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Original

Epidemiological Profile and Prognostic Factors of Cranioencephalic Injury by Firearm Projectile in a Reference Hospital in the Metropolitan Region II

Perfil epidemiológico y factores pronósticos de lesión craneoencefálica por proyectil de arma de fuego en un hospital de referencia de la Región Metropolitana II

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ABSTRACT

Introduction: *Traumatic brain injury (TBI) is a serious condition with high morbidity and mortality worldwide.* **Objective**: *The Epidemiological Profile and Prognostic Factors of Head Trauma due to Low-Energy FAP in Metropolitan Region II of the State of Rio de Janeiro were analyzed.* **Methods**: *The medical records of 50 patients who arrived alive, victims of TBI due to low-energy Firearm Projectile (FAP), treated at the Alberto Torres State Hospital (ATSH) Trauma Center, from January 2015 to August 2022 were evaluated, considering the variables age group, sex, race, Glasgow Coma Scale (GCS) at entry, affected brain regions, laterality, middle line crossing in the coronal plane, proposed treatment — whether conservative or surgical — and Glasgow Outcome Scale (GOS).* **Results**: *it was found that the greatest epidemiological variables occurred in males, mixed race and in the age group under 30 years of age. The predictive indices of severity and death occurred in patients who were admitted with severe Glasgow Coma Scale, with lesions that crossed the coronal middle line, bi-hemispheric, and in cases with a greater number of injured brain regions. The parietal lobe was the most affected. All cases of TBI due to FAP that did not penetrate the cranial cavity evolved well.* **Conclusion**: *the epidemiological results and predictive prognoses presented in this study are in accordance with the literature.*

Keywords: *TBI; skull; FAP.*

RESUMEN

Introdución: *La lesión cerebral traumática (LCT) es una afección grave con alta morbilidad y mortalidad a nivel mundial.* **Objetivo**: *Se analizó el perfil epidemiológico y los factores pronósticos del trauma craneoencefálico por PAF de baja energía en la Región Metropolitana II del Estado de Rio de Janeiro.* **Methods**: *Se evaluaron los historiales médicos de 50 pacientes que llegaron vivos, víctimas de LCT por Proyeto de Arma de Fuego (PAF) de baja energía, atendidos en el Centro de Traumatologia del Hospital Estatal Alberto Torres (HEAT), entre Enero de 2015 y Agosto de 2022. Se consideraron las variables: grupo de edad, sexo, raza, Escala de Coma de Glasgow (ECG) al ingreso, regiones cerebrales afectadas, lateralidad, cruce de la línea media en el plano coronal, tratamiento propuesto —conservador o quirúrgico— y la Escala de Resultados de Glasgow (Glasgow Outcome Scale-GOS).* **Resultados**: *Se observó que las mayores variables epidemiológicas se presentaron en varones, personas de raza mestiza y en el grupo de edad menor de 30 años. Los indicadores predictivos de gravedad y muerte se presentaron en pacientes ingresados con lesiones graves en la ECG, con lesiones que cruzaban la línea media coronal, bihemisféricas y en casos con mayor número de regiones cerebrales lesionadas. El lóbulo parietal fue el más afectado. Todos los casos de LCT por PAF que no penetraron la cavidad craneal evolucionaron favorablemente.* **Conclusión**: *Los resultados epidemiológicos y los pronósticos predictivos presentados en este estudio concuerdan con la literatura.*

Palabras-clave: *LCT; cráneo; PAF.*

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1 INTRODUCTION

TBI is considered one of the leading causes of death and disability worldwide, causing primary injury and a complex interaction of secondary pathophysiological events that follow[1], especially among young adults[2].

Since gunpowder was discovered in the 9th century in China and the invention of the first revolver in 1835 by Samuel Colt, brain injuries caused by firearm projectiles have become a challenge for neurosurgeons.

