

Shotgun injuries: Need for a special point of view

Lesiones por disparo de escopeta. Necesidad de un punto de vista especial

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Abstract

Background: Shotgun injuries (SGIs) are infrequent, but due its special ballistics, are related to adverse outcomes. **Objective:** The objective of the study was to analyze operative and administrative variables, critical for the institution. **Methods:** Demographics and health care-related variables from SGI patients admitted to Military Central Hospital (Mexico City) between July 2006 and August 2019, were retrospectively studied. Statistics methods used were dispersion measures and relative occurrence frequency. **Results:** Over a 15-month span, 21 SGI patients were admitted. Mean age was 36.9 ± 13.6 years (range: 14-61) and male gender was dominant ($n = 20$; 95%). Type II SGIs were the most common injuries (62%; 13/21). Mean hospital length of stay was 37.1 ± 28.7 days (range: 3-109) while stay at ICU was 20.3 ± 22.5 days (range: 3-99). Global rate of morbidity was 82% (17/21) and most frequent complications were infective. Global mortality rate was 24% (5/21). **Conclusions:** Once SGIs cause prolonged length of stay, high rate of morbidity, and of enormous consuming of material and human resources, primary prevention strategies are convenient for health-care systems compromised to the care of these cases.

Keywords: Injury. Shotgun. Ballistics.

Resumen

Antecedentes: Las lesiones por disparo de escopeta (LE) son infrecuentes, pero debido a su balística especial se relacionan con un pronóstico adverso. **Objetivo:** Analizar variables operativas y administrativas de los pacientes con LE, de interés para la institución. **Métodos:** Se estudiaron retrospectivamente variables demográficas y asistenciales de pacientes con LE admitidos al Hospital Central Militar (Ciudad de México) entre julio de 2006 y agosto de 2019. Los métodos estadísticos usados fueron medidas de dispersión y frecuencia relativa de ocurrencia. **Resultados:** En 158 meses se admitieron 21 pacientes con LE. La edad media fue de 36.9 ± 13.6 años (rango: 14-61) y predominó el sexo masculino ($n = 20$; 95%). La LE tipo II fue la más frecuente (62%; 13/21). La estancia hospitalaria media fue de 37.1 ± 28.7 días (rango: 3-109) y en cuidados intensivos fue de 20.3 ± 22.5 días (rango: 3-99). La tasa global de morbilidad fue del 82% (17/21) y las complicaciones más frecuentes fueron infecciosas. La tasa global de mortalidad fue del 24% (5/21). **Conclusiones:** Las LE son causa de estancia hospitalaria prolongada, alta tasa de morbilidad y un enorme consumo de recursos humanos y materiales, por lo que las estrategias de prevención primaria son convenientes para los sistemas de salud comprometidos con el cuidado de estos casos.

Palabras Clave: Lesión. Escopeta. Balística.

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Introduction

Shotgun injuries (SGIs) are a major public health problem, especially in emerging countries¹. The most affected group has been estimated to be that of males between 20 and 29 years of age, and although these injuries account only for 0.5-2% of total gunshot wounds, they cause a significant rate of disease-related morbidity, consume a large amount of human and material resources for their approach, and are related to a mortality rate that cannot be belittled²⁻⁴.

Given that SGI effects ballistics entail the presence of multiple trauma by individual pellets that vary in weight and size, with different penetration potential, that scatter or concentrate within an area of variable size and that transmit a specific amount of energy depending on the type of weapon and firing distance, it is essential for the surgeon to understand that the anatomical features of these injuries are not similar and cannot be compared to those produced by conventional firearm projectiles, regardless of the speed of the missile. This should lead to awareness that the SGI management strategy remains unclear, which limits the ability to study the injury mechanism, and the operator must implement the most pertinent diagnostic and therapeutic behavior to optimize the results concerning survival and functionality rates⁵.

It is of primary interest for the Central Military Hospital Trauma Group to analyze the institutional panorama, both epidemiological and administrative, that involves the approach to these patients, to evaluate the results obtained with their management and define areas of opportunity to propose and implement improvement strategies in specific management protocols.

