Analysis of 76 civilian craniocerebral gunshot wounds

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A retrospective analysis of 76 civilian craniocerebral gunshot wounds treated over a 20-month period is presented. The authors report a 62% mortality rate and conclude that the admission Glasgow Coma Scale (GCS) score is a valuable prognosticator of outcome. Other important findings were: 1) patients with a GCS score of 3 invariably died, with or without surgical intervention; and 2) the presence of intracranial hematomas, ventricular injury, or bihemispheric wounding was associated with a poor outcome. Standardized methods of data reporting should be adopted in order to allow multicenter trials or comparisons that might lead to management practices that could improve results.

KEY WORDS - head injury - gunshot wound - Glasgow Coma Scale - prognostic factors

Craniocerebral gunshot wounds continue to constitute a dilemma for the neurosurgeon. Many of the published studies were either based upon high-velocity wounds treated in military practice, or gathered before computerized tomography (CT) played such an important role in neurosurgery. Consideration of this problem is further complicated in that most reported series involve either small numbers of patients or heterogeneous management policies; as a result, any conclusions are tenuous.

There has been tremendous interest in the neurosurgical management of head injury and many of its particular complications, however, for some reason low-velocity craniocerebral gunshot wounds as seen in civilian neurosurgery have not received much attention. A review of the literature reveals no reported series of low-velocity craniocerebral gunshot wounds that reflects: 1) prompt neurosurgical evaluation in relation to the wounding; 2) full use of computerized tomography (CT) in the evaluation; and 3) a team approach whereby all associated injuries are treated promptly with a homogeneous protocol. In this paper we report the results of a retrospective study of 76 craniocerebral gunshot wounds treated over a 20-month period ending August, 1985. These data are used as a basis for a review and discussion of the literature concerning the basic ballistics, epidemiology, and management of low-velocity craniocerebral gunshot wounds.

Clinical Material and Methods

The 76 patients included in this study were treated by the authors at the Elvis Presley Memorial Regional Trauma Center, Memphis, Tennessee, in the 20-month period ending August, 1985. Patients with injuries to systems other than the brain or requiring resuscitation were managed by means of a team approach. Individuals who were dead on arrival or who had gunshot wounds of the scalp that did not penetrate the cranium were not included in this series.

All patients were subjected to neurosurgical evaluation including a rating on the Glasgow Coma Scale (GCS), skull radiographs, and a cranial CT scan. All received intravenous prophylactic antibiotic and anti-convulsant therapy. If patients experienced seizures on arrival, phenobarbital or diazepam was given acutely and appropriate loading doses of phenytoin were administered after the seizure activity had terminated. The only patients who did not undergo CT scanning of the head were those whose systemic hypotension could not be controlled by vigorous resuscitation efforts.
These patients were evaluated and taken directly to surgery where exploratory surgery and debridement were performed, usually in cooperation with the general surgical trauma team.

Outcomes were assessed by the Glasgow Outcome Scale (GOS) which classifies neurological disability according to five categories.\(^{15}\) Classification was based upon the patient's status at the time of discharge from the hospital, and did not attempt any consideration of long-term results. Patients considered to have "good recovery" were able to resume a normal life even though they might have minor neurological and psychological deficits. Those with "moderate disability," although disabled, were still capable of functioning independently in their daily life. Patients with "severe disability" were conscious but, by reason of mental or physical deficits, were dependent for the activities of daily living. Patients in a "persistent vegetative state" remained unresponsive and speechless for weeks or months after acute brain damage. The final outcome category was death.

Patients names and record numbers were obtained from the trauma registry. Patient records, medical examiner reports, and police reports provided the data included in this analysis.

### Results

The demographic characteristics of the patients in this series are portrayed in Table 1. The mortality rate was 62%, which included 42 brain deaths and five deaths from other causes. Three patients received gunshot wounds to other organ systems that resulted in death from hemodynamic collapse in two and one fatal case of sepsis. One patient had fatal pulmonary embolism and one died of meningitis.