In 1976, James K. Styner developed the systematization of emergency room care for trauma patients, with the ABCDE protocol, known as ATLS[3]. In 2018, with the 10th edition of ATLS, the letter "X" was added to the ABCDE protocol (XABCDE), as a reference to external bleeding.

In 2018, Brazil led the world ranking for violent deaths by firearms, followed by the United States (USA), Mexico and Colombia[4].

TBI can be classified by severity, biomechanics, and pathophysiology. Regarding severity, the most widely used criterion is the Glasgow Coma Scale (GCS)[5]. The biomechanics of the injury divides blunt and penetrating traumas. And pathophysiological injuries into primary and secondary[6].

2 FIREARM BULLETS

The most common causes of fatal TBI by penetrating objects are by firearm projectiles, both in major emergencies and in forensic medical institutes (FMI). Primary brain injuries by FAPs are consequences of homicides, suicides, and accidents.

Considering that kinetic energy (KE) is calculated by multiplying the mass by the velocity squared, dividing this total by two ($KE = M \times V2/2$)[7], low-energy FAP injuries are those in which the velocity of the projectile is less than 300 m/s[8]. High-energy injuries are those in which the speed is greater than 600 m/s[8], and are incompatible with life. Injuries caused by firearm projectiles (FAP) occur as a result of the projectile's piercing-blunt action against the skull and, therefore, are of high energy[8]. TBI caused by FAP includes different injuries, such as lacerations, hemorrhages, pneumocephalus, edema, infarction and cerebrospinal fluid fistula, in addition to those that carry skin, hair, tissues, among others, into the brain parenchyma, causing infection and abscess[9].

These injuries can be classified as tangential[10], penetrating and transfixing. Projectiles are considered traumatic agents of the piercing-blunt class[9], as are umbrella tips, spearfishing harpoons, rebars, ice picks, among others. The assessment of the characteristics of the entry and exit holes already demonstrates the possible paths and injuries that occurred (Figure 1).

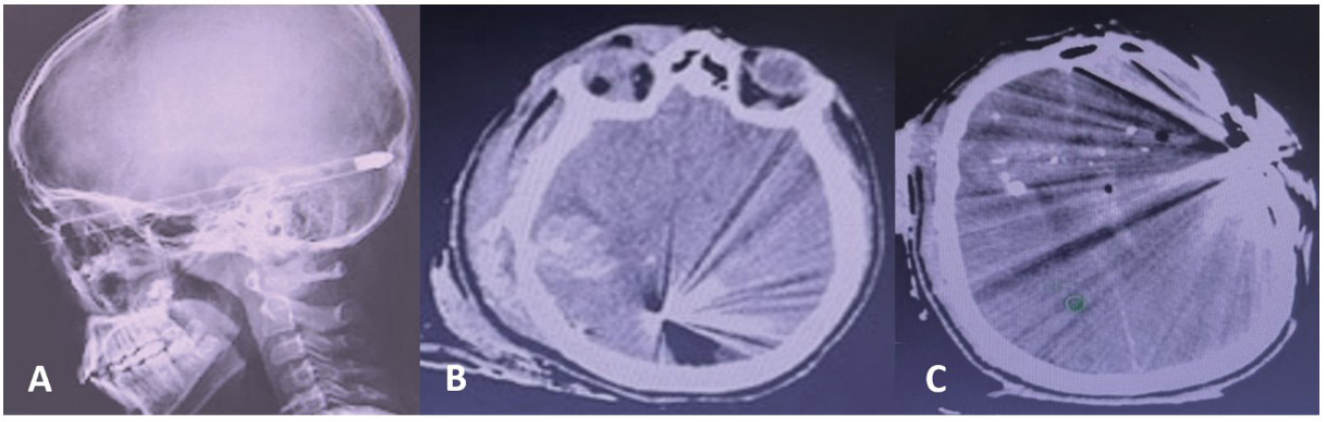

Figure 1. (A) Skull lateral X-ray with FAP; (B-C) CT scans with penetrating and transfixing FAP.