Methods

This series corresponds to a retrospective study (158 months, from July 2006 to August 2019) on epidemiological and administrative aspects of interest to the institution, which analyzes the variables obtained from medical records of patients with SGI admitted to the Central Military Hospital in Mexico City, which is a military and urban trauma center, and a training hospital in trauma surgery for surgeons of the armed institute. Demographic variables (gender and age), variables at arrival (systolic and diastolic blood pressure, heart and respiratory rate, Glasgow score, the revised trauma score [RTS] score and the injury

severity score [ISS]), diagnostic and therapeutic interventions on arrival, surgical and adjuvant interventions that were performed, injuries to specific organs and prognostic variables (hospital stay, intensive care unit stay, mechanical ventilatory support duration, specific and overall morbidity rate, mortality rate and cause, and place of death) were evaluated. All variables were subjected to descriptive statistical analysis with measures of dispersion (mean $\pm$ standard deviation) and relative frequency of occurrence, using the Microsoft® Excel® program for Office 365 MSO (ProPlus, version 1908). When applicable, due to the sample size, Student's t-test was used for statistical comparison.

Results

During a 158-month period (July 2006-August 2019), 21 patients with SGI (0.1 patient/month) were admitted to the Central Military Hospital, out of which 20 were male (95.2%) and 1 (4.8%) was female; mean age was 36.9 ± 13.6 years (range: 14-61). Patients arrived with mean systolic blood pressure values of 115.6 ± 20.7 mmHg (range: 87-175) and diastolic at 76.1 ± 12.7 mmHg (range: 54-104), respiratory rate of 23.1 ± 6.1 breaths/min (range: 17-40), temperature of $36.3 \pm 0.6^\circ\text{C}$ (range: 34.9-37.2), Glasgow score of 14.7 ± 0.6 (range: 13-15), RTS score of 6.91 ± 1.11 (range: 4.79-7.84), and ISS score 44.5 ± 13.6 (range: 16-69), which indicate the inclusion of a study population that was physiologically stable, but that had lesions of a high anatomical severity index. Most our patients had type II SGI (62%; 13/21), followed by type I lesions (19%; 4/21), with the least common being type III (19%; 4/21) (Fig. 1).

Given that all patients who are received at the emergency department of our institution are managed with the American College of Surgeons ATLS® protocols, in 100% of them (21/21), peripheral intravenous lines were placed. Fourteen patients (32%) had one or two pleural tubes inserted, while 5 (24%) had a central venous catheter placed, and 4 (19%) were orotracheally intubated. Of note, in 1 patient (5%) with complex facial trauma, a needle cricothyrotomy was performed using the Seldinger technique. Ultrasound-guided focused assessment with sonography for trauma was performed in 9 patients (43%), 20 underwent portable plain radiological assessment (95%), and in all patients of the series (100%; 21/21), plain or contrast computed tomography was performed.

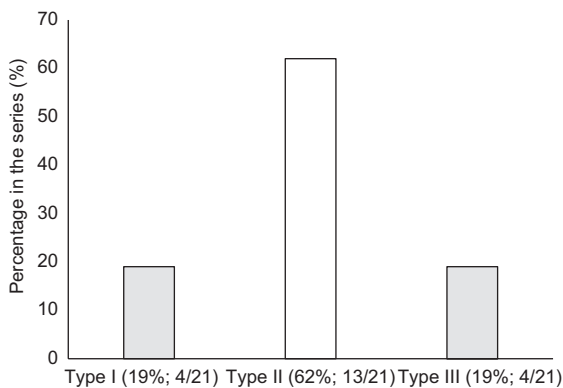


Figure 1. Shotgun injuries distribution, according to Trunkey and Blaisdell classification⁶ (Source: Trauma Surgery Section Registry, Department of General Surgery, Hospital Central Militar, SEDENA, Mexico City).

