and diaphyseal fractures accounted for 45% (33 cases). In the tibia, proximal and diaphyseal fractures predominated (27 cases, 37%), so that up to 41% of the sample (30 patients) had war trauma injuries with knee joint involvement (Figure 3).

Table. Average costs of medical and hospital care at the Central Military Hospital

	Number (mean, SD)	Cost per unit*	Average cost*
Hospital stay (days)	37 (27)	\$275,300	\$10,461,400
Orthopedic Controls	5 (3)	\$67,000	\$351,750

*In Colombian pesos. SD = standard deviation.

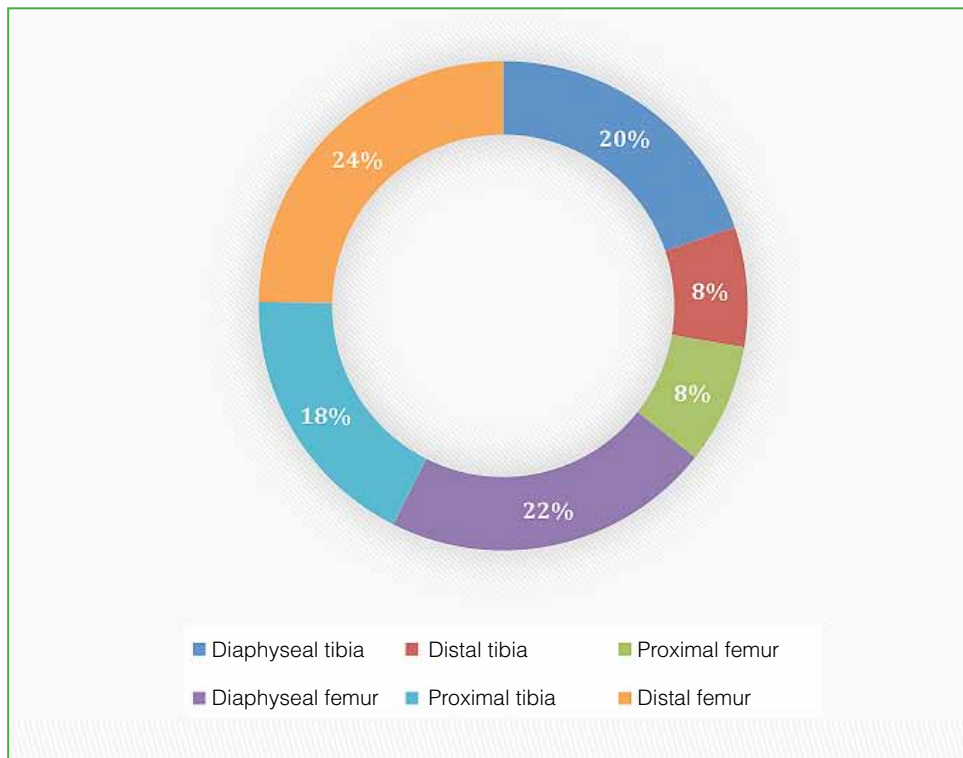


Figure 3. Location of fractures in patients seen at the Central Military Hospital, between 2012 and 2020.

Forty percent of the fractures were type IIIb of the Gustilo and Anderson classification, followed by type IIIa (33%) for a total of 53 of the 72 injured in the sample. Type IIIc fractures accounted for 16%; type II, 5%; three cases (4%) corresponded to closed fractures (Figure 4). In addition, the rate of bone loss increased with fracture severity (Figure 5).

All fractures were treated with external fixation: 40% with monolateral fixators for diaphyseal fractures and 59% with transarticular fixators for fractures of the proximal or distal thirds of the affected bone segments.

Ninety-one percent (66 cases) had some type of complication: nerve injury (9 cases, 12.5%), vascular injury (9 cases, 12.5%), coverage defect (39 cases, 54%), infection (55 cases, 76%) and nonunion (26 cases, 36%).