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The entry hole (EH) generally presents a rounded or oval injury, inverted edges, abrasions and a drying area (Figure 2)[11]. There may be a burn area (barrel touching), smoke and gunpowder tattooing when the attack is at close range[12].

When the lesions present concentric abrasion edges, that is, they have the same thickness around the lesion, we can say that the shot was fired perpendicular to the target.

When the edges are eccentric, we can say that the incidence of the shot was oblique. The longest portion of the abrasion edge indicates the direction of the shot. The wider the thickness of the abrasion, the more inclined the incidence of the shot[13].

The exit orifice (EO) in perforating and blunt injuries caused by low-energy projectiles presents characteristics with an irregular and/or star-shaped shape, an abrasion edge and everted edges[13] (Figure 3).

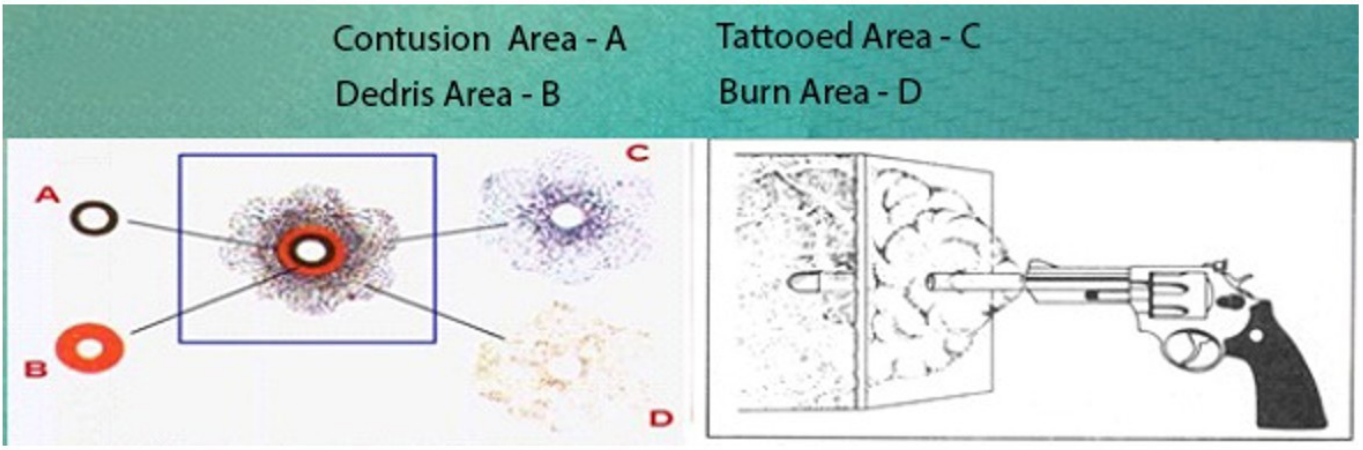

Figure 2. Injury zones diagram.