Although all patients underwent surgical intervention in our institution at some point during their hospital stay, 5 (24%) had already been surgically intervened at referring hospitals (four by exploratory laparotomy and one by left posterolateral thoracotomy). In 2 patients (10%), cervical exploration was performed, 7 (33%) required thoracotomy, and 17 (81%) required primary or second inspection exploratory laparotomy for therapeutic approach. Five patients required tracheostomy, with four procedures being percutaneously performed assisted by bronchoscopy in the intensive care unit and one in the operating room. One patient (5%) required sequential complex facial reconstruction with external facial fixators, and 6 (29%) required reconstructive procedures with sequential surgical cleaning (6/6), skin grafts (4/6), and free or pedicled flaps (2/6). In 16 patients (76%), sequential procedures were performed, with a mean of 5.3 (range: 2-17) procedures per patient, most of them in soft tissues (9/16) and abdomen (8/16). As non-surgical adjuvant procedures, two arteriographies were performed with selective angioembolization (10%) and four percutaneous drainages for cavitory collections (19%).

One hundred injuries to specific organs were recorded, with an average of 4.8 injuries per patient. The most commonly injured organs were the skin and appendages (100%; 21/21), followed by trauma to peripheral vascular organs, liver, lung (7/21; 33% each), jejunum-ileum, and colon (5/21; 24% each). The distribution of all specific injuries is shown in table 1.

Mean hospital stay was 37.1 ± 28.7 days (range: 3-109). One patient with complex facial trauma

remained bedridden for 3 days and succumbed to sepsis and multiple organ failure. Mean stay at intensive care unit was 20.3 ± 22.5 days (range: 3-99) and mechanical ventilatory support mean duration was 16.1 ± 20.8 days.

Overall morbidity rate was significantly high and was on the order of 82% (17/21). A total of 106 specific complications were recorded, with a mean of five complications per patient. The most common specific complications were infectious in nature, including superficial or deep surgical site infection (76%; 16/21), urinary tract infection (71%; 15/21), and ventilator-associated pneumonia and sepsis (43%; 9/21 each). The organ failure that most consistently occurred was kidney failure (38%; 8/21) followed by multiple organ failure (33%; 7/21) and acute respiratory failure (24%; 5/21). Of note, in 2 cases (10%), there was small pellet projectile (birdshots) embolism, one toward the gastropancreatic splenic circulation and another toward the right pelvic limb distal circulation, both, curiously, with no ischemic repercussion. The distribution of all specific complications is shown in table 2.

Overall mortality rate was 24% (5/21). The causes of death were multiple organ failure in 3 patients (14%), non-coagulopathic bleeding in 1 patient (5%), and respiratory failure refractory to ventilatory strategies in 1 patient (5%). The most common place of death was the intensive care unit (3/21; 14%), while two patients succumbed in the regular hospitalization unit. Of note, all four patients with type III SGI passed away, with a specific mortality of 100% for this type of lesions, while one patient with type II SGI died, with a specific mortality of 7% (1/13). There were no deaths in the group of patients with type I SGI.

Discussion

SGIs are an uncommon, but ubiquitous and preventable epidemic, which cause not only serious mental and anatomical harm to the victim but also emotionally and financially damage society. This infrequency has generated inexperience in urban trauma centers and has caused for the surgeon not to reason or to belittle the injury mechanism that is so peculiar of SGI, which leads to an inadequate approach and failure to define injuries' general conditions^{1,4,6,7}.

It is essential that, from the beginning, the doctor who treats a patient with SGI understands that the injury pattern and trauma severity critically depend on firing distance, caliber of the shotgun barrel and size of the pellets^{7,8}. Thus, a wide variety of wounds can

