Ruth Prieto et al. Predictive Factors for Craniopharyngioma Recurrence

World Neurosurgery 2009, violent deaths (homicide, suicide, car

accident, and others) accounted for 18% of total deaths in the country (9). In civilian practice, mortality secondary to penetrating craniocerebral gunshot wounds (PCGWs) is >50% (10, 26). Intracranial infection is a major problem among patients with


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Risk Factors for Intracranial Infection Secondary to Penetrating Craniocerebral Gunshot Wounds in Civilian Practice

Carlos Mario Jimenez, Jonathan Polo, Julian Andres España

Key words

Brain abscess
Gunshot wounds
Infection
Meningitis
Penetrating craniocerebral trauma
Prophylactic antibiotics

Abbreviations and Acronyms

CT: Confidence interval
CSF: Cerebrospinal fluid
CT: Computed tomography
GCS: Glasgow Coma Scale
PCGW: Penetrating craniocerebral gunshot wound
RR: Relative risk

To whom correspondence should be addressed:
Carlos Mario Jimenez, M.D., M.Sc.
E-mail: carlosjimenez@une.net.co

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INTRODUCTION

Craniocerebral trauma accounts for 70% of emergency services in Colombia (13); in 2009, violent deaths (homicide, suicide, car

OBJECTIVE: To determine risk factors for intracranial infection secondary to penetrating craniocerebral gunshot wounds (PCGWs) in civilian practice, in patients who underwent surgery with removal of bullet fragments, wound debridement, and watertight dural closure.

METHODS: An observational, analytical, prospective, cohort-type study was conducted with follow-up in a group of patients with PCGWs caused by a low-velocity projectile admitted between January 2000 and November 2010. There were 160 patients, 59 of whom were administered prophylactic antibiotics based on the decision of the treating neurosurgeon. Average follow-up time was 39 months (range, 3–92 months).

RESULTS: Infection occurred in 40 patients (25%); 20 patients received antibiotics (20 of 59 [33.9%]), and 20 patients did not receive antibiotics (20 of 101 [19.8%]). Three variables were independent risk factors for infection: (i) persistence of parenchymal osseous or metallic fragments after surgery ($P < 0.0001$, relative risk [RR] 7.45); (ii) projectile trajectory through a natural cavity with contaminating flora ($P = 0.03$, RR 2.84); and (iii) prolonged hospitalization time ($P < 0.0001$, RR 3.695).

CONCLUSIONS: Administration of prophylactic antibiotics was not associated with the incidence of intracranial infection secondary to PCGWs. Projectile trajectory through potentially contaminating cavities, persistence of intraparenchymal osseous or metallic fragments after surgery, and prolonged hospital stay were independent risk factors for intracranial infection.
PCGWs who survive and receive medical treatment (5); infection is due to contamination with fragments of skin, scalp, bone, and metal, which are disseminated on the brain parenchyma following the projectile trajectory. Other factors, such as the projectile trajectory through paranasal sinuses, wound dehiscence, and cerebrospinal fluid (CSF) fistulas can increase infection risk (5).

Infection frequency related to PCGWs varies among several series. In the preantibiotic age, during World War I, infection frequency was 58.8% (24), which promoted the use of prophylactic antibiotics as part of a therapeutic approach; from World War II on, prophylactic antibiotics were used for all PCGW cases. There are no controlled randomized clinical trials supporting the use of prophylactic antibiotics in PCGWs; clinical practice guidelines have been developed based on descriptive studies of case series, the opinion of experts, and observations conducted in the battlefield (5). However, the nature of trauma, type of firearm, seriousness of lesion, contamination probability, and access to medical services are different in civilian and military environments. In a nonmilitary context, most wounds caused by firearms involve low-velocity projectiles with lesions secondary to the crushing effect of the pressure wave following the projectile in its way through the brain tissue; in contrast, in a military context, most wounds are caused by high-velocity projectiles that cause a secondary shock wave and a big cavitation resulting in destruction of tissues away from the projectile trajectory, tissue necrosis, serious destruction of the brain parenchyma, and more secondary contamination and infection (5, 27). It follows that therapeutic approaches should not be the same when the PCGW occurs in a military versus a civilian environment.

This article reports the results of a prospective follow-up analytical study of a cohort of patients with PCGWs who underwent surgery for wash, debridement, and removal of osseous and metallic fragments from the brain tissue. The purpose of this study is to identify risk factors of intracranial infection secondary to PCGWs. It is a prospective cohort-type study of patients seen in a civilian medical practice at San Vicente de Paúl University Hospital in Medellin City, Colombia.