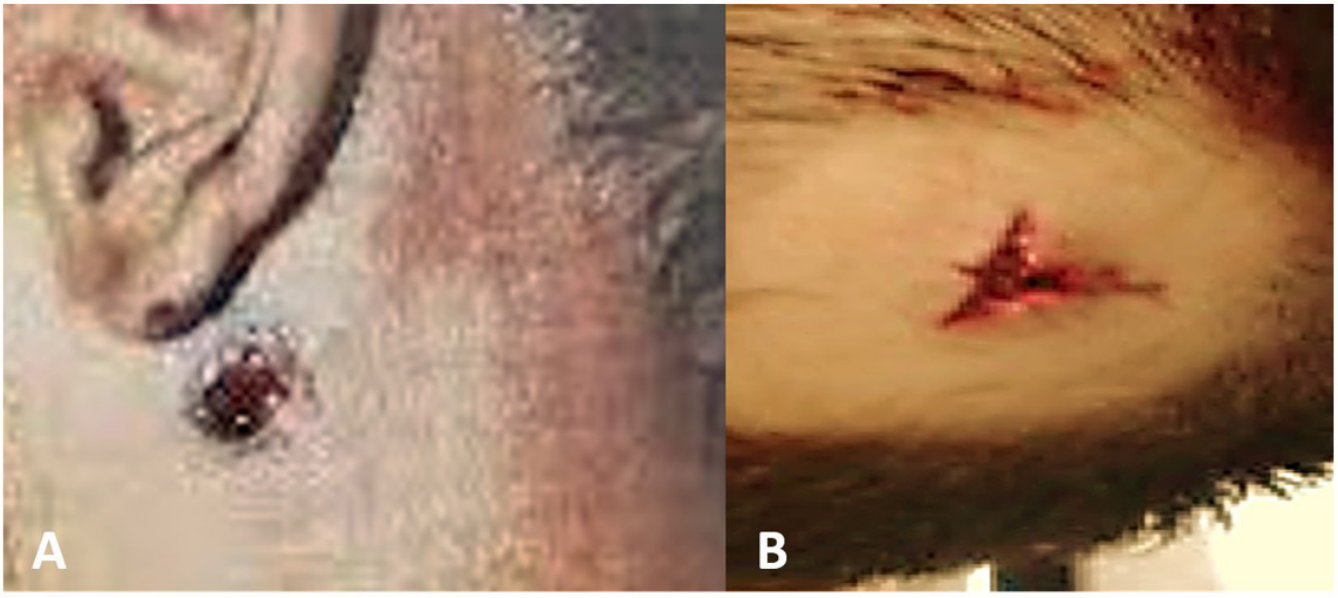

Figure 3. Low-energy skull FAP with entry (A) and exit hole (B).

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Figure 4. High-energy skull PAF with entry and exit hole.

In contrast, high-energy FAP injuries have entry holes similar to low-energy injuries, but their exit shows large irregular lesions, destroying all the tissues along their path until their exit.

This occurs due to the large kinetic energy dissipated by this firearm, which causes injuries beyond the mechanical injury of the projectile itself, given the dissipation of gases along the path that increases the diameter of this tunnel. In the skull, this type of injury is incompatible with life (Figure 4).

It should be noted that an entry wound may correspond to two or more exit wounds. This may occur due to bone fragments fractured by the projectile's path, which transforms these fragments into secondary projectiles[9].

Entry wounds in soft tissues have characteristics of piercing more and causing less bruising; in hard tissues, such as the skull, the projectile pierces and causes bruising, leading to associated fractures, from the point of entry.

All these concepts regarding the characteristics of entry and exit wounds also help to assist forensic medical-legal expertise in the judiciary[14].

3 RESULTS

The analysis of the 50 patients with FAP injuries found 15 patients under 20 years of age, between 21 and 30 years of age, there were 17 patients, between 31 and 40 years of age, there were 7 patients, between 41 and 50 years of age, there were the same rate of 7 patients, between 51 and 60 years of age, there were 2 patients and over 61 years of age there were also 2 patients. If the patients under 30 years of age are added, the total of 64% of the total cases is reached, and if the cases under 40 years of age are added, the total of 78% of the participants is reached. The evaluation of the cases in this study regarding race showed that the brown race was the most common, with 24 patients, followed by the black race, represented by 15 patients (30%), and the white race, represented by 11 patients. Regarding gender, males were predominant, with 44 cases (88% of the total), while six patients were female (12%).

When analyzing the GCS variable at the time of admission of patients who arrived alive at HEAT, 18 patients had mild GCS, eight patients had moderate CSG and 24 patients had severe GCS; of these with severe GCS, 8 cases (16%) arrived at the hospital with a 3-point GCS (Figure 5).