Table 1. Injuries to specific organs in patients with shotgun injuries

Specific organ injured	n/N (%)
Skin and appendages	21/21 (100)
Peripheral vascular organ	7/21 (33)
Liver	7/21 (33)
Lung	7/21 (33)
Ribcage	6/21 (29)
Jejunum-ileum	5/21 (24)
Colon	5/21 (24)
Thoracic vascular organ (other than aorta and vena cava)	4/21 (19)
Abdominal vascular organ	4/21 (19)
Spleen	4/21 (19)
Bony pelvis	3/21 (14)
Spine and spinal cord	3/21 (14)
Esophagus (cervical or thoracic)	3/21 (14)
Kidney	3/21 (14)
Stomach	2/21 (10)
Rectum	2/21 (10)
Cervical vascular organ	2/21 (10)
Pancreas	2/21 (10)
Heart and pericardium	2/21 (10)
External genitalia	2/21 (10)
Larynx and trachea	2/21 (10)
Ureter	1/21 (5)
Bronchi	1/21 (5)
Facial skeleton	1/21 (5)
Hypopharynx	1/21 (5)

Total: 100 specific injuries (4.8 injuries per patient)

Source: Trauma Surgery Section Registry, Department of General Surgery, Hospital Central Militar, SEDENA, Mexico City.

Table 2. Overall rate of specific morbidity and morbidity in patients with shotgun injuries

Specific complication	n/N (%)
Surgical site infection	16/21 (76)
Urinary infection	15/21 (71)
Mechanical ventilation-associated pneumonia	9/21 (43)
Sepsis	9/21 (43)
Kidney failure	8/21 (38)
Multiple organ failure	7/21 (33)
Acute respiratory distress syndrome	5/21 (24)
Bleeding (technical, non-coagulopathic cause)	5/21 (24)
Empyema	4/21 (19)
Coagulopathy	4/21 (19)
Incisional hernia	3/21 (14)
Bowel obstruction	3/21 (14)
Major depressive syndrome	3/21 (14)
Pneumatocele	2/21 (10)
Intestinal fistulization	2/21 (10)
Necrotizing myofascitis	2/21 (10)
Lung abscess	2/21 (10)
Missile embolism	2/21 (10)
Peripheral vascular organ pseudo-aneurysm	2/21 (10)
Pancreatic fistula	1/21 (5)
Brain death	1/21 (5)
Subglottic stenosis	1/21 (5)

Total: 106 specific complications (five injuries per patient)

Overall morbidity rate: 82% (17/21)

Source: Trauma Surgery Section Registry, Department of General Surgery, Hospital Central Militar, SEDENA, Mexico City.

be found, ranging from superficial punctate lesions induced by isolated small pellets to deep destructive lesions, with concentration of several small or medium missiles within a limited area or generated by large, solid slugs^{5,7-9}.

In general terms, the surgeon's understanding on SGI ballistics is quite poor. A shotgun is a smooth tube included in a grabbing and aiming system, which has a magazine, which houses a cartridge made up of a plastic or cardboard shell, an ignition mechanism at

its base, an explosive propellant, and a load of pellets that conventionally weigh between 5.71 and 45.5 g, which, depending on their size, are known as bird-shots (small), buckshot (medium), or slugs (large, solid missiles). It should also be borne in mind that each pellet can generate a permanent cavitation (injury or intrusion tract), which depends on the mass of the missile, or cause an eccentric initial temporary cavitation and another of a concentric late temporal nature, which is directly related to the velocity of the projectile (most shotguns fire missiles with a speed ranging from 556 to 402 m/s). The length of the barrel, the dimension of the opening of its mouth, and the firing

distance largely define the concentration of pellets and, consequently, the transmission of energy on the target. The energy transmitted by each individual pellet has been calculated to reach from 880 to 3700 J, which explains the great power of destruction when a large number of them converge within a defined area, as in short-range shots. In addition, there are other factors that define the injury pattern, such as the profile (shape and material of the missile, fragmentation), external ballistic phenomena (precession, nutation, tumbling, and yaw), target tissue anatomical and physical characteristics, and mitigating or modifying elements, such as clothing and military body armor^{3,5,6-8,10-12}.