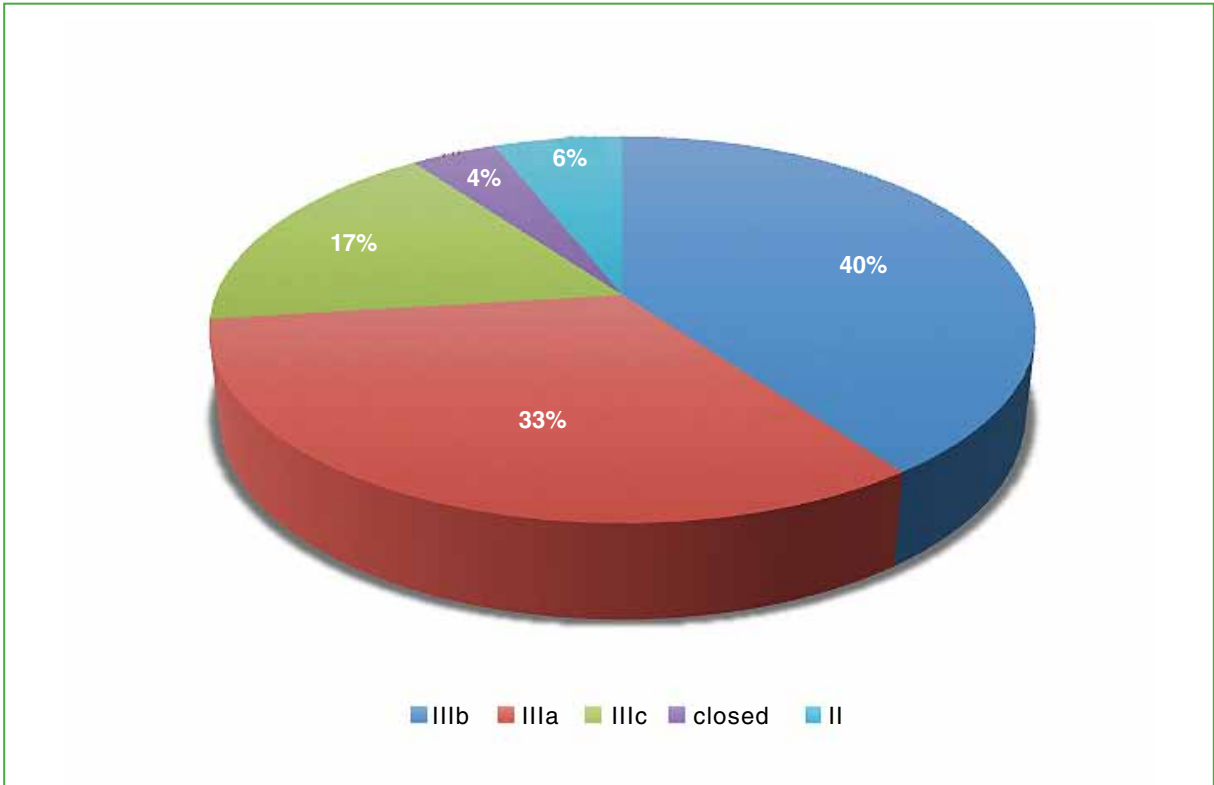


Figure 4. Gustilo and Anderson classification of patients seen at the Central Military Hospital between 2012 and 2020.

