Gunshot Wounds to the Spine: Study of 246 Patients

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Summary: Gunshot wounds to the spine are a devastating calamity. Specific literature is scarce, as are large series. In the absence of extensive data, it is difficult to evaluate the complications and the effect of the several forms of treatment. The objective of this study was to add information to improve the handling of the pathology. This review was based on the analysis of 246 patients with gunshot wounds to the spine admitted to the Hospital da Restauração, Recife, Brazil, between January 1981 and June 1998. Eleven patients (4.5%) were female. The age of the patients ranged from 10 to 65 years. The neurologic condition was judged according to the classification of Frankel/ASIA/IMSOP. In grade A there were 147 (59.8%) patients; in B, 6 (2.4%); in C, 51 (20.8%); in D, 35 (14.2%); and in E, 7 (2.8%). All patients underwent radiologic investigation, and 51 (20.7%) underwent computed tomography. The hospital stay ranged from 3 to 182 days. Follow-up ranged from 3 to 397 days (mean 76.3 days). One hundred fifty-seven (63.8%) patients were managed conservatively and 89 (36.2%) underwent surgical treatment. Thirty-five (14.2%) patients died. Decompressive laminectomies were associated with a higher level of complications and did not improve patient outcome. The authors strongly recommend that a prospective multicenter study should be organized with a larger population of patients to allow a better understanding of the complexity of this pathology. Key Words: Traumatic spinal cord lesion—Gunshot wound to the spine.

The spinal lesions resulting from gunshot wounds are some of the most serious traumatic injuries but, at the same time, one of the less discussed. Few papers have been published on this topic and have considered in depth in the civilian population the effects of the available forms of treatment on the final outcome.¹

HISTORICAL PERSPECTIVE

Circa 1700 BC, Imhotep, in the Edwin Smith Papyrus, reported traumatic injuries to the spine.² Galen (130–200 AD) was the first to show that longitudinal lesions to the cord did not cause severe functional damage, whereas transverse lesions were associated with paraplegia below the lesion. When the lesion was made between the first and the fourth cervical segments, all movements and sensations below the incision level disappeared. He also observed that lesions between the fourth cervical and the second thoracic segments were accompanied by less diaphragmatic and respiratory muscle disturbance, and this was progressively more evident when the lesion was made at even lower levels. Because of these observations, Galen could be considered the pioneer of spinal surgery.³ Paul of Aeginet (625–690 AD) was one of the first authors to recommend decompressive laminectomies as the treatment of acute spinal compressive lesions.⁴

Ambroise Paré (1557) established the first description of a spinal cord lesion caused by a missile weapon.⁵ Geraud (1753), during a session of the Académie Royale de Chirurgie, reported a case where the bullet, entrapped in the body of the third lumbar vertebra, caused bladder and lower limb paralysis. He eventually removed the bullet. Although the wound became infected, the patient

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obtained a slight recovery of muscle power in the lower limbs.  

Admiral Nelson was victim of this kind of lesion. During the final hours of the Battle of Trafalgar, he was fatally wounded by a bullet that entered through the thoracic cavity and reached the spinal cord, causing immediate paraplegia. His surgeon said, “My lord, unfortunately for our country, there is nothing that can be done.” Lord Nelson died shortly after that.  

James A. Garfield, the 20th president of the United States, also suffered a gunshot wound to the spinal canal. There was an incomplete conus and cauda equina lesion, leading to his death 79 days later. According to Sonntag, during the American Civil War 642 cases of gunshot wounds to the spine were reported in the Medical and Surgical History of the War of the Rebellion. Surgical options were not discussed, probably because of the lack of surgical resources at that time. The death rate reached 55%. 

It is ironic to think that increasing spinal cord trauma is the result of the same technologic advances that later allowed its study. The incidence of traumatic wounds to the spine had grown side by side with the Industrial Revolution and the invention of cars and modern weapons.  

The introduction of x-ray imaging allowed anatomic understanding of gunshot wound lesions. Harvey Cushing, who began studying the application of x-rays to the investigation of neurologic problems, pioneered its intraoperative use. Cushing’s first publication dealt with the role of x-rays in the diagnostic workup of a neurosurgical patient. In 1896 he admitted a woman who had been shot by her husband; she presented with Brown-Sequard syndrome, and the x-ray disclosed a bullet lodged in the lower cervical spinal cord.  