Although there have been multiple attempts to classify these injuries, none has been able to regulate the behavior or establish the need for surgical treatment with certainty. García-Núñez et al.³, in a review of the literature concerning the subject, refer that Asensio, from the Los Angeles Trauma Group, proposed in 2004 a modification to the Trunkey and Blaisdell classification⁵ based on the shooting distance, with a proposal being made for an approach supported by clinical experience:

- Type I: also called “distant-range” injuries. These are wounds caused by shots fired from a distance > 7 yards that usually require superficial care and pellet removal is accessible to the operator. In general, prognosis is good for life and function, and estimated mortality is 0-5%.
- Type II: also known as “intermediate-range” wounds. Shooting distance is 3-7 yards toward the victim. Injuries are deep, a thorough diagnostic approach is required and the need for early surgical intervention is high. Prognosis for life and function is reserved, with a mortality rate of 5-10%.
- Type III: also known as “short-range” wounds. Shooting distance is < 3 yards. There is usually deep destruction of the anatomy. All patients require aggressive surgical intervention and many must be operated on under the policy of the damage control strategy. Prognosis for function is consistently poor and the mortality rate reaches 15-20%. This type of wound is the cause of death in 85% of SGI-related mortality cases.

In our series, most SGI victims were young males, which is consistent with the findings reported in large epidemiological series for this type of injury and trauma in general^{1,2,5,13}. Due to current socioeconomic and

demographic conditions of the country, where it is easy to clandestinely obtain high-power weaponry, SGIs account for a minority of gunshot wounds, which is why our hospital, despite being a military and urban trauma center that receives cases from other national military echelons, admits a mean of 0.1 patients per month, mainly from the suburban arena. This prevalence of cases is comparable to that reported by Schellenberg et al.⁸ who inform about an incidence of 0.5 cases per month for a Level I trauma center in the United States. This can lead to the development of limited experience by contact physicians and to the implementation of inadequate diagnostic and therapeutic procedures, with potential damage to survival and functionality prognostic indices.

Due to SGI particular ballistics^{3,5,7,9-12}, the patients in our series arrived generally stable from the physiological point of view (RTS: 6.91 ± 1.11), but with wounds of a high anatomical severity index (ISS: 44.5 ± 13.6)¹⁴. The particular mechanism of the injury is also a cause for aggressive diagnostic and therapeutic approach in the emergency department, wherein one-third of the patients pleural tubes had to be used and in one-fifth, endotracheal intubation was required. The use of computed tomography was necessary in 100% of cases, since, clinically, it was impossible for the anatomic pathology of the damage to be defined, a situation logically imposed by the impact of multiple pellets. However, this is the ideal time to pause for caution, emphasizing that these patients are highly sensitive to radiological findings misinterpretation – a condition described in the literature as victim of modern imaging technology – therefore, here, the collaboration between the surgeon and the radiologist is critical¹⁵.

As an expected consequence of pellets dispersion or confluence in the victim, which affects large bodily regions or transmits a large amount of energy within a reduced anatomical area^{3-5,7,8,10,12}, in our study, we found a huge amount of injuries to specific organs and a high average of injured organs per patient (4.8 injuries/patient), which also required the performance of 49 primary procedures (2.3 procedures/patient) and that, in 76%, a mean of 5.3 sequential surgical procedures had to be carried out. The need for multiple surgical interventions has been described in various studies reported in the literature, given the extent of the damage caused by SGI^{4,6-8,10-12,16,17}. The above factors clearly explain the prognostic indices that were obtained. Prolonged hospital (37.1 ± 28.7 days) and intensive care unit stays (20.3 ± 22.5 days) were observed, as well as a significant number of days during

which patients required mechanical ventilation (16.1 ± 20.8 days). Morbidity was on the order of 82% (17/21), with the most common specific complications being those of an infectious nature. We consider that patient serious anatomical disruption, prolonged hospital stay, immobilization and malnutrition, the level of invasive monitoring, and the large number of procedures that were practiced on SGI victims¹⁵⁻¹⁷ reveal the nature of trauma as an immunosuppressive condition, which turns patients into an easy target of healthcare-related infections and which has a high rate of non-infectious complications and significant mortality, reflecting the torpid evolution many of these patients exhibit.