**METHODS**

**Study Population, Sampling Size, and Admission Criteria**

An observational, analytical, prospective cohort study was conducted. The study population consisted of patients >15 years old with PCGWs caused by low-velocity projectiles and admitted to the emergency department of Hospital Universitario San Vicente de Paúl in Medellin, Colombia, between January 2000 and November 2010. Criteria to be admitted to the study were as follows: PCGW; treatment consisting of wound debridement, removal of osseous and metallic fragments of brain tissue, and watertight dural closure; and follow-up of at least 3 months after the wound.

A sampling size of 59 patients per group was determined; the sampling size was estimated with the administration of prophylactic antibiotics as the main independent variable with the following criteria: level of confidence (95%), statistical power (80%), two-tailed analysis, and expected infection frequency in the group in patients not given antibiotics (30%). A decrease of 20% was assumed as clinical usefulness in regard to infection incidence in the group that was given prophylactic antibiotics. Anticipating potential losses in the follow-up period, we decided to recruit an additional 80% of the estimated sampling size, and we proposed conducting a follow-up in 105 patients in each group; however, when the study was under development, 160 patients completed their follow-up. Of 160 patients, 59 were given prophylactic antibiotics, and 101 were not given antibiotics. Follow-up was at least 3 months; average follow-up time was 39 months (range, 3–92 months).

An intracranial infection (only dependent variable) was diagnosed in patients if at least one of the following conditions was met and confirmed by clinical, imaging, or bacteriologic criteria: meningitis, cranial osteitis, epidural abscess, subdural empyema, cerebritis, brain abscess, or ventriculitis. The other independent variables were age; sex; urban versus rural origin; comorbidities that could potentially affect the immune response (e.g., diabetes, drug addiction, malnutrition, primary or secondary immunosuppression conditions); seriousness of the neurologic compromise as defined by the Glasgow Coma Scale (GCS); date of admission and date of discharge; neurologic status during a 3-month follow-up period based on the Glasgow Outcome Scale; projectile trajectory through natural orifices with contaminating flora, especially paranasal sinuses or oral cavity; presence of CSF fistula during the postsurgical period; persistence of osseous or metallic fragments in the brain parenchyma according to findings from follow-up computed tomography (CT) scan after surgery; and time elapsed from the time of injury to surgery.

**Statistical Analysis**

The statistical analysis was conducted in three stages: descriptive, univariate, and multivariate. During the descriptive stage, results were analyzed as means and medians for quantitative variables and as relative and absolute frequencies for qualitative variables.

During the univariate stage, existence of a statistically significant association of each independent variable with the only dependent variable was analyzed. Statistical significance tests used were $\chi^2$ for qualitative variables and Student $t$ test for quantitative variables, provided that data obtained were a normal distribution.

During the multivariate stage, a multivariate model of logistic regression was constructed to include variables that reached a $P$ value $< 0.25$ in the univariate model, and these variables were incorporated in the model according to the forward stepwise method, which makes a comparison of both the entry based on the score statistical significance and the elimination based on Wald’s statistic significance. Finally, variables independently associated with posttraumatic intracranial infection derived from this model were identified, eliminating the confusion bias.

Information obtained was processed with the IBM SPSS Statistics, version 19 software (SPSS Inc., Chicago, Illinois, USA). This study was approved by the ethics committees of Hospital Universitario San Vicente de Paúl and University of Antioquia, Medellin, Colombia. The research group strictly observed the ethical principles for medical research involving human subjects, as set forth in the Declaration of Helsinki (30).

**RESULTS**

Most patients (145 [90.6%]) were men; mean age was 28.9 years (range 15–61 years). Average hospital stay was 17.3 days (range 1–77
days). All wounds were caused by low-velocity firearm projectiles. Intracranial infection was documented in 40 of 160 patients (25%). In 95% of cases, intracranial infection emerged during the first 30 days of follow-up; the latest infection was diagnosed on day 64. A major comorbidity was present in 5 of 160 patients: 3 had diabetes, and 2 were immunosuppressed (1 patient had acquired immunodeficiency syndrome, and 1 patient had long-term consumption of oral steroids). No association between comorbidity and infection was found. At admission, 66.2% of patients had a GCS score ≥9; 92.5% had a GCS score ≥7. All patients included in the study underwent surgery, and a relatively high GCS score indicates only patients who showed an acceptable neurologic condition at the time of their admission were operated on. Most patients (73.8%) came from an urban area (Table 1).