During World War I, Cushing developed the basis for modern techniques for the treatment of gunshot injuries to the nervous system. Despite his efforts, the results in cord wounds were disappointing. Only patients with incomplete lesions of the cord survived, and the overall death rate exceeded 60%, probably as a result of the more powerful weapons then in use. 

World War II was marked by changes in surgical technique and the use of antibiotics. The management of cord lesions at the end of the conflict consisted of early surgery, with removal of debris and the application of dural patches when needed. The death rate decreased to 14.1% among 485 patients. Spurling, studying 1,260 patients, observed 15% functional recovery, mainly patients with incomplete lesions. British authors also reported a positive change. Guttmann reported a death rate of 9.5%. This improvement was attributed to the standardized postoperative management of spinal cord-injured patients, including prevention of decubiti and urinary and respiratory infections and the use of blood and blood products.  

More recent conflicts such as Israel and Lebanon, Iran and Iraq, and the Balkans war have shown that surgery in itself was not responsible for the lower death rate. Indeed, surgical management was associated with higher rates of complications that reached 14.5% and included cerebrospinal fluid (CSF) fistulas, meningitis, and wound infection. 

### CURRENT DATA

Gunshot wounds in civilians occur with shorter guns with lower velocities and smaller calibers. According to Miller, guns with calibers .22, .25, .32, and .38 are the most frequently used, and the patients wounded in this setting are mainly young men. In the United States, African Americans are involved in 53% of the events, Latinos in 28%, whites in 18%, and Asians in 1%, probably reflecting the variety of social, economic, and cultural issues that exist in urban centers. Civilian gunshot wounds to the spine most frequently involve the thoracic region (54%); the lumbosacral area and the cervical area are affected in 33% and 13%, respectively. 

The experience acquired treating war lesions predicted that the surgical indications and options would be used to treat civilian injuries. However, recent studies have pointed out that civilian lesions can differ significantly from injuries sustained on the battlefield. Simpson et al., in a retrospective study, showed no benefit from surgical decompression in civilian patients; indeed, a higher rate of complications was seen in the surgically treated group. 

Kupcha et al., analyzing 28 patients with gunshot wounds to the cervical region, observed a very similar result. No clear benefit was seen in patients with complete or incomplete lesions who underwent surgical decompression. Infection and instability occurred most frequently in this group. The presence of a bullet inside the spinal canal, or its removal, made no difference in the final outcome of patients with complete lesions. 

Although recognizing the small number of publications that address this matter, Yashon et al., Benzel et al., and Miller recommended that functional deterioration, incomplete lesions, and the presence of bone or metallic fragments in the spine are indications for surgical decompression. Heiden et al. suggested surgical treatment as a way to remove debris and correct CSF leak. 

Turgut et al., observing 17 patients between 1968
and 1990, found that decompressive laminectomy was an important event for neurologic improvement. Yoshida et al.\textsuperscript{28} described a significant association between removal of a bullet inside the thoracolumbar canal and neurologic improvement.

**PATIENTS AND METHODS**

Two hundred forty-six patients with gunshot wounds to the spine, admitted to the Department of Neurological Surgery, Hospital da Restauração/Recife, Brazil, between January 1981 and June 1998 were retrospectively studied (Table 1). Two hundred thirty-five (95.5\%) were male. The mean age at admission was 26.6 years (SD = 9.2).

According to the Frankel/ASIA/IMSOP classification,\textsuperscript{1} 147 (59.8\%) were grade A, 6 (2.4\%) grade B, 51 (20.8\%) grade C, 35 (14.2\%) grade D, and 7 (2.8\%) grade E (Table 2). All patients had spinal x-rays, and 51 (20.7\%) underwent CT scanning.

No military weapons were involved in these lesions. The cervical spine was involved in 72 (29.3\%) patients, the thoracic spine in 113 (45.9\%), and the lumbar region in 61 (24.8\%) (Table 3). Among the 61 patients with lumbar lesions, 47 (77\%) had lesions between L2 and L5. These patients, with cauda equina injuries, represented 19\% of the patients studied.

The mean hospital stay was 28.3 days. The mean follow-up was 76.3 days. One hundred fifty-seven patients (63.8\%) were treated conservatively. Eighty-nine (36.2\%) patients underwent surgery.

Dexamethasone was given to 10.6\% of the patients; anticoagulant drugs were prescribed to 33.7\%. Neuropathic pain, when present, was treated with nonopiates, carbamazepine, and/or amitriptyline. All patients received active physiotherapy during their hospital stay.