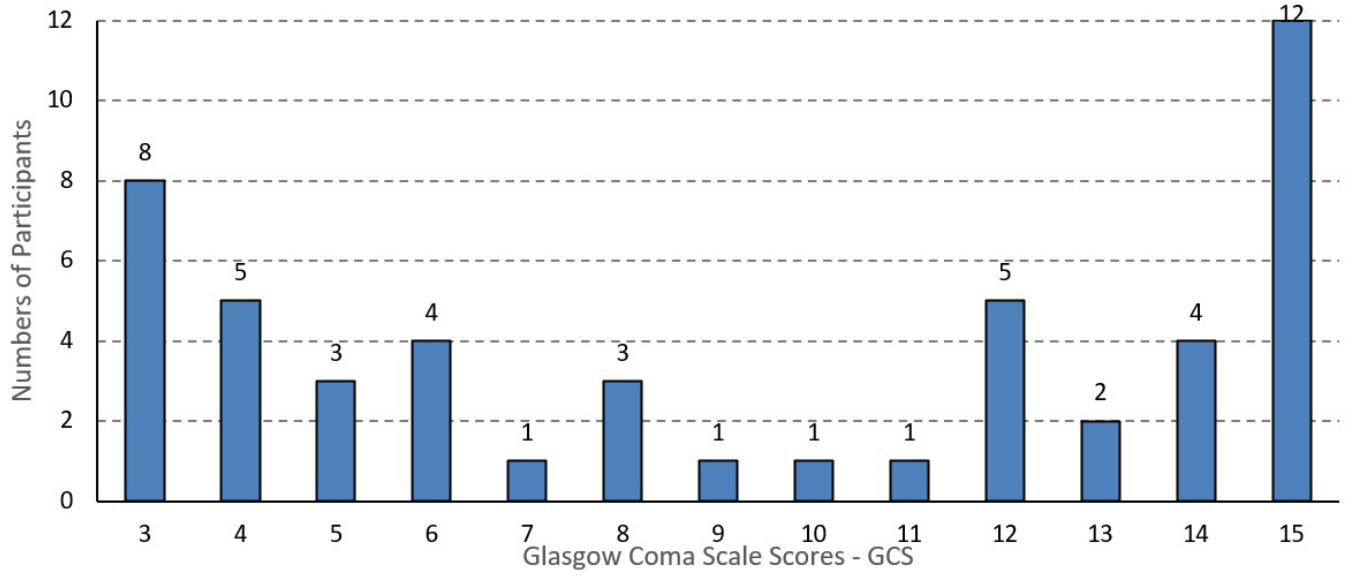

Figure 5. Distribution of participants' entry GCS scores.

Table 1. Frequency of cases in the combined ECG and GOS scales.

GOS / GCS	GOS1 Dead	GOS2 Vegetative State	GOS3 Lower Severe Disability	GOS4 Moderate Disability	GOS5 Good Recovery	Total
Serius Injury (GCS de 3-8)	13	02	06	01	01	23
Moderate Injury (GCS de 9-12)	04	0	0	01	03	08
Mind Injury (GCS de 13-15)	03	0	0	02	13	18
Total	20	2	6	4	17	49

The total number of cases differing from the initial 50 is explained by the lack of information for one of participants who was transferred sedated and after, it was not possible to obtains information.

The Glasgow Outcome Scale (GOS) was developed by Jennett and Bond (1975). Comparative evaluation of the admission GCS with the GOS outcome showed that of the 18 patients with mild admission GCS, three progressed to GOS 1, two patients progressed to GOS 4 and 13 patients were discharged with GOS 5.

Of the eight patients who entered with moderate ECG, four of them progressed to GOS 1; one patient progressed to GOS 4 and three patients progressed to GOS 5.

Of the 24 patients with severe admission ECG, 13 cases progressed to GOS 1; two patients progressed to GOS 2; six patients to GOS 3; one patient to GOS 4 and one patient progressed to GOS 5. There was one case in which the GOS could not be analyzed, as the patient was transferred sedated and it was not possible to make contact (Table 1).