The decision to administer prophylactic antibiotics before surgery was made exclusively by the treating neurosurgeon. Antibiotics were administered to 59 of 160 patients (36.8%). Most antibiotics were third-generation cephalosporins, especially ceftriaxone; however, a significant number of patients were given ampicillin/sulbactam (Table 2). Posttraumatic intracranial infection developed in 40 patients (25%): 20 (12.5%) had meningitis, 10 (6.25%) had brain abscess, 3 (3.13%) had subdural empyema, 3 (3.13%) had cerebritis, 2 (1.56%) had osteitis, and 1 patient (1.56%) had ventriculitis (Table 3). Mean hospital stay was 12.5 days (range, 1–77 days). According to the Glasgow Outcome Scale, 43.8% of patients had an unfavorable outcome. Three patients died during the follow-up period; two died of causes directly associated with an intracranial infection (both cases were due to a brain abscess). The most frequently isolated organism from bacterial cultures was methicillin-sensitive Staphylococcus aureus (54%), followed by Streptococcus pneumoniae (15%), Klebsiella pneumoniae (15%), methicillin-resistant Staphylococcus aureus (8%), and Escherichia coli (8%).

Univariate analysis found that administration of prophylactic antibiotics was not associated with incidence of posttraumatic intracranial infection. Among the 40 patients with infection, 20 (50%) were given prophylactic antibiotics. Of the 59 patients (33.9%) who were given prophylactic antibiotics, 20 developed an infection; of the 101 patients (49.8%) who were not administered antibiotics, 20 were diagnosed with intracranial infection at some time during their course. Five statistically significant variables were associated with posttraumatic intracranial infection: (i) prolonged hospital stay (P = 0.002); (ii) projectile trajectory through potentially contaminating orifices, such as the oral cavity or the paranasal sinuses (P = 0.027); (iii) presence of osseous or metallic intracranial fragments persisting after surgery, according to CT scan (P < 0.0001); (iv) poor neurologic condition at hospital admission, according to a GCS score ≤8 (P = 0.00389); and (v) poor neurologic condition when discharged, according to the Glasgow Outcome Scale (P = 0.02) (Table 4).

After the multivariate analysis according to the logistic regression model, three variables reached a statistically significant association independent from the postrau- matic intracranial infection: (i) presence of osseous or metallic intraparenchymal fragments on the postsurgical follow-up CT scan (P < 0.0001, relative risk [RR] 7.45, confidence interval [CI] 3.02–18.40) (Figure 1); (ii) projectile trajectory through natural orifices with potentially contaminating bacterial flora (P = 0.03, RR 2.84, CI 1.11–7.28); and (iii) prolonged hospital stay (understood as hospitalization period greater than the median of the group—12.5 days) (P < 0.0001, RR 3.695, CI 1.44–9.46) (Table 5).

DISCUSSION

Few studies have been published concerning the risk factors for infection associated with PCGW, and most have been descriptive studies derived from the battlefield during wartime (3, 5). Technically speaking, there is a high risk of intracranial infection in patients with PCGWs, and it probably results from the presence of contaminated foreign bodies (i.e., metallic fragments,
skin pieces, hair, osseous fragments) that penetrate the skull and touch brain tissue following the projectile trajectory (5). During the preantibiotic era, before World War I, most patients with PCGWs (58.8%) developed intracranial infection, and most died, as reported previously (24). After World War II, with the introduction of sulfas and penicillin applied both locally and systemically, infection frequency decreased to 5.7%–31% (25, 28). At the present time, follow-up studies show posttraumatic infection incidence associated with PCGWs ranging from 4%–11%. After the introduction of antibiotic therapy, incidence of specific lesions such as brain abscesses decreased from 8.5% to 1.6%–3.1% (24).

In most centers with a high volume of PCGWs, prophylactic antibiotics are administered routinely at the time the patient is admitted (21). In wartime, infection rates range from 1%–59% (24). During the Lebanese conflict, frequency of meningitis and brain abscesses ranged from 1%–8% (7, 20). PCGWs in civilian practice (usually in urban areas) are mostly caused by low-velocity projectiles (<1200 feet/second); these wounds differ from wounds sustained in a battlefield, with a more favorable prognosis (17). When these patients have been given prophylactic antibiotics, infection frequency ranges from 1%–14% (6, 27).