Cervical instability was evaluated using neutral and dynamic x-rays according to the recommendations of Bailey\textsuperscript{29} and White et al.\textsuperscript{30} In the thoracolumbar area the instability was evaluated according to Denis.\textsuperscript{31}

A bullet was considered lodged in the spinal canal when 50\% or more of its mass was inside the canal.

All surgical procedures were carried out under general anesthesia. Emergency surgeries were those performed within the first 24 hours of admission. Extensive dural lesions were repaired using fascia lata, and iliac bone crest was the donor site for all bone grafts used. Posterior cervical fixation was performed according to the Roy-Camille et al.\textsuperscript{32} technique. All patients undergoing cervical fixation wore an external orthosis (rigid collar) for 12 weeks. Improvement or deterioration of the neurologic condition was considered when there was an increase or decrease of at least one grade on the Frankel/ASIA/IMSOP classification.

EPI INFO, 6.04 version, was used to analyze clinical aspects, complications, and outcome of the population studied. Statistical analysis used the chi-square test with Yates correction or the Fischer test when applicable. The Fischer-Freeeman-Halton test was used when needed. A significance level was taken as 5\% in all tests.

**RESULTS**

Thirty-five (14.2\%) patients died during the study period (Table 4).

Forty-four percent of patients had urinary tract infec-

### TABLE 1. Annual distribution of patients

| Year | Patients |
|------|----------|
| 81   | 12 (4.88\%) |
| 82   | 14 (5.69\%) |
| 83   | 12 (4.88\%) |
| 84   | 23 (9.35\%) |
| 85   | 8 (3.25\%)  |
| 86   | 8 (3.25\%)  |
| 87   | 10 (4.07\%) |
| 88   | 9 (3.66\%)  |
| 89   | 15 (6.10\%) |
| 90   | 9 (3.66\%)  |
| 91   | 5 (2.03\%)  |
| 92   | 9 (3.66\%)  |
| 93   | 7 (2.85\%)  |
| 94   | 11 (4.47\%) |
| 95   | 11 (4.47\%) |
| 96   | 13 (5.28\%) |
| 97   | 46 (18.70\%)|
| 98   | 24 (9.76\%) |
| Total| 246 (100\%) |

### TABLE 2. Neurologic condition at admission

| Frankel/ASIA/IMSOP grade | Patients |
|--------------------------|----------|
| A                        | 147 (59.8\%) |
| B                        | 6 (2.4\%)  |
| C                        | 51 (20.8\%) |
| D                        | 35 (14.2\%) |
| E                        | 7 (2.8\%)  |
| Total                    | 246 (100\%) |

### TABLE 3. Level of vertebral injury

|                  | Patients |
|------------------|----------|
| Cervical         | 72 (29.3\%) |
| Thoracic         | 113 (45.9\%) |
| Lumbar           | 61 (24.8\%)  |
| Total            | 246 (100\%)  |
tions, 35.9% had decubiti, and 58 (23.6%) had pulmonary infections, which were statistically related to lack of mobility (Frankel/ASIA/IMSOP A and B) (Table 5). Pulmonary infection occurred in 48.6% of patients with cervical lesions, 18.6% of those with thoracic lesions, and 3.3% of those with lumbar injuries (Table 6). Pulmonary infections were statistically related to death (Table 7).

Diagnostic laparotomy was performed in 46 (18.7%) patients and did not influence the death rate. Hemopneumothorax was diagnosed in 26.4% of the population, but this complication has not related to a higher death rate. Pulmonary embolus was the major cause of death in 10 patients (4.1%). There was a trend for pulmonary emboli to occur in patients with worse neurologic grade and less mobility, but it was not statistically significant.

Among the 89 patients who underwent a neurosurgical procedure, 15 (16.9%) had emergency surgeries (all decompressive laminectomies) and 74 (83.1%) had elective surgeries (Table 8). The elective surgeries were laminectomies in 61 (82.4%) and anterior approaches to the cervical spine for decompression and fusion in 12 (16.2%); 1 patient (1.4%) had a posterior approach performed for fusion.

According to the Frankel/ASIA/IMSOP classification, 22.4% of the grade A patients were treated surgically, as were 83.3% of grade B patients, 62.7% of grade C patients, and 54.3% of grade D patients. There was no surgically treated patients who were grade E. Patients with incomplete lesions (grades B, C, and D) had significantly greater percentages of surgical treatment (60.9%) compared with those with complete injuries (22.4%) (Table 9). However, patients with absolutely no function (grade A) were statistically more likely to undergo emergency surgery than those with incomplete lesions (Table 10).