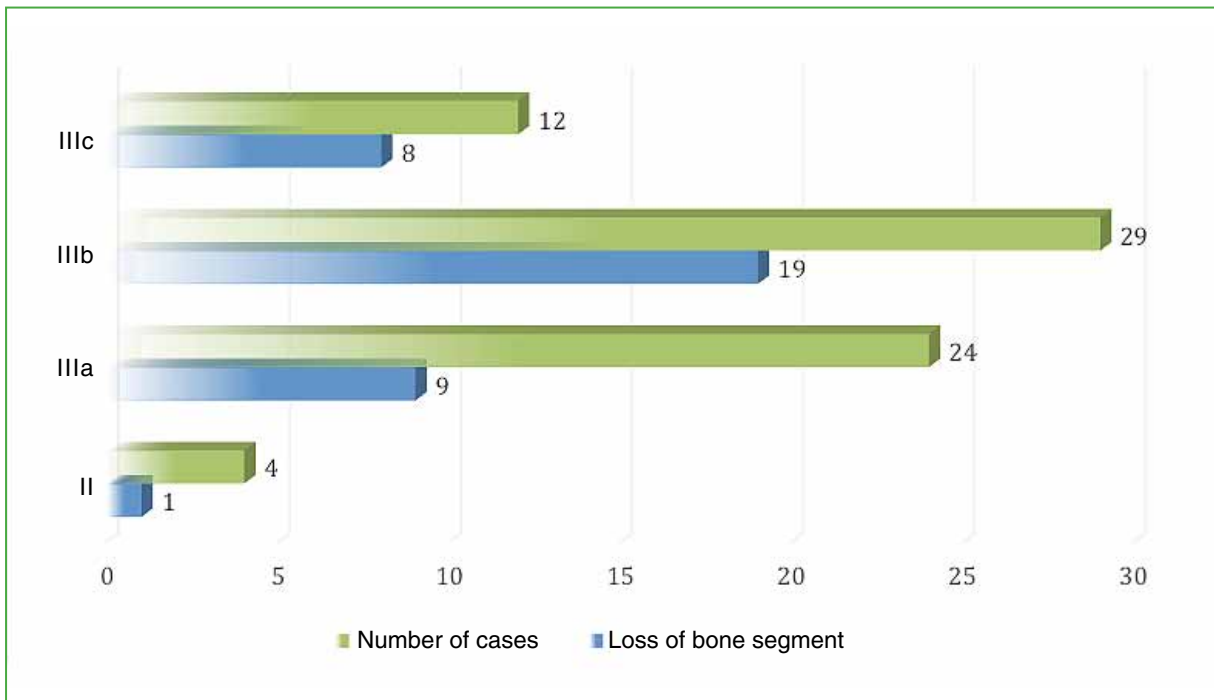


Figure 5. Patients who lost a bone segment as a result of war trauma injuries between 2012 and 2020.

Forty-four percent (32 cases) had superficial infection and 65% (47 cases) had deep infection; there were 24 cases (33%) of episodes of both superficial and deep infections. For the initial management of coverage defects and deep infections, surgical lavages were performed; more than half of the cases required more than three surgical lavages (56%). In addition, a germ was isolated in 63% of the cases. Gram-positive and gram-negative microorganisms and the number of cases are listed in Figure 6. In only eight patients, polymicrobial infections were documented.