Bi-hemispheric FAP lesions due to coronal middle line crossing occurred in 11 cases; there were nine deaths, one case evolved to GOS 2 and one case had an unknown result, since the patient was transferred sedated.

The distribution according to the number of injured hemispheres showed 19 cases in the right and left cerebral hemispheres each and in both cerebral hemispheres there were 12 cases.

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Regarding the number of affected lobes, 19 patients had only one lobe affected, 22 patients had two lobes and 09 patients had three or more cerebral lobes affected. Of the nine patients affected in three or more cerebral lobes, seven cases progressed to GOS 1, one case to GOS 3 and one case to GOS 5. Of the 22 patients with lesions in two cerebral lobes, we had the following distribution regarding GOS: nine cases progressed to GOS 1, two cases to GOS 2, four cases to GOS 3, three cases to GOS 4, three cases to GOS 5 and one case had an unknown result, since the patient was transferred. As for the patients with only one cerebral lobe affected, 13 cases progressed to GOS 5, one case progressed to GOS 4, one case to GOS 3 and four cases to GOS 1.

In total, there were 84 lobes damaged by intracranial FAPs. The parietal lobe was the most affected, in 35.7% of cases; followed by the frontal lobe, in 27.4%; the temporal lobe, in 19% and, finally, the occipital lobe was affected in 17.9% of cases.

Twenty-five decompressive craniectomies were performed. Of the nine cases of severe GCS in which decompressive craniectomies were performed with survival, there were two cases with GOS 2, five cases with GOS 3 and two cases with GOS 4. In 11 cases (22%), there was no surgical approach.

In relation to transfixing FAPs, there were 12 patients, in which six cases evolved to GOS 1, one case evolved to GOS 2, another case evolved to GOS 3 and, in three patients, there was evolution to GOS 5. One case of GOS had an unknown result, as the patient was transferred sedated.

Variables related to the circumstances that led the victims to suffer TBI due to FAP in Metropolitan Region II were also analyzed. Among them were: accidental, assault, mugger, robbed, stray bullet, homicide, military police officer, suicide and drug trafficking.

When discussing social classes, the patients' medical records were found, based on the evaluations of the Social Service, as low-income and middle-class social classes. The Social Service classified patients who received government welfare benefits and those without income as low-income. Patients who had income, such as salaried workers and retirees, were classified as middle-class. Of these patients, 21 were classified as low-income and 12 patients as middle-class. In 17 cases, no information regarding these variables was found in the medical records.

The time elapsed between the patient admission and death ranged from three hours to 148 days of hospitalization.

4 DISCUSSION

The type of projectile, such as caliber, mass and design, the speed of the shot and the dissipated kinetic energy will influence the outcome of brain injuries. As with the admission GCS, ventricular hemorrhages, injuries in both hemispheres and a greater number of affected lobes will also influence the neurological results. The assessment of the severity of these patients' injuries upon arrival at the hospital always represents an emergency situation, in which the time of arrival is crucial, given that the peak mortality rate occurs in the first three hours[15]. The application of emergency care protocols by ATLS entails immediate assessment of the clinical picture, its initial diagnosis confirmed by imaging tests and the consequent specific treatment.

Computed tomography (CT) is the best complementary diagnostic test for entry, since it has greater sensitivity and specificity in detecting and assessing the extent of traumatic injuries, providing all the information necessary for surgical planning and prognostic prediction[16]. The author Bakay described 14 cases of cranial injuries due to FAP in which CT was superior to other imaging tests[17].

This study showed that, in terms of age, 64% of patients with TBI due to FAP were under 30 years old. If the age group under 40 years is considered, this rate rises to 78%. The average age was 29.9 years. The study by Martins et al. (2003) showed an average age of 26 years and a mortality rate of 67%, with a predominance of males, reaching up to 93% of cases[18]. Tsuei et al.[19] described an average age of 30.9 years. Souza et al.[20], in turn, an average of 31 years. Cunha et al.[7] obtained an average age of 28.7 years. Liebenberg et al.[21] described an average age of 24.9 yeas. Robinson et al.[22] reported a mean age of 36.5 years.