The presence of the bullet inside the spinal canal was verified in 43.9% of the population; metallic fragments (less than 50% of the bullet) were detected in 56.1%. A greater mass of the intraspinal missile was significantly associated with the choice for surgical management (Table 11), although it was not statistically related to the need for emergency surgery (Table 12).

Patients with cauda equina injuries were more likely to undergo surgery (72.3%) than those with spinal cord injuries (27.6%); the difference was statistically significant (Table 13).

A CSF leak was seen in 10 (4.1%) patients and was significantly associated with surgical management (Table 14). Meningitis was diagnosed in 12 (4.9%) of the patients and was statistically related to CSF leak (Table 15) and to surgical management (Table 16), and especially to emergency surgery (Table 17).

Thirty-one (21.1%) patients in group A died, 2 (33.3%) in group B died, and 2 (3.9%) in group C died. There were no deaths in groups D and E. The absence of neurologic function was statistically associated with a higher death rate (Table 18). The death rate was 29.2% for patients with cervical spine injuries, 11.5% for those with thoracic lesions, and only 1.6% for those with lumbar lesions.

Among the 211 survivors, 191 (90.5%) showed no change in their neurologic condition by the last follow-up when compared with admission, 18 (8.6%) improved, 2 (0.9%) got worse, and 1 (0.5%) died. The absence of neurologic function was statistically associated with a higher death rate (Table 18). The death rate was 29.2% for patients with cervical spine injuries, 11.5% for those with thoracic lesions, and only 1.6% for those with lumbar lesions.

### Table 4. Deaths

|       | Patients |
|-------|----------|
| Yes   | 35       |
| No    | 211      |
| Total | 246 (100%) |

### Table 5. Neurologic condition versus respiratory infection

| Frankel/ASIA/IMSOP grade | Respiratory infection |  |
|---------------------------|-----------------------|--|
|                          | Yes | No | Total |
| A + B                    | 47 (30.7%) | 106 (69.3%) | 153 (100%) |
| C + D + E                | 11 (11.8%) | 82 (88.2%) | 93 (100%) |
| Total                     | 58 (23.6%) | 188 (76.4%) | 246 (100%) |

Chi-square = 10.43; P < 0.005.

### Table 6. Vertebral level versus respiratory infection

| Vertebral level | Respiratory infection |
|-----------------|-----------------------|
| Cervical        | Yes 35 (48.6%) | No 37 (51.4%) | Total 72 (100%) |
| Thoracic        | Yes 21 (18.6%) | No 92 (81.4%) | Total 113 (100%) |
| Lumbar          | Yes 2 (3.3%) | No 59 (96.7%) | Total 61 (100%) |
| Total           | 58 (23.6%) | 188 (76.4%) | 246 (100%) |

Chi-square = 40.56; P < 0.001.

### Table 7. Respiratory infection versus death

| Respiratory infection | Death |
|-----------------------|-------|
| Yes                   | Yes 24 (41.4%) | No 34 (58.6%) | Total 58 (100%) |
| No                    | Yes 11 (5.9%) | No 177 (94.1%) | Total 188 (100%) |
| Total                 | 35 (14.2%) | 211 (85.8%) | 246 (100%) |

Chi-square = 42.98; P < 0.001.

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and 2 (0.9%) deteriorated after decompressive laminectomy (Table 19). There was no significant difference in outcome between patients with cauda equina and spinal cord injuries (Table 20).

Patients with metallic fragments had an improvement rate of 13.3%, compared with 3.1% for those presenting with the full mass of the bullet inside the spinal canal. The difference was significant (Table 21). The subsequent occurrence of neuropathic pain was similar in these two groups. Neuropathic pain was seen in 19.1% of the lesions affecting the cauda equina and in 9.5% of the lesions involving the spinal cord. Surgical management did not influence the outcome of the neuropathic pain.

Among patients who survived and did not deteriorate after surgery, 119 (93.7%) were unchanged and 8 (6.3%) improved with conservative management. In the surgical group, 72 (87.8%) did not have a change in neurologic condition and 10 (12.2%) increased at least one grade on the Frankel/ASIA/IMSOP classification; the differences were not statistically significant (Table 22). No patients who underwent emergency laminectomies experienced a change in their neurologic status, although there was a trend toward a better outcome for patients who underwent elective surgery (14.3%); however, these differences did not reach statistical significance (Table 23).