Table 2. Prophylactic Antibiotics

<table>
<thead>
<tr>
<th>Antibiotic</th>
<th>Frequency (Number of Patients)</th>
<th>Percentage</th>
<th>Dose</th>
<th>Time Elapsed from Trauma to Administration (hours)</th>
<th>Average Time Before Surgery (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ampicillin/sulbactam</td>
<td>11</td>
<td>18.6</td>
<td>2 g (ampicillin) and 1 g (sulbactam) IV every 6 hours</td>
<td>6.2 (mean)</td>
<td>39.5 (mean)</td>
</tr>
<tr>
<td>Cephalothin</td>
<td>2</td>
<td>3.4</td>
<td>1 g IV every 6 hours</td>
<td>6 (mean)</td>
<td>37.5 (mean)</td>
</tr>
<tr>
<td>Cephazolin</td>
<td>4</td>
<td>8.7</td>
<td>2 g IV every 6 hours</td>
<td>6 (mean)</td>
<td>35 (mean)</td>
</tr>
<tr>
<td>Cephradine</td>
<td>11</td>
<td>18.7</td>
<td>1 g IV every 8 hours</td>
<td>5.2 (mean)</td>
<td>28.5 (mean)</td>
</tr>
<tr>
<td>Cephradine/amikacin</td>
<td>2</td>
<td>3.4</td>
<td>1 g IV every 8 hours (cephradine) and 1 g IV every 12 hours (amikacin)</td>
<td>8 (mean)</td>
<td>58 (mean)</td>
</tr>
<tr>
<td>Ceftriaxone</td>
<td>21</td>
<td>35.6</td>
<td>2 g IV every 12 hours</td>
<td>9.3 (mean)</td>
<td>18.8 (mean)</td>
</tr>
<tr>
<td>Ceftriaxone/clindamycin</td>
<td>2</td>
<td>3.4</td>
<td>2 g IV every 12 hours (ceftriaxone) and 300 mg IV every 8 hours (clindamycin)</td>
<td>4.5 (mean)</td>
<td>40.6 (mean)</td>
</tr>
<tr>
<td>Ceftriaxone/metronidazole</td>
<td>1</td>
<td>1.7</td>
<td>2 g IV every 12 hours (ceftriaxone) and 1 g IV every 12 hours (metronidazole)</td>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td>Ceftriaxone/oxacillin/metronidazole</td>
<td>1</td>
<td>1.7</td>
<td>2 g IV every 12 hours (ceftriaxone), 2 g IV every 4 hours (oxacillin), and 1 g IV every 12 hours (metronidazole)</td>
<td>22</td>
<td>90</td>
</tr>
<tr>
<td>Ceftriaxone/vancomycin</td>
<td>1</td>
<td>1.7</td>
<td>2 g IV every 12 hours (ceftriaxone) and 1.5 g IV every 12 hours (vancomycin)</td>
<td>31</td>
<td>30</td>
</tr>
<tr>
<td>Clindamycin</td>
<td>1</td>
<td>1.7</td>
<td>300 mg IV every 8 hours</td>
<td>1.5</td>
<td>45</td>
</tr>
<tr>
<td>Vancomycin</td>
<td>1</td>
<td>1.7</td>
<td>1.5 g IV every 12 hours</td>
<td>9.2</td>
<td>20</td>
</tr>
<tr>
<td>Vancomycin/meropenem</td>
<td>1</td>
<td>1.7</td>
<td>1.5 g IV every 12 hours (vancomycin) and 2 g IV every 8 hours (meropenem)</td>
<td>30</td>
<td>180</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All antibiotics were administered during a minimum period of time of 72 hours. IV, intravenously.

Table 3. Infectious Complications

<table>
<thead>
<tr>
<th>Type of Complication</th>
<th>Frequency (Number of Patients)</th>
<th>Percentage</th>
<th>Good (4–5)</th>
<th>Bad (1–3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meningitis</td>
<td>20</td>
<td>50</td>
<td>10 (50%)</td>
<td>10 (50%)</td>
</tr>
<tr>
<td>Osteitis</td>
<td>2</td>
<td>5</td>
<td>1 (50%)</td>
<td>1 (50%)</td>
</tr>
<tr>
<td>Brain abscess</td>
<td>10</td>
<td>25</td>
<td>8 (80%)</td>
<td>2 (20%)</td>
</tr>
<tr>
<td>Cerebritis</td>
<td>3</td>
<td>7.5</td>
<td>1 (33.3%)</td>
<td>2 (66.7%)</td>
</tr>
<tr>
<td>Ventriculitis</td>
<td>2</td>
<td>5</td>
<td>1 (50%)</td>
<td>1 (50%)</td>
</tr>
<tr>
<td>Subdural empyema</td>
<td>3</td>
<td>7.5</td>
<td>2 (66.7%)</td>
<td>1 (33.3%)</td>
</tr>
<tr>
<td>Total</td>
<td>40</td>
<td>100</td>
<td>23 (57.5%)</td>
<td>17 (42.5%)</td>
</tr>
</tbody>
</table>

GOS, Glasgow Outcome Scale.