Regarding the gender variable, there was an absolute predominance of males, with 88% of patients affected in relation to females, which occurred in 12% of cases. Liebenberg et al.[21] described that, of their patients, 88.8% were male. In the series presented by Souza et al.[20], it was observed that, of the 181 patients studied, 85% were male. Other authors, such as Cunha et al.[7], Meneses et al.[23],

Delgado et al.[24], Tsuei et al.[19] and Solmaz et al.[25] also described males as the most affected.

Because Brazil is a highly racially mixed country, the highest number of cases were found among the mixed race, corresponding to 48% of cases, followed by the black race, with 30%, and the white race, with 22% of cases. The study by Chiu, Fuentes and Metha (2019) did not show any difference in the evaluation of results in patients who suffered head trauma from a firearm projectile in relation to race[26].

The distribution of the study participants according to the severity of the injury on arrival at the ATSH according to the Glasgow scale showed that severe GCS occurred in 24 of the cases (48%), moderate GCS in eight (16%) and mild GCS in 18 (36%). Participants with severe GCS evolved to death in 13 cases (26.53%); those with moderate GCS evolved to death in four cases (8.16%) and those with mild GCS resulted in three deaths (6.12%). All patients with GCS between 3 and 4 died. Liebenberg et al. (2005) reported that patients with GCS between 3 and 8 at admission accounted for 70.4%. Worse results were recorded in patients admitted with bilateral mydriasis[18,21,27] and bi-hemispheric lesions[18,21,25,27-29]. Patients admitted with severe GCS had better results with the surgical procedure[20].

In the study by Freitas et al. (2000), the overall mortality observed was 63.1%, with more than half of the cases evolving to death within the first six hours after the first treatment[28]. Only 10.6% survived more than 48 hours. The authors describe deep coma, bi-hemispheric lesions, and involvement of several lobes as poor prognoses[28]. Important predictive factors for better prognoses in TBI due to FAP are GCS greater than 8, one brain lobe lesions on computed tomography, when treated aggressively with surgery[19,30] and shorter time of action to the patient[31]. The authors Grahm et al. (1990) and Souza et al. (2013) described the indication of aggressive surgical treatment in patients with severe GCS[20,32].

Predictive factors with worse prognoses occur in severe GCS[19,21,23,25,28], bi-hemispheric lesions[18,21,25,27-29], multi lobar lesions[18,27,28] and lesions with ventricular involvement[7,25,33].

Patients admitted to emergency units who survived the first hours of TBI due to FAP received initial care, according to ATLS protocols, for initial stabilization and, afterwards, follow-up protocols for preventing secondary consequences. In the retrospective study by Cavaliere et al. (1988), of 178 civilian patients who were victims of FAP of the head, there were 93% of deaths, 88% of which occurred within the first three hours[15].

In the present study, the right and left cerebral hemispheres were affected equally in 38% of cases and, in 24% of the total, the involvement was bilateral. Regarding the number of brain lobes injured, the following percentages were recorded: one lobe (38%); two lobes (44%); three or more lobes (18%). The parietal lobe was the most affected, corresponding to 35.7% of cases. The total number of affected lobes was 84. In the series by Souza et al. (2013), the most affected lobe was the frontal lobe, in 27.6% of cases[9].

This study also showed 11 cases of patients with lesions in both hemispheres. Of this total, nine died, accounting for 81.8% of cases. Similar results were found in the studies by Martins et al.[18], Freitas et al.[28], Hazama et al.[30], Maragkos et al.[27], Turco et al.[29], Solmaz et al.[25], among others.