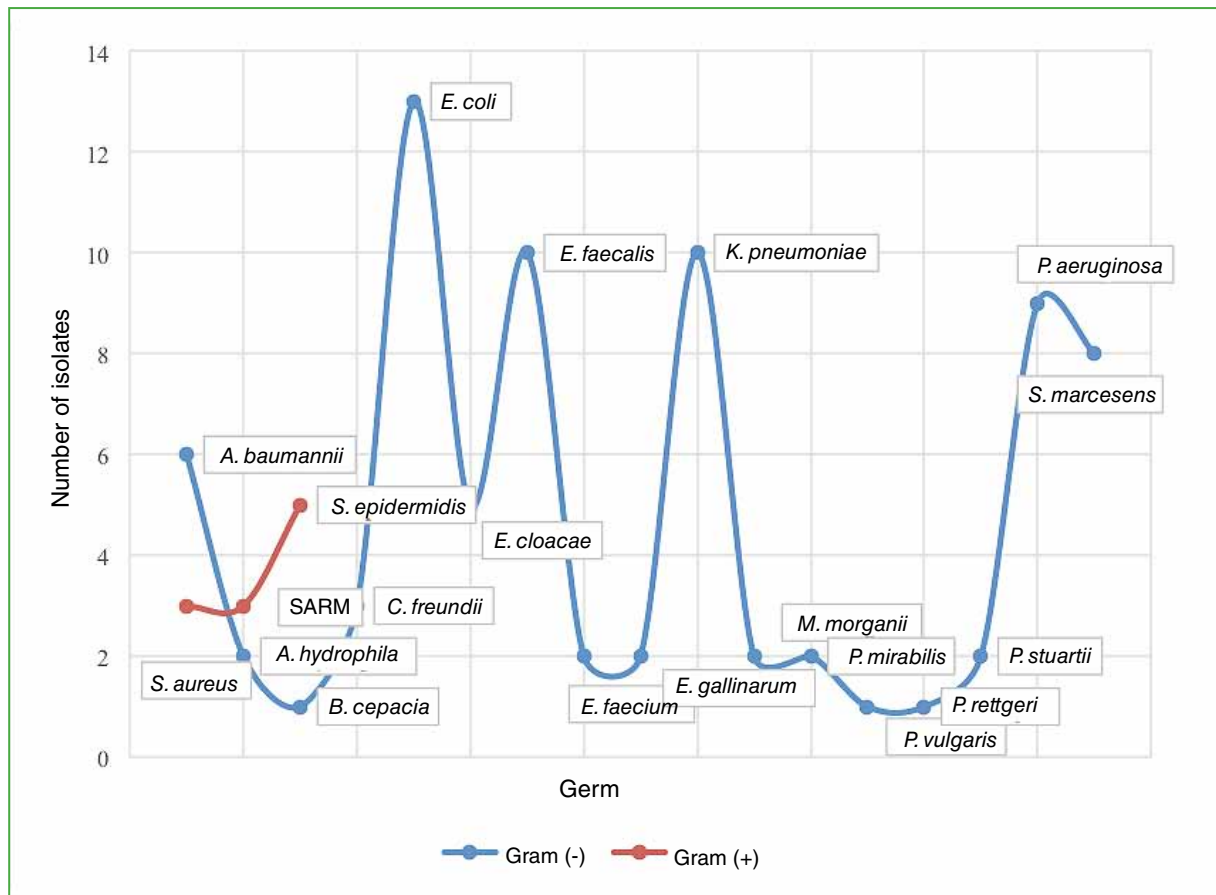


Figure 6. Gram-positive (red line) and gram-negative (blue line) microorganisms isolated from war trauma patients between 2012 and 2020.

DISCUSSION

Orthopedic damage control is not a new concept, it was developed from the management of polytraumatized patients with severe abdominal injuries, and highlighted the increased survival rate by temporarily controlling rather than definitively managing injuries leading to the lethal triad of hypothermia, acidosis and coagulopathy.

With over 80 years of service to all combat wounded of the Military Forces, the Central Military Hospital has shaped its casuistry under the premise of “do no more harm” by applying all the concepts of a damage control approach in the management of severely injured extremities by unconventional, intentionally contaminated, and high energy weaponry; all of this through rapid stabilization of fractures with external fixators up to physiological stabilization and definitive management.^{6,19-22,24}

The typical war wounded serviceman, as evidenced by the sample, is a young patient, with an average age of 24 years (min. 18, max. 37). Although high-velocity projectile trauma was the most common, it is not always the most common mechanism of injury, because patients injured by other weapons, such as mines and explosive devices, often die or require amputation of the limb, so they are not included in this study. Likewise, lesions predominated in the left lower limb and were more frequent in the femur (Case 1) (Figure 7).