Organ failure is another problem that surgeons committed to the care of the surviving patient must face at some stage of hospital stay. In our series, we found kidney failure (38%; 8/21) to be the most common organ failure followed by multiple organ failure (33%; 7/21). Systemic inflammation and sepsis are known to be independent inducers and promoters of acute kidney failure, due to the production of cytokines causative of nephritis, mitochondrial injury by peroxynitrite, microvascular constriction mediated by the renin-angiotensin-aldosterone system, increased vascular permeability by humoral and cellular cytotoxicity, and cytologically mediated organ oxidative stress. On the other hand, these same conditions, coupled with the ischemia-reperfusion phenomenon induced by traumatized patient resuscitation and rhabdomyolysis following extensive soft-tissue injury, can not only lead the patient to exclusive kidney failure but can also reflect on varied organ failures, as it was observed in our study^{4,5,7,10,18,19}.

The mortality rate was not negligible in our series. Five patients died, out of whom 3 (60% of deaths) did it due to multiple organ failure. One patient experienced non-coagulopathic bleeding of retroperitoneal origin that was resolved with packing and selective angiographic embolization, but that led the patient to a state of refractory shock and death. One last patient died of progressive respiratory failure. It is especially important mentioning that no patient with type III SGI survived, with a specific mortality rate of 100% (4/4), which is not surprising in the analysis of these lesions, since high-energy transmission, severe anatomical disruption, multiple diagnostic and therapeutic interventions, and sequential hits, as well as invasive monitoring and the pro-inflammatory and immunosuppressive response they entail as a consequence in the victims of these injury mechanisms, are factors known in the

literature as related determinants or independent predictors of high mortality^{1,2,4,5,7,8,10,12,18-21}.

The limitations of this study should be considered. Although it consists of an analysis of the cases recorded in a national military and urban trauma center, the frequency of SGIs is low, and this limited the study universe. In addition, the shooting distance could not be accurately defined, given that this information was obtained by directly questioning the victim, with all the vagueness this entails. Finally, the retrospective and single-center nature of the study has inherent design limitations. In the future, these limitations could be mitigated with a multicenter, prospective study that clarifies the national data required to validate the proposals and conclusions obtained by this research.

Finally, this study offers the Mexican surgical community a contemporary analysis of the epidemiology, injury pattern, diagnostic evaluation, and surgical management of patients with SGIs admitted to the Central Military Hospital and represents, to the best of our knowledge, if not the only, the largest study reported in the national literature on trauma surgery. Patients who suffer SGIs are epidemiologically similar to those who sustain projectile trauma from other types of firearms and can be initially approached the same way, covering common needs. However, the surgeon should be alert to the limitations imposed by clinical evaluation and currently available diagnostic tests. Even computed tomography has shown a high failure rate (false positives and negatives) due to artifacts caused by the clustering of pellets^{15,16}. Therefore, we recommend maintaining a high degree of suspicion about multiple organ injury and subjecting patients to formal periods of hospital observation prior to discharge, even if there is an apparently negative tomographic result with regard to organ injury.

Conclusions

SGIs are a rare traumatic condition, but with peculiar ballistics that cause highly characteristic organ damages. Due to their low frequency, surgeons develop limited experience in the management of these cases, making mistakes when addressing highly complex injuries, which affect prognostic indices. Due to the confluence of several morbid factors with the injury mechanism, significant anatomical disruption, high number of specific lesions present in the victims, the large volume of diagnostic and therapeutic interventions they are subjected to, and the physiological

compromise they experience during their evolution, these patients usually incur prolonged hospital and intensive care unit stays, need for several days of mechanical ventilatory support, high morbidity rates and high frequency of infectious complications, as well as significant mortality, mainly driven by multiple organ failure. This entails a high consumption of human, material and administrative resources, which is why societal intervention with vigorous primary prevention strategies appears to be the most convenient behavior for institutions that are committed to the medical-surgical care of these patients.

Conflicts of interests

The authors declare that there is no financial or personal relationship with any person or organization that could generate any conflict of interests.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments have been performed on humans or animals for this research.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained informed consent from the patients and/or subjects referred to in the article. This document is in the possession of the corresponding author.

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