Thirty-five of the wounds were caused by documented suicides or suicide attempts, while the remaining 41 wounds were not self-inflicted. There was a definite racial predisposition toward both suicide and homicide: 86% of the suicides were in Caucasians and 78% of the homicides (not self-inflicted) were in blacks (chi-square = 30.52, 1 df, \(p < 0.0001\)). Within each of these groups, there was a definite male predominance.

Twenty-six of the 35 total attempted suicides were in Caucasian males (74%) and 30 of the 41 attempted homicides were in black males (73%). Also, while there appeared to be a definite trend in the association of a positive blood ethanol test and homicides (39%) versus suicides (24%), this difference was not statistically significant (chi-square = 3.51 df, \(p = 0.067\)).

Thirty-three of the brain-dead patients were evaluated at the hospital, and did not attempt any consideration of a positive blood ethanol test and homicides (39%) versus suicides (24%), this difference was not statistically significant (chi-square = 3.51 df, \(p = 0.067\)).

### Table 1

Demographic factors in 76 gunshot wound cases

<table>
<thead>
<tr>
<th>Race &amp; Sex</th>
<th>Age (yrs)</th>
<th>Total Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;18</td>
<td>18-30</td>
</tr>
<tr>
<td>black male</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>black female</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>white male</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>white female</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>total cases</td>
<td>10</td>
<td>35</td>
</tr>
</tbody>
</table>

Morbidity was categorized according to the GOS. Three patients (3.9%) were discharged in a persistent vegetative state. Eleven and 14 patients, respectively, were classified as moderately disabled or with a good recovery. Only one patient survived with a severe disability. The GCS score at admission did seem to discriminate between patients with an ultimate good outcome (GOS Grade 1 or 2) and those with a poor outcome (GOS Grade 3, 4, or 5). The mean GCS score on admission was 9.48 ± 3.2 for the good-outcome group versus 3.68 ± 1.3 for those with a poor outcome (\(t = 9.2, p < 0.0001\)).

Postoperative complications were fortunately few. There were no cerebrospinal fluid leaks, one postoperative hematoma requiring reoperation, one wound dehiscence, and two cases of meningitis. The GCS score obtained in the immediate postoperative period tended to be about 1.0 to 1.5 points higher than the admission GCS score, but these differences were not statistically significant. Seizures occurred in only three patients (3.9%), and were focal in one. Each of these patients had more than one episode of seizure activity. Most seizures were easily controlled once adequate serum phenytoin levels were attained.

Ventricular injury was associated with a poorer outcome. Of the 39 patients with involvement of the ventricular system, 35 (89.7%) had a poor outcome (GOS Grade 3, 4, or 5). In contrast, of the 29 who had no ventricular involvement, only seven patients (24.1%) had a poor outcome (chi-square = 30.8, 1 df, \(p < 0.0001\)). Likewise, injury to both cerebral hemispheres tended to presage a poorer outcome. Bihemispheric wounds led to a poor outcome in 85.7% of patients, while only 35.5% of those with injury to a single cerebral hemisphere had a poor outcome (chi-square = 34.7, 1 df, \(p < 0.0001\)).

Major vascular injuries, defined as injury to one of the major intracranial arterial tributaries or one of the dural venous sinuses, occurred in only 13 patients. While this was too few to allow any meaningful testing for statistical significance, it is interesting to note that
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62% of these were venous sinus injuries. Hematomas resulted from the original wounding in 51.1% of patients. Of interest is the virtual absence of epidural hematomas (2.0% of the series), whereas 22% of patients had subdural hematomas and in 27% the collection was within the cerebral hemispheres.

Other factors that were of no prognostic significance included large versus small caliber of weapon ($p = 0.07$) and the interval between injury and evaluation. It is important to note, however, that 89% of patients were evaluated within 2 hours of injury, and 67% were seen in the 1st hour.