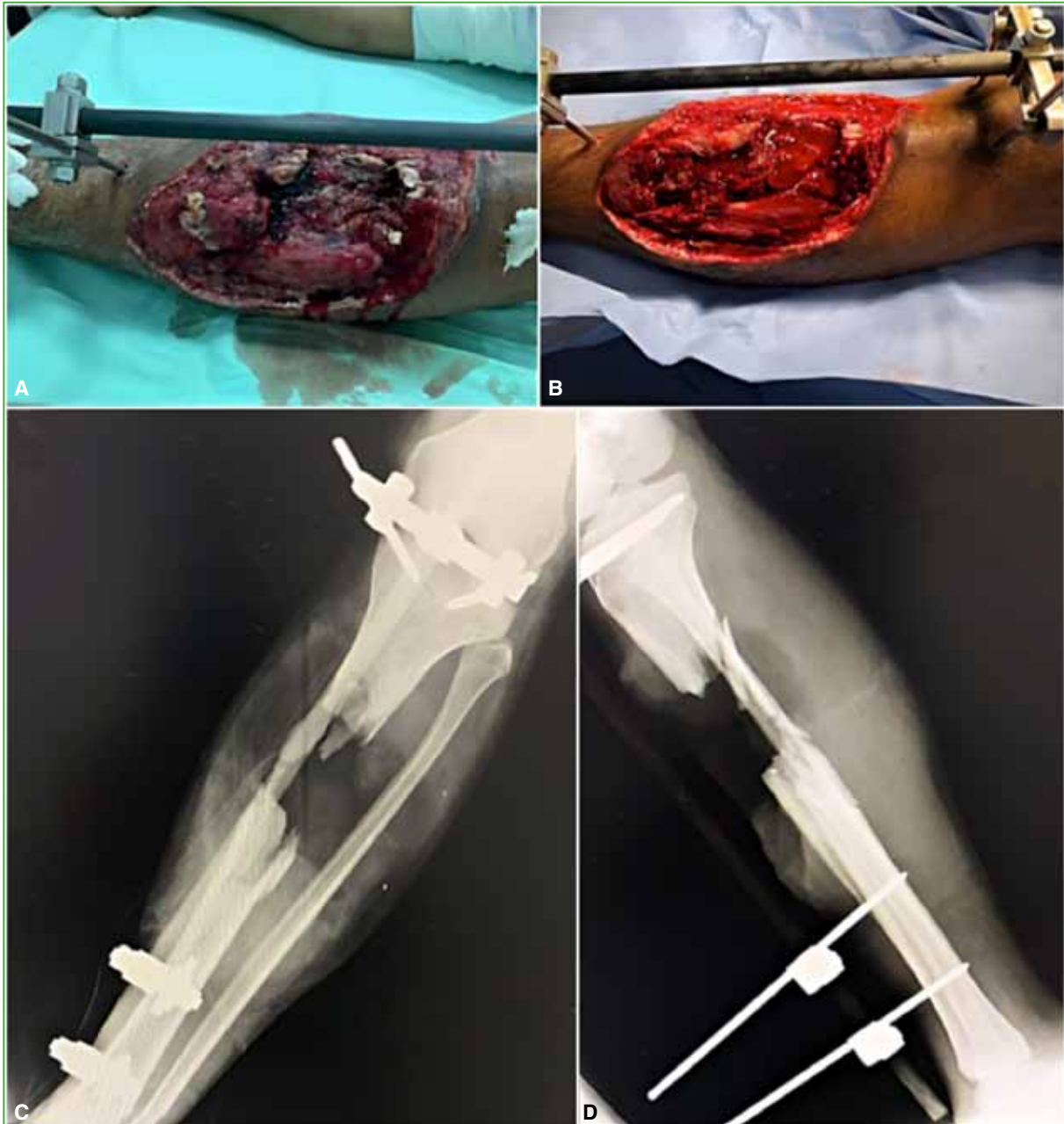


Figure 7. 19-year-old soldier with trauma secondary to a gunshot wound to the left leg. **A.** Clinical image on admission. **B.** Intraoperative image of the first surgical lavage. **C and D.** Anteroposterior and lateral radiographs of the left knee.