In the patients with cauda equina lesions, there was an improvement rate of 6.3% among the 32 surgically treated patients versus 15.4% in those conservatively managed (Table 24). Of the patients with spinal cord lesions, neurologic improvement was detected in 4 (10.5%) of the 38 who underwent decompressive laminectomy and in 6 (5.3%) of the 114 who were conservatively treated (Table 25). The differences shown in Tables 24 and 25 did not reach statistical significance.

### TABLE 8. Treatment

| Treatment         | Patients |
|-------------------|----------|
| Conservative      | 157 (63.8%) |
| Elective surgery  | 74 (30.1%)  |
| Emergency surgery | 15 (6.1%)   |
| Total             | 246 (100%)  |

### TABLE 9. Neurologic condition versus surgery

| Frankel/ASIA/IMSOP grade | Surgery | No | Yes | Total |
|--------------------------|---------|----|-----|-------|
| A                        |         | 114 (77.6%) | 33 (22.4%) | 147 (100%) |
| B+C+D                    |         | 36 (39.1%)  | 56 (60.9%)  | 92 (100%)   |
| Total                    |         | 150 (62.8%) | 89 (37.2%)  | 239 (100%)  |

Chi-square = 31.81; P < 0.001.

### TABLE 10. Neurologic condition versus timing of surgery

| Boston/ASIA/IMSOP grade | Elective | Emergency | Total |
|-------------------------|----------|-----------|-------|
| A                       | 24 (72.7%) | 9 (27.3%) | 33 (100%) |
| B+C+D                   | 50 (89.3%) | 6 (10.7%) | 56 (100%) |
| Total                   | 74 (83.1%) | 15 (16.9%) | 89 (100%) |

Chi-square = 4.06; P = 0.044.

### DISCUSSION

Yashon et al.\(^24\) believed that an average neurosurgeon would treat no more than two patients with gunshot wounds to the spine each year. This number is obviously too low to allow a neurosurgeon, working alone, to establish reliable management guidelines. Such guidelines can be drawn only from the analysis of large series, and papers reporting a large number of patients are few.

Simpson et al.\(^33\) published in 1989 their data on the treatment of 142 patients with this type of injury. Cybuslki et al.\(^34\) described their experience with 88 patients, collected during a period of 19 years. Velmahos and Demetriades,\(^35\) in Johannesburg, published a series of 153 patients with spinal lesions from gunshot wounds. Levy et al.\(^36\), in Los Angeles, studied 252 patients treated between 1980 and 1993. Also from the United States came the publication by Heary et al.\(^37\), who reported 254 patients treated during a period of 15 years.

The current series, analyzing 246 patients, is one of the most extensive in the neurosurgical literature. Although retrospective, its size and careful follow-up can almost certainly throw some light on the most important aspects of this pathology, specifically the response to surgical treatment.

Table 1 shows that 70 patients were admitted to the hospital between January 1997 and June 1998. This number represents nearly 30% of the population in the study and speaks to the increase in violence that affects most urban centers throughout the world.

In civilian gunshot wounds, men are more likely to be the victims: several authors reported rates around...
The present series had a male incidence of 95.5%. The mean age of the patients varied from 25 to 32 years. The mean age of the patients in this review was 26.6 years. Half were younger than 25 years. The neurologic status at admission attests the high complication rate of this pathology (see Table 2). Almost 60% of the patients reach the hospital with no function below the level of the lesion. Many factors seem to work together to make guns so destructive to neural tissues. Yashon et al. pointed to the cavitation effect and shock waves as having considerable destructive power, even when the missile has not violated the spinal canal. The velocity of the missile is more important than its mass as a determinant of destructive properties. According to Benzel et al., working in the United States and reporting civilian injuries, also found a death rate of around 10%. However, the absence of death in several publications from the United States reflects the excellence of medical care in those centers. Thus, a death rate of 14.2% is typical for most series.

The precise follow-up period necessary for conclusions to be drawn is the subject of controversy in the literature. Guttmann believed that patients who have complete lesions for more than 2 weeks probably would remain unchanged for life. Yashon et al. considered a period of 6 months of observation as a landmark to exclude the possibility of functional improvement. Hammoud et al., studying 64 patients, based their conclusions on a mean follow-up of 10 weeks. Levy et al., analyzing the effects of methylprednisolone, derived their information from a mean follow-up of 27 days. In the current series, the mean period of follow-up was 76.3 days, which was considered long enough to validate conclusions.

