Traumatic brain injury by a firearm projectile: a 16 years experience of the neurosurgery service of Santa Casa de São Paulo

Traumatismo cranioencefálico por projétil de arma de fogo: experiência de 16 anos do serviço de neurocirurgia da Santa Casa de São Paulo

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A B S T R A C T

Objective: To evaluate the epidemiology and prognostic factors associated with traumatic brain injury by a firearm projectile (FAP). **Methods**: We reviewed the medical records of 181 patients in the Department of Neurosurgery of Santa Casa de São Paulo (São Paulo Holy House) diagnosed with traumatic brain injury (TBI) resulting from FAP from January 1991 to December 2005. Were evaluated: age, sex, Glasgow Coma Scale (GCS) on admission, brain region affected by the FAP, type of injury (penetrating or tangential), type of treatment and outcome, based on GCS. The relationship between therapeutic strategy and outcome was analyzed using the Chi-square test with Yates correction. The Fisher test was used to verify the same correlation individually for each group stratified by GCS on admission. **Results**: Of the181 patients, 85% were male (n = 154) and 15% female (n = 27). Mean age was 31.04 years (± 10.98). The mostly affected brain region was the frontal lobe (27.6%), followed by temporal (24.86%) and occipital (16.57%) ones. Of the TBIs evaluated, 16% were tangential and 84%, penetrating. **Conclusion**: Patients undergoing surgical treatment had better outcome than those submitted to conservative treatment, and patients who were more severe at admission (GCS 3-8) have better results with the neurosurgical procedure.

Key words: Wounds and injuries. Firearms. Wounds, gunshot. Craniocerebral trauma. Brain injuries.

INTRODUCTION

Traumatic Brain Injuries (TBI) caused by firearm projectiles (FAP) have a major socioeconomic impact, representing a worldwide epidemic[1]. They mainly affect the population of adolescents and young adults, who are economically active[1]. Besides the high cost with direct patient care, there is also the potential loss of years of productive life [2].

Several factors have been associated with worse prognosis, such as neurological level, hemodynamic and respiratory status at hospital admission, injuries resulting from suicide attempt, type of projectile, pupil size and reactivity, as well as the CT findings[3]. In this study we evaluated epidemiological and prognostic factors in a series of 181 patients sustaining FAP wounds to the head, admitted to our hospital over a period of 16 years.

METHODS

After approval of the Ethics Committee, the patients treated by the Neurosurgery Service of SCSP diagnosed with TBI resulting from FAP from January 1991 to December 2005 had their medical records reviewed for gathering information for this study .

We included information of 181 patients victims of civil FAP injuries, the following information being recorded: age, gender, Glasgow Coma Scale (GCS) on admission, brain region affected by the FAP, type of injury (penetrating or tangential), type of treatment and outcome, based on GCS.

Based on GCS on admission, patients were classified into four categories: A – No deficit or minimal neurological deficit (13-15), B – significant deficit without coma (9-12), C – Comatose but not moribund (6-8); and D – Moribund (3-5).

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As for outcome, patients were grouped into five different categories: 1) death, 2) persistent vegetative state, 3) severe disability (dependent on daily support), 4) moderate disability (independent), and 5) good recovery.

In order to verify the correlation between the therapeutic strategy and prognosis, patients with satisfactory and poor outcome were stratified into conservative and surgical treatment.

For statistical analysis of prognosis, we classified the patients into two groups: A – Bad result (GCS groups 1 and 2), and B – Satisfactory Results (GCS groups 3-5).

The relationship between therapeutic strategy and outcome was globally analyzed using the Chi-square test with Yates correction. The Fisher test was used to individually verify the same correlation for each group stratified by GCS.

RESULTS

In our series of 181 patients, 85% were male (n = 154) and 15% female (n = 27). The mean age was 31.04 years (± 10.98). Of the total, 22% were between 11 and 20 years, 47% between 21 and 30 years, 20% between 31 and 40 years, 10% between 41 and 50 years and 1% between 51 and 60 years of age(Figure 1).

The main brain region affected by FAP was the frontal lobe (27.6%), followed by temporal (24.86%), occipital (16.57%) and parietal (14.36%) ones, and facial region (11%). Multiple injury sites occurred in a minority of cases (5.5%), as shown in Figure 2. Of the TBIs evaluated, 16% were tangential (fracture, contusion or hematoma) and 84% penetrated the dura mater (Figure 3).