In our institution, victims of war trauma are admitted to the emergency department where they are comprehensively evaluated and antibiotic management is initiated to cover gram-positive and gram-negative bacteria, since it is evident that the vast majority of the microorganisms isolated in our sample are gram-negative bacteria. External fixation is preferred for orthopedic management, which corresponds to the global trend for the management of severe injuries and polytraumatized patients.^{23,24} The patient is routinely taken to surgery for a quick inventory of the injuries, regardless of their size. All are thoroughly explored, followed by surgical lavage and debridement of the devitalized tissue, taking into account the following evaluation criteria: color, muscle contractility, and bleeding. If the fracture has already been fixed with an external fixator, the stability and position of the fracture are assessed for future operations, therefore they frequently require fast adjustments. Preferably, monolateral fixation is performed in diaphyseal fractures and transarticular fixation when the bone lesion is metaphyseal or articular, always with modular systems (Case 2) (Figure 8).



Figure 8. 31-year-old soldier with trauma secondary to a gunshot wound to the right thigh. **A.** Clinical image on admission. **B.** Comparative radiography of the hip. **C.** Intraoperative imaging with external fixator. **D and E.** Anteroposterior radiographs of the right femur after surgery.

The concept of timely damage control is based on rapid stabilization for subsequent evacuation from the operating area or first level hospitals with insufficient resources and personnel, bleeding control, pain management, and avoiding additional damage to soft tissues and neurovascular structures by free bone fragments, as described by some authors.^{24,25} Although a correlation of musculoskeletal trauma with the involvement of other systems was not undertaken in this study, relationships with cranial, thoracic, and abdominal trauma were found in general. The use of mini-osteosynthesis with screws has been described to stabilize some fragments, especially articular fragments;⁹ we do not routinely perform this procedure. Furthermore, the use of osteosynthesis systems, such as plates or intramedullary systems, is not considered until any infectious process has been ruled out through serial cultures of secretion, soft tissues, bone, and until enough covering of the surrounding soft tissues has been achieved.

We use a multidisciplinary paradigm of treatment and management that is staged through early and rapid stabilization of the fracture with external fixation by orthopedics in order to control other life-threatening injuries or until physiological stability is established. Infections are treated with surgical lavage and antibiotics directed at isolated bacteria, with drug sensitivity evaluated using antibiograms and infectious diseases analyses. Simultaneously, soft tissue care is accomplished by dressings, and when there are coverage defects, vacuum-assisted closure and more complex plastic surgery methods are employed. Due to tissue conditions or recurrent infections in bone and soft tissues, conversion to plates or intramedullary systems is rarely performed. During this time, some fractures consolidate with the external tutor or are revised to revive the focus and apply either autologous bone graft, predominantly from the iliac crest, or allograft from the bone bank for subsequent consolidation.

Hospitalization and outpatient follow-up times are lengthy, and emergency readmissions occur frequently due to infectious complications; in our sample and during follow-up of all patients, more than 70% were readmitted for infection or pain. When an infectious process was documented, it was impossible to determine whether it was a recurrence of the original infection or a new infection caused by the fixator or previous surgical procedures.

During treatment and while they are active in the military, patients are provided with housing and transportation facilities at the expense of the force to which they belong. Follow-up of patients on leave or who have completed their service is often incomplete.

CONCLUSIONS

Extensively affected extremity bone injuries sustained during combat with various types of weaponry require comprehensive tiered therapeutic management based on damage control principles.

War trauma continues to represent one of the etiologies of polytrauma in young patients in our country, which, in turn, continues to cause great clinical and economic consequences, and affects the short and long-term quality of life of patients.

The characteristics and variables documented in our study make it possible to identify probable fields of action for future analytical studies that will allow us to compare populations and tools susceptible to improvements in the treatment and prevention of complications in patients with war trauma.

Conflict of interest: The authors declare no conflicts of interest.

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