Associated lesions to other vital organs can occur in 25% of civilian injuries. Abdominal lesions were observed in 18.7% of the patients described in this review. Although some authors have reported a higher death rate in patients who undergo laparotomy, this tendency was not detected in our series.

The death rate observed in this study was 14.2%. Cushing, during World War I, reported a death rate of 71%. Guttmann, 40 years later, reduced the death rate to less than 10%. Heiden et al. and Benzel et al., working in the United States and reporting civilian injuries, also found a death rate of around 10%. However, the absence of death in several publications from the United States reflects the excellence of medical care in those centers. Thus, a death rate of 14.2% is typical for most series.

Tables 5, 6, and 7 emphasize the role played by respiratory infections and its association with death. Absence of motor power and cervical injuries is significantly associated with pulmonary infections. Therefore, any patient arriving at the hospital in poor neurologic condition and who has a high lesion should immediately undergo a vigorous regimen of respiratory physiotherapy. Kupcha et al., analyzing patients with cervical wounds, found a 42.9% rate of pulmonary infections, similar to the incidence found in this review (48.6%).

Table 7 shows that 41.4% of the patients with pulmonary infections eventually died, in contrast to the population without this kind of infection, in which only 5.9% died. These differences were significant, again stressing the importance of preventing this type of complication.

### Table 12. Radiologic findings versus timing of surgery

| Timing of surgery | Elective | Emergency | Total |
|-------------------|----------|-----------|-------|
| Bullet inside canal | 45 (77.6%) | 13 (22.4%) | 58 (100%) |
| Metallic fragments inside canal | 29 (93.5%) | 2 (6.5%) | 31 (100%) |
| Total | 74 (83.1%) | 15 (16.9%) | 89 (100%) |

Chi-square = 2.62; \( P = 0.105 \).

### Table 13. Lesion versus surgery

| Lesion | No (63.8%) | Yes (36.2%) | Total (100%) |
|--------|------------|-------------|--------------|
| Spinal cord | 144 (72.4%) | 55 (27.6%) | 199 (100%) |
| Cauda equina | 13 (27.7%) | 34 (72.3%) | 47 (100%) |
| Total | 157 (63.8%) | 89 (36.2%) | 246 (100%) |

Chi-square = 32.9; \( P < 0.001 \).

### Table 14. Surgery versus cerebrospinal fluid leak

| Surgery | Yes (9.0%) | No (91.0%) | Total (100%) |
|---------|------------|------------|--------------|
| Yes | 8 (9.0%) | 81 (91.0%) | 89 (100%) |
| No | 2 (1.3%) | 155 (98.7%) | 157 (100%) |
| Total | 10 (4.1%) | 236 (95.9%) | 246 (100%) |

Chi-square = 6.8; \( P = 0.009 \).

### Table 15. Cerebrospinal fluid leak versus meningitis

| Leak | Yes (40.0%) | No (60.0%) | Total (100%) |
|------|------------|------------|--------------|
| Yes | 4 (40.0%) | 6 (60.0%) | 10 (100%) |
| No | 8 (3.4%) | 228 (96.6%) | 236 (100%) |
| Total | 12 (4.9%) | 234 (95.1%) | 246 (100%) |

Chi-square = 20.38; \( P < 0.001 \).
Guttmann, leader in the conservative care philosophy, nonetheless recommends surgical treatment for patients with gunshot wounds to the spine as soon as possible. Yashon et al. performed decompressive laminectomies in 69.2% of their patients. Stauffer et al. reported that 54.6% of patients were surgically treated; Robertson and Simpson, reporting cauda equina lesions, operated on around 50% of their patients. However, Benzel et al., Simpson et al., and Kupcha et al. reported lower percentages of patients undergoing surgery (respectively, 37.1%, 21.8%, and 17.8%). Table 8 shows that 36.2% of the current population underwent surgery, in accord with the overall tendency shown in the literature.

Not many publications seem to have paid attention to the timing of surgery. Emergency surgery might have played a role in the outcome of the patients. Yashon et al. operated on 80% of their patients during the first 24 hours after the trauma, Stauffer et al. on 57.4%. Benzel et al. performed emergency laminectomies in only 7.7% of their series. In this report, emergency procedures were performed in 16.9% of those who underwent surgery, which is certainly not high.

Incomplete lesions (grades B, C, D) seem to play a role in persuading the surgeon to suggest an operative procedure. Benzel et al. operated on 15% of their grade A patients but 66.7% of the patients with incomplete lesions.