According to the GCS on admission, 57 patients (31.53%) formed the group "A", with minimal or no deficit, 22 (12.1%) group "B", with significant deficit without coma; 35 (19.3%) group "C", presenting comatose but not dying, and 67 (37%) group "D", presenting moribund (Table 1).

Patients with satisfactory final outcome (n = 91, 50.3% of cases) were treated conservatively in 28.6% (n = 26) of cases, and surgically, in 71.4% (n = 65).

As for patients with final outcome rated as poor (n = 90, 49.7% of cases), 29.9% (n = 26) underwent surgical treatment and 70.1% (n = 64) were treated conservatively (Table 2).

Thus, best results were observed with surgical treatment. We carried out the Chi-square test with Yates correction ($x^2 = 31.7$, $p < 0.001$).

Patient groups A, B, C and D, distributed according to the GCS on admission, were analyzed individually (Table 3) also by the Chi-square test with Yates correction. Patients in group C and D showed better results when undergoing surgical treatment (Table 3) with p = 0.01850 and p = 0.00008, respectively. Groups A and B did not differ significantly with respect to conservative and surgical treatments.

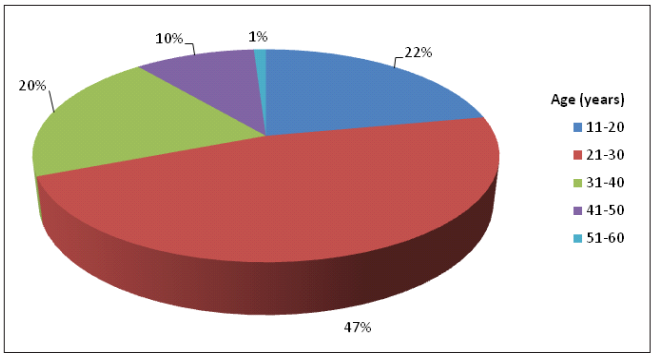

Figure 1 - *Distribution of the 181 patients according to age.*

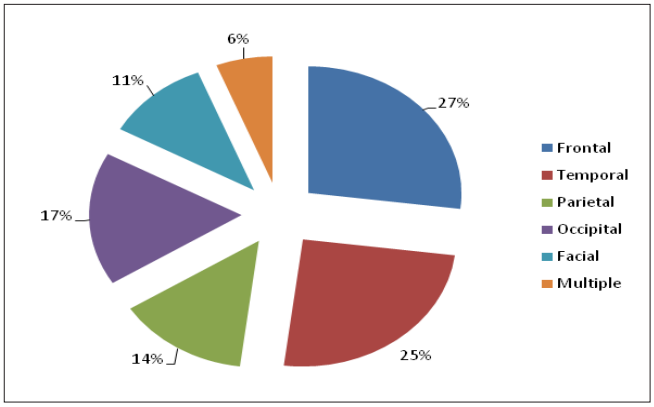

Figure 2 - *Distribution of the site affected by the FAB wound.*

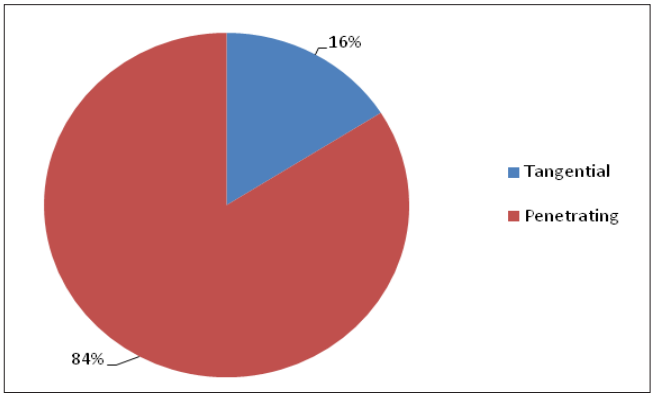

Figure 3 - *Distribution of the patients according to TBI type.*

DISCUSSION

Before the fourteenth century, when gunpowder was introduced to Europe by the Mongols, most of head injury was caused by low-speed objects such as swords, spears, arrows and stones[4]. The breakthrough in the development of weapons, such as the reduction of friction between the projectile and gun, and the burning of more efficient thrusters, resulted in a capacity of bullet velocity of up to 615m/s [4]. Currently, firearms are responsible for up to 67% of all penetrating injuries to the human body[2].