Discussion

Most of the knowledge concerning craniocerebral missile wounds comes from information compiled during the four major wars. These injuries, unlike civilian wounds, are the result of high-velocity ($> 2500$ ft/sec) missiles. It is generally accepted that the total kinetic or destructive energy (KE) imparted to the cranium and brain is related to one-half the mass of the projectile times its velocity squared. This can be expressed as $KE = \frac{1}{2} MV^2$. To be more precise, the amount of energy associated with the projectile as it exits the cranium should be subtracted, leaving the final relationship

$$KE = \frac{M_1V_1^2 - M_2V_2^2}{2},$$

where $M_1$ and $V_1$ are the mass and velocity of the projectile as it enters the cranium, and $M_2$ and $V_2$ are the mass and velocity of the projectile as it exits. This calculation ignores the configuration, design, and composition of the bullet or projectile, as well as any kinetic energy associated with spin. However, it does allow an estimate of the destructive power achieved in civilian craniocerebral gunshot injuries.

The gunshot wounds seen in civilian practice are most commonly inflicted by small-caliber (.22 to .38) low-velocity (900 to 1300 ft/sec) projectiles, usually delivered over a range of less than 50 yards. They frequently do not show the massive scalp destruction, remote skull fractures, large gaseous cavitation of the brain, or explosion and shattering of the skull often seen with high-velocity projectiles. As a result, many neurosurgeons advocate a much more conservative approach to the management of these low-velocity wounds.

In general, our results indicate that the conservative surgical approach advocated by both Raimondi and Samuelson and Yashon, et al., continues to have merit. Basically, our approach consists of careful exploration of the wound, with removal of any intracranial hematomas, depressed or in-driven bone fragments, hair, or other foreign bodies; debridement of necrosed brain; removal of the bullet or fragments only when accessible and not requiring an approach through uninjured cerebral tissues; and meticulous closure of the dura, either primarily or with the use of a free graft of fascia or pericranium.

Several investigators have shown that trauma centers can reduce the mortality from motor-vehicle accidents, but this has not been demonstrated for civilian craniocerebral gunshot wounds. In spite of the fact that 89% of the patients in this series were evaluated by a neurosurgeon within 2 hours of wounding, the high mortality rate persists. Furthermore, while a team approach to the management of trauma is logical, quite efficient, and of proven effectiveness in other types of injury, only three of the deaths in this series (6.3%) were the immediate result of wounds to other organ systems. Thus, even though the overall mortality rate remains unaffected by either access to a trauma center or the use of a team approach to management, it is interesting to speculate regarding the effects of these factors plus a helicopter transport system on the number of patients now receiving neurosurgical evaluation who earlier would have died before any assessment could be performed. This is particularly important when one considers that, in this series, 89% of the deaths were brain deaths, 76% of those who died had an admission GCS score of 3, and all of those with an admission GCS score of 3 died regardless of surgical intervention.

Other authors have commented regarding the difficulty of assessing the prognosis for recovery of neurological function in the early stages after wounding. While this probably remains true for some patients with higher GCS scores, the death of all patients in this series with a GCS score of 3, whether or not surgery was performed, must cause us to question the value of surgical intervention in these cases.

Certain other data from this study may further aid efforts to develop a prognosis for patients with low-velocity craniocerebral gunshot wounds. Although the level of consciousness at the time of admission has long been recognized as an important predictor of survival, most of these studies have not reported these data in a standardized reproducible manner that facilitates easy comparison. The results of this study would indicate that either patients survived and achieved a moderate or good recovery (32.7%), or the results were dismal (65.7% died or survived in a persistent vegetative state). Furthermore, the admission GCS scores of those who survived (9.2 ± 3.2) were significantly different from the scores of those who did not (3.5 ± 1.1) ($t = 14.9$, $p < 0.0001$). The present study represents the first attempt of which we are aware to report the use of widely accepted coma and outcome scales in a series of civilian craniocerebral gunshot wounds. This type of data standardization is an important step toward the design and conduct of multicenter trials to study this entity.

Other important prognostic factors for these patients were the presence of intracranial hematomas, ventricular injury, or bihemispheric wounds. The incidence of associated intracranial hematomas in our civilian
FIG. 1. Computerized tomography scan demonstrating a bullet trajectory through the ventricular system. Some artifact from the metallic