In this report, there was a tendency to treat grade A patients conservatively; patients in grades B, C, and D were more likely to undergo surgery (see Table 9). The differences reached significance and reflect the long-accepted concept that decompressive laminectomies would mostly benefit patients who had some neurologic function.

Patients with complete loss of function (grade A) underwent more emergency operations than those in grades B, C, and D. The differences were significant (see Table 10) and suggest that, unlike the data in Table 9, complete lesions more frequently drove the neurosurgeon to consider an emergency laminectomy. This observation has not received much interest in the literature.

Kupcha et al. are among the few authors who analyzed the presence of the full mass of the bullet inside the spinal canal in relation to the timing and likelihood of surgical procedures. Table 11 shows that a bullet inside the spinal canal significantly directed the neurosurgeon toward a surgical option. Interestingly, the presence of the bullet was not sufficient to prompt an emergency operation (see Table 12).

Anecdotal reports have claimed throughout the decades that patients of the last century with cauda equina injuries would have a better outcome if they underwent surgical treatment. Robertson and Simpson reported that 54.5% of their 33 patients with cauda equina lesions underwent laminectomies. Table 13 shows that 72.3% of our patients with lesions below L1 underwent surgery, in comparison with 27.6% of those with injuries affecting the spinal cord. These differences were significant.

The presence of CSF leak is relatively common in patients with gunshot wounds to the spine. In this review, we found 10 patients with this complication. Two (1.3%) developed CSF leaks through the traumatic wound, which resolved with the use of lumbar drainage for 7 days. In the surgical group, 9% developed CSF elimination through the surgical wound (see Table 14). The differences were significant and pointed out that decom-

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**Table 16. Surgery versus meningitis**

| Surgery | Meningitis |  |
|---------|------------|---|
| Yes     | 8 (9.0%)   | 81 (91.0%)   | 89 (100%)   |
| No      | 4 (2.5%)   | 153 (97.5%)  | 157 (100%)  |
| Total   | 12 (4.9%)  | 234 (95.1%)  | 246 (100%)  |

Chi-square = 5.08; $P = 0.032$.

**Table 17. Timing of surgery versus meningitis**

| Meningitis |  |
|------------|---|
| Elective   | Yes | 4 (5.4%) | 70 (94.6%) | 74 (100%) |
| Emergency  | 4 (26.7%) | 11 (73.3%) | 15 (100%) |
| Total      | 8 (9.0%) | 81 (91.0%) | 89 (100%) |

Chi-square = 4.54; $P = 0.033$.

**Table 18. Neurologic condition versus death**

| Frankel/ASIA/IMSOP grade | Death |  |
|---------------------------|-------|---|
| A                         | 31 (21.1%) | 116 (78.9%) | 147 (100%) |
| B + C + D                | 4 (4.3%) | 88 (95.7%) | 92 (100%) |
| Total                     | 35 (14.6%) | 204 (85.4%) | 239 (100%) |

Chi-square = 12.69; $P = 0.001$.

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**Table 19. Outcome**

| Neurologic condition | Patients |
|----------------------|----------|
| Unchanged            | 191 (90.5%) |
| Improved             | 18 (8.6%) |
| Worse                | 2 (0.9%) |
| Total                | 211 (100%) |

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pressive laminectomy is a risk that patients and surgeons must face in these circumstances. Stauffer et al. reported, among patients surgically treated, an incidence of 5.9%. Aarabi et al., in a military experience, reported that almost 15% of the surgical population had this complication.

Meningitis occurred in 4.9% of our patients (see Table 15). Simpson et al. are among the few authors who have related CSF leak to meningitis. This review shows a likelihood that 40% of patients with CSF leak will develop meningitis, with a much lower incidence in those without elimination of the fluid. The differences were significant, emphasizing the need for a watertight closure of the dura mater.

Simpson et al. found an incidence of meningitis three times greater in patient who underwent surgery versus those who were conservatively managed. Aarabi et al. found an overall incidence of meningitis in 7.3% of their series and agreed that surgical treatment is a risk factor. Table 16 shows the significant risk of meningitis that surgery can bring.