Table 1 - Distribution of the patients according to GCS at admission.

Glasgow Coma Scale	Total
3-5	68
6-8	35
9-12	20
13-15	58
Total	181

Table 2 - Type of treatment and outcome.

	Conservative	Surgical	Total
Satisfactory outcome	26	65	91
Poor outcome	64	26	90
Total	90	91	181

Briefly, the factors related to tissue damage, besides the speed of the FAP, are the design of the projectile, the propensity to tumble, the release of energy, the size and mass of the projectile, the target density and the projectile trend of velocity loss[5]. The variables for the penetration of the bullet in the skull are the energy impact on the bone, the area of contact between the projectile and the bone and the bone thickness in the area of impact[4].

In general, the concept that tissue injury is directly proportional to the kinetic energy of a projectile ($E = 1/2\ MV^2$) is not proven in practice. This is because not all the potential energy is transmitted to the target[6]. For example, the outlet of the projectile is generally higher than the inlet, despite the velocity being higher in the entrance orifice[5]. Moreover, if the projectile passes through the target, it will surely not transmit all its potential energy to it.

All these evidences are important, especially when evaluating FAP lesions to soft tissues[7], such as the abdomen. A historical example of this statement occurred when, in 1890, the British fought in India with weapons that provided the higher speed to the projectiles and observed that the damage to opponents did not increase[7], since the projectiles crossed through the abdomen. On that occasion, the soldiers of the front did change the bullets to cause more tissue damage. These began to be called "dumdum" bullets, after Indian city of Dum Dum[7].

However, in the case of head injuries, which represent 20.6% of FAP trauma[2], the projectile velocity determines greater propensity to overcome the cranial vault, worsening prognosis. This is because the bone fragments will be transformed into "secondary projectiles"[4]. Moreover, faster projectiles can easily transfix the skull and injure more lobes, with a greater chance of damaging vital structures, being associated with higher mortality.

The term "tangential injury" is credited to Dodge and Mierowsky, in 1952, for publications during the Korean War[8]. These lesions do not cross the inner table, and thus cause no injury to the dura mater. Nonetheless, this type of injury can cause intracranial lesions, such as subdural and epidural hematomas, contusions and traumatic subarachnoid hemorrhage[8]. Of the 181 patients, 16% had tangential lesions, and 84%, penetrating (Figure 3). This relatively large proportion of tangential injuries is due to the employment of firearms with low speed projectiles.

Be the injuries caused by high velocity projectiles, which can more easily cross the skullcap[4], or by the low speed ones, which can be devastating at short range[7], management of patients is certainly a challenge for the neurosurgeon.

From an epidemiological standpoint, Martins *et al.*[3] showed a predominance of males, reaching up to 93% of cases, with a mean age of 26 years and a mortality rate of 67%. According to these authors, the mortality in the literature ranged from 23 to 92%[3]. In our series of 181 patients, 85% were male and the mean age was 31.04 years (± 10.98). We observed no patient under the age of ten years and only 1% of patients were older than 51 years. This represents a huge loss of potential years of life worked, with the social economic impact already described[2].

According to Liebenberg *et al.*[9], infectious processes reached a rate of 8% of cases, but did not cause death or disability. However, infectious processes were related to a poor prognosis[10], antibiotic prophylaxis being recommended. Jimenez *et al.*[11] mention an infection rate of 25%, with the following independent risk factors for infection: persistence of bone or metal fragments in the

Table 3 - Distribution of the patients according to GCS, type of treatment and outcome.

	Satisfactory outcome		Poor outcome		
Glasgow Coma Scale	Conservative	Surgical	Conservative	Surgical	Total
3-5	0	4	55	9	68
6-8	2	20	6	7	35
9-12	5	10	1	4	20
13-15	19	31	2	6	58
Total	26	65	64	26	181

parenchyma after operation (relative risk – RR – 7.45), trajectory of the projectile by a natural cavity with contaminated flora (RR 2.84) and lengthy hospitalization (RR 2.84%). The use of prophylactic antibiotics in cases of head injury by FAP remains controversial[11].