5.7%–31% (25, 28). At the present time, follow-up studies show posttraumatic infection incidence associated with PCGWs ranging from 4%–11%. After the introduction of antibiotic therapy, incidence of specific lesions such as brain abscesses decreased from 8.5% to 1.6%–3.1% (24).

In most centers with a high volume of PCGWs, prophylactic antibiotics are administered routinely at the time the patient is admitted (21). In wartime, infection rates range from 1%–59% (24). During the Lebanese conflict, frequency of meningitis and brain abscesses ranged from 1%–8% (7, 20). PCGWs in civilian practice (usually in urban areas) are mostly caused by low-velocity projectiles (<1200 feet/second); these wounds differ from wounds sustained in a battlefield, with a more favorable prognosis (17). When these patients have been given prophylactic antibiotics, infection frequency ranges from 1%–14% (6, 27).
In a study of 54 patients with PCGWs who survived in a civilian practice, in whom prophylactic antibiotics were administered, no deep intracranial infections, such as meningitis or brain abscesses, occurred, and there were only three superficial infections of the traumatic wound (6); Hofbauer et al. (17) reported similar findings during a follow-up of a cohort with 85 patients. As concluded from these studies, the incidence of intracranial infection is greater when wounds occur in a battlefield than when they occur in civilian practice (6). Compared with reports in the literature, incidence of intracranial infection was high in our study—40 (25%) of 160 patients were diagnosed with intracranial infection. This higher incidence could be due to the kind of weapons used in Colombia, with projectiles that sometimes are contaminated on purpose so that they can be more lethal.

Most posttraumatic infections caused by PCGWs appear early after the wound: 55% during the first 3 weeks and 90% before the sixth week (4, 14, 18), however, some brain abscesses have been described 15 years after the trauma (11, 22). In this study, all infections were diagnosed during the first 64 days after the wound, and 95% were diagnosed at <30 days.

### Risk Factors for PCGW Posttraumatic Infection

The presence of CSF fistulas, projectile trajectory through paranasal sinuses, and dehiscence of the traumatic or surgical wound have been proposed as infection risk factors after a PCGW, according to descriptive studies of several cases that occurred in battlefields (20, 25, 28). Arendall and Meirovsky (4) reported a frequency of intracranial infection of 29% in the presence of paranasal sinus lesions and 49% when there is a CSF fistula. A retrospective analysis of 964 patients injured during the Iran-Iraq war in the 1980s proposed that CSF fistulas, paranasal sinus lesions, and transventricular trajectory of the projectile or its pass through the middle line can predict independently the future occurrence of a posttraumatic intracranial infection (2). In our study, the three statistically significant variables associated with posttraumatic infection were (i) projectile trajectory through paranasal sinuses or oral cavity, (ii) persistence of osseous or metallic fragments on the postsurgical CT scan, and (iii) prolonged hospital stay. The presence of CSF fistula was not associated with posttraumatic infection.

An association between the presence of osseous or metallic fragments persisting in the cerebral parenchyma and intracranial infection has been the subject of considerable discussion (3, 21); individuals defending this association have proposed that an extended debridement and an exhaustive wash of the brain tissue affected are the main objectives of surgery for patients with PCGWs (17, 21, 23). However, authors such as Aarabi, from a personal experience in the Iran-Iraq conflict, consider that neither the projectile trajectory through the paranasal sinuses or oral cavity nor the presence of osseous or metallic fragments in the brain parenchyma increases the risk of intracranial infection (1, 2); this concept has been accepted by Gönül et al. (12), based on a follow-up study of 35 patients with PCGWs. Similar findings were reported by Kim et al. (19) in other cases, this time with a nonwar origin in South Korea; persistent fragments were detected in the brain parenchyma in 36.4% of patients, but the authors found no statistically significant association with the presence of infection. However, Taha et al. (28), in a retrospective analysis of 30 infected patients with PCGWs, all coming from the Lebanese conflict in the 1980s, found that osseous or metallic fragments in the brain parenchyma were persistent in 23 patients, according to observations made in a postsurgical follow-up CT scan. These authors also reported that 70% of infections had developed in the brain parenchyma in close contact with the fragments, and they proposed that the presence of these fragments after surgery is a risk factor for infection. In this study, persistence of osseous or metallic fragments on the postsurgical CT...
scan was found to be an independent risk factor for infection (RR 7.45). However, based on the results of this research, we cannot recommend aggressive debridement as a way to prevent infection because this variable was not specifically included.