Severe neurologic impairment is doubtless associated with a higher death rate. According to Benzel et al., death occurred in only 5.6% of patients with incomplete lesions. Our death rate among patients with incomplete lesions was 4.3%. This contrasts with the death rate of 21.1% in grade A patients (see Table 18). The differences were significant, pointing to the increased risk of death in patients with complete loss of neurologic function.

| TABLE 20. Lesion versus outcome | TABLE 22. Surgery versus outcome |
|--------------------------------|--------------------------------|
| Neurologic condition           | Neurologic condition           |
| Unchanged | Improved | Worse | Total | Unchanged | Improved | Total |
| Spinal cord | 150 (90.9%) | 14 (8.5%) | 1 (0.6%) | 165 (100%) |
| Cauda equina | 41 (89.1%) | 4 (8.7%) | 1 (2.2%) | 46 (100%) |
| Total | 191 (90.5%) | 18 (8.6%) | 2 (0.9%) | 211 (100%) |

\[ P = 0.535. \]

Most publications lack precise methodologic parameters for gauging outcome. For example, Cybulski et al. considered a significant neurologic improvement when the sensory level was found to have lowered at least two segments, or when some motor improvement was detected. Using this imprecise methodology, they reported a 41% rate of neurologic improvement. Stauffer et al., studying 79 patients with incomplete lesions, reported noticeable motor progress in 71% of the surgically treated group and in 76.5% of those conservatively managed.

We strongly believe that a precise and reproducible way to gauge neurologic improvement or deterioration should take into consideration a modification in neurologic function of at least one grade according to the Frankel/ASIA/IMSOP classification. Aarabi et al. are among the few authors who also ascribe to this idea and use these criteria, reporting no change in 75% of patients and improvement in only 10%.

Using these criteria, Table 19 shows that among the survivors in this study, 90.5% remained unchanged and 8.6% improved; two patients deteriorated after decompressive laminectomies.

Traditionally, neurosurgical lore suggests that cauda equina injuries have a better prognosis than lesions affecting the spinal cord. Many authors agree that spinal wounds below L1 have a less gloomy outcome. Unfortunately, this was not the message extracted from our data, where patients with spinal cord and cauda equina injuries behaved in a similar way (see Table 20).

Yashon et al. postulated that the presence of the entire mass of the bullet inside the spinal canal would...
produce a worse outcome. This has been echoed by Stauffer et al.\textsuperscript{18} Our study showed that patients with metallic fragments inside the canal fared statistically better than those with the entire mass of the bullet in the canal (see Table 21).

The impact of any therapy on the outcome of patients with gunshot wounds to the spine requires a better prospective analysis. Still, based on these data, some generalizations can be made. Yashon et al.\textsuperscript{24} postulated that decompressive laminectomies influenced the outcome of their patients; this opinion was shared by Heiden et al.\textsuperscript{26} Stauffer et al.\textsuperscript{18} and Cybulski et al.\textsuperscript{34} Hammoud et al.\textsuperscript{13} stated that at least surgical treatment would offer a psychological benefit to the patients and relatives. We disagree with this conclusion, based on our data.

Table 22 shows that in the surgical group, 12.2% improved. In the nonsurgical group, 6.3% did better. The differences are not statistically significant. Despite the unfavorable results in the surgical group, neurosurgeons still often advocate decompressive laminectomies. It is even more difficult to support emergency surgery when we found that no patient benefited from this policy (see Table 23).

Benzel et al.\textsuperscript{25} concluded that decompressive laminectomies should not be denied to patients with cauda equina injuries because surgical treatment should play a positive role in the outcome. However, our data showed that conservative management was associated with a higher improvement rate (15.4%) compared with surgery, although the differences were not significant (see Table 24).

Thus, we found that decompressive laminectomy could not be significantly associated with a better outcome (see Table 25) at any level. From our data it seems difficult to find a scientifically based reason to recommend surgery to patients with gunshot wounds to the spine to improve function. We agree with Yashon et al.\textsuperscript{24} when they stated that the final result of these spine-injured patients is related to their initial neurologic status and entirely unassociated with decompressive laminectomies or other surgery.

| Laminectomy | Neurologic condition | Total |
|-------------|----------------------|-------|
| Yes         | Unchanged 30 (93.7%) | 2 (6.3%) | 32 (100%) |
| No          | 11 (84.6%) | 2 (15.4%) | 13 (100%) |
| Total       | 41 (91.1%) | 4 (8.9%) | 45 (100%) |

\(P = 0.57.\)

### CONCLUSIONS

From this retrospective study, it can be concluded that decompressive laminectomies have no positive impact on the outcome of patients with gunshot wounds to the spine. Indeed, surgical procedures were significantly associated with higher rates of CSF leak and meningitis. We no longer recommend surgery for these patients.\textsuperscript{13}

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