Regarding prognosis, the factors identified as determinants include: neurological status on admission, injuries resulting from suicide attempts, type of projectile, diameter and pupillary reactivity, tomographic findings, and bilobar lesions, bi-hemispheric lesions[3], diabetes insipidus and trans-ventricular injuries over the sella (vector trajectory of the bullet less than 4cm from the back of the sella) [12].

In our series, we observed a worse prognosis in patients with GCS 3-5 (group D) on admission. This group developed unfavorable outcome (GOS 1-3) at 94.11% when compared to the other groups (C: 39.39%, B: 25%, H: 13.79%).

Of the total, 50.2% of patients underwent surgical treatment and the remainders were treated conservatively. Comparing the final result (poor and good) of patients with respect to the type of treatment used (surgical or conservative), the best results were observed among patients who underwent surgery, with $x^2 = 31.07$ p <0.001.

We further stratified, as for GCS on admission, the four categories of patients (A, B, C and D) among conservative and surgical treatment (Table 2). We observed in groups C and D a better prognosis in patients undergoing surgical treatment, with statistical difference, p = 0.01850 and p = 0.0008, respectively. In groups A and B there was better surgical outcome, but without significant differences. The results may indicate that neurosurgical treatment is related to better prognosis, being more important for the more severe patients (GCS 3-8 on admission).

Liebenberg *et al.*[9] and Martins *et al.*[3] showed that surgical treatment was performed in 21.6% and 48.9% of cases, respectively. The mortality rate for patients with GCS 3-8 was 86.36% in the former and 45.58% in the latter. Among the patients with GCS between 9 and 15 at admission, the former showed a mortality of 29.7%, and the latter, 12.9%. Therefore, it is possible that the operation is also related to lower mortality, despite the problems presented by the first author, as the delay in completion of the surgical procedure, with an average of 11 days from admission, and few resources for treatment.

Despite the biases inherent to our study and to the studies evaluated, such as the the criteria for selection of patients for surgical treatment and specification of surgical procedures employed, there are, in our view, two important final evidences: patients operated evolve better and patients who are more severe at admission (GCS 3-8) have more benefit with the neurosurgical procedure.

R E S U M O

Objetivo: *avaliar os aspectos epidemiológicos e fatores prognósticos associados a uma série de pacientes vítimas de traumatismo cranioencefálico por projétil de arma de fogo (PAF).* ***Métodos:*** *Foram revisados os prontuários de 181 pacientes da Disciplina de Neurocirurgia da Santa Casa de São Paulo com diagnóstico de traumatismo cranioencefálico (TCE) decorrente de agressão por PAF no período de janeiro de 1991 a dezembro de 2005. Foram avaliados: idade, sexo, pontuação na escala de coma de Glasgow (ECG) à admissão, região encefálica acometida pelo PAF, tipo de lesão (penetrante ou tangencial), tipo de tratamento realizado e resultado ou desfecho, baseado na Escala de coma de Glasgow. A relação entre estratégia terapêutica e o resultado final foi analisada pelo teste Chi-quadrado de Pearson com correção de Yate. O teste de Fisher foi utilizado para verificar a mesma correlação individualmente para cada grupo estratificado pela ECG à admissão.* ***Resultados:*** *Na nossa série de 181 pacientes, 85% eram do sexo masculino (n=154) e 15%, do sexo feminino (n=27). A média de idade foi 31,04 anos (+/- 10,98). A principal região encefálica acometida foi o lobo frontal (27,6%), seguido pelo temporal (24,86%) e occipital (16,57%). Dos TCE avaliados, 16% eram tangenciais e 84% penetrantes.* ***Conclusão:*** *Os pacientes submetidos ao tratamento cirúrgico evoluíram melhor do que os submetidos ao tratamento conservador, e os pacientes que se apresentam mais graves à admissão (com ECG entre 3-8) apresentam melhores resultados com o procedimento neurocirúrgico.*

Descritores: *Ferimentos e lesões. Armas de fogo. Ferimentos por arma de fogo. Traumatismos craniocerebrais. Traumatismos encefálicos.*

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