Prolonged hospitalization has been cited as a not very studied factor with respect to the risk of posttraumatic intracranial infection after a PCGW. In this study, hospital stay >12 days was independently associated with the presence of infection (P < 0.0001, RR 3.695, CI 1.44–9.45); however, we should be cautious with respect to the causal association between these two variables because the infection diagnosis was probably the factor that forced a longer hospital stay.

Prophylactic Antibiotics

Efficacy of prophylactic antibiotics for a PCGW is not unanimously accepted, and some authors affirm that infection prophylaxis is more dependent on early surgical treatment of the wound than on the use of antibiotics, including debridement of the affected tissue, with healing and hermetic closing of the posttraumatic dural defect (8). As a result of the poor evidence supporting the use of prophylactic antibiotics as part of treatment for patients who sustained a PCGW in a civilian practice (24), some neurosurgeons do not accept their use.

There is significant variability in antimicrobial agents used for prophylaxis of a PCGW. The study by Kaufman et al. (18) on neurosurgical practice in the United States reported that 87% of surgeons use cephalosporin, 24% of surgeons use chloramphenicol, 16% of surgeons use penicillin, 12% of surgeons use aminoglycosides, and 6% of surgeons use vancomycin; erythromycin, miconazole, and tetracycline are less frequently used. In a study conducted in South Africa, the most frequently used antimicrobial agents were cefazolin, penicillin, chloramphenicol, and metronidazole (21).

Several studies have defended the benefits of prophylactic antibiotics in elective neurosurgical procedures. In the 1980s, Haines (15, 16) proposed a statistically significant decrease in the postsurgical infection risk with prophylactic antibiotics. In 1991, results of a meta-analysis supporting the use of prophylactic antibiotics in neurosurgical practice were published, under specific conditions and in both clean and contaminated wounds (29). However, in 2000, another meta-analysis made it clear that there are no studies proving efficacy of prophylactic antibiotics in PCGWs in civilian practice, where wounds caused by low-velocity projectiles are very common (5).

The use of prophylactic antibiotics in this study did not have an impact on the infection incidence, which was even higher among patients who were administered antibiotics than among patients who did not receive them; antibiotic use was associated with an increased incidence of infection in patients.

Table 5. Analysis Results of Logistic Regression Multivariate Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>P Value</th>
<th>Exp (β) (OR)*</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postsurgical intraparenchymal fragments</td>
<td>0.0001</td>
<td>7.452</td>
<td>3.018–18.402</td>
</tr>
<tr>
<td>Time hospitalized</td>
<td>0.006</td>
<td>3.695</td>
<td>1.444–9.455</td>
</tr>
<tr>
<td>Trajectory through contaminated orifice</td>
<td>0.03</td>
<td>2.841</td>
<td>1.109–7.279</td>
</tr>
</tbody>
</table>

OR, odds ratio; CI, confidence interval.
*Exp (β) is equivalent to OR.
the univariate analysis stage, but this association disappeared in the multivariate stage. Most importantly, prophylactic antibiotics were not associated with a decreased incidence of infection. The presence of infection was associated with an unfavorable outcome, whereas the use of antibiotics had no association with the outcome. In other words, there seem to be more important measures to improve the final result than the use of prophylactic antibiotics.

**Study Limitations**

Infections may develop 20 years after a cranial gunshot injury; our study had a mean follow-up period of 39 months, which is relatively short. This study included only patients who underwent surgery, which creates a selection bias for patients in fair or good clinical condition, leaving out patients with more serious injuries.

**CONCLUSIONS**

Persistence of osseous or metallic fragments in the brain parenchyma after a surgical procedure, projectile trajectory through the paranasal sinuses or oral cavity, and prolonged hospital stay are three variables independently associated with the risk of posttraumatic intracranial infection in patients with PCGWs attended in a civilian practice who have been injured with low-velocity projectiles. Use of prophylactic antibiotics does not independently associate with the risk of posttraumatic intracranial infection in patients with more serious injuries.

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