Regarding the relationship between the number of injured lobes and the progression to death, this study showed that patients with injury to only one lobe (19 patients) died in four cases (21%). Patients with injury of two brain lobes injured (22 patients) died in 9 cases (40%). Finally, in cases in which three or more lobes were injured (9 cases), the progression to death was seven cases (77.7%). The studies by Martins et al.[18], Freitas et al.[28] and Maragkos et al.[27] also describe worse results according to the greater number of brain lobes affected.

In the 11 cases of TBI due to transfixing FAP, six patients died, that is, 54.5% of the cases. Cunha et al. (2010)[7] described in their work that patients with transfixing projectiles or ventricular involvement reached 100% mortality.

Among the protective measures against secondary injuries are: orotracheal intubation; elevation of the head between 30-45 degrees; cardiac, blood pressure and oximetry monitoring; maintenance of cerebral perfusion pressure (CPP) above 60 mmHg; optimization of regular analgesia, avoiding pain and increased intracranial pressure (ICP); osmotherapy; sedation to prevent agitation and respiratory asynchrony[6]. Hemodynamic control, metabolic and hydroelectrolytic control, maintenance of oxygen saturation above 94% and monitoring of expired CO2, anticonvulsant for one week, temperature control, in addition

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to neurocheck every 2 hours and neurosurgical intervention to install ICP-DVE or the surgery itself are also necessary. The aim is to minimize sequel, improving patients survival and quality of life, as evidenced in the work of Gentile et al.[34]. However, for all this support to occur, there is a need to value and train the nursing team in the knowledge, understanding and handling of critical patients in intensive care units[35].

There was no evidence of satisfactory results in simple closure of FAP with cleaning and suturing[36]. Some other authors proposed a non-surgical line of therapy for severely comatose patients with cranial injuries due to unilateral or bilateral FAP[37].

Late complications, such as those that occur after months, are lead poisoning, as described in the work of Araujo et al. (2021), in which the lead lodged in the brain is affected by the cerebrospinal fluid, and the pH promotes solubilization in the plasma, which, over time, causes neurological and systemic weaknesses[8]. It is also worth highlighting the work of Robinson et al. (2019), who related patients who underwent cardiopulmonary resuscitation maneuvers and had a survival rate of 2.1%[22].

According to data from the 2018 Violence Atlas, the cities with the highest rates of violence in Brazil have nine times more people living in extreme poverty than the least violent cities. Municipalities with better levels of development, such as housing, education, insertion into the job market, among others, have lower rates of violence. When the state is unable to offer basic living conditions and citizenship, these people who live in precarious economic conditions, enter the job market early, drop out of school very early and live in areas without infrastructure are the most vulnerable to violence[38].

The present study demonstrated the circumstances that led to TBI due to FAP in the patients evaluated, in relation to the variables accident, aggression, assaulted, assaulter, stray bullet, homicide, military police officer, suicide and drug trafficking. Higher rates of cases are observed among victims of assault, muggers, assault victims and stray bullets. If we associate victims of TBI due to FAP with muggings, homicides and deaths in drug trafficking as "homicides in general", we find the highest percentage of cases.

When discussing social classes in this study, we found a higher number of cases in the lower social classes, in patients with no income and beneficiaries of government welfare.

These data on the circumstances of victims who suffered FAP attacks to the head and on their social classes allow analysis and discussion so that preventive measures can be taken to reduce violence in the city of São Gonçalo and in several regions of Brazil and to be treated as a public health problem.

5 CONCLUSIONS

Brain injuries resulting from gunshot wounds result in high rates of morbidity and mortality, and are a permanent challenge to neurosurgeons. The variables evaluated for the epidemiological profile of patients with TBI due to FAP show that the age group up to thirty years, male gender and mixed race were the most frequent in the study. Regarding the predictive prognostic factors, the variables of severe entry GCS, greater number of affected brain lobes (three or more) and bi-hemispheric injuries had the highest rates of progression to death.

Many of the results found in this study are in agreement with the studies described in the literature. Future studies on the subject should be carried out with the aim of collecting larger numbers of statistical variables that can influence more robust neurosurgical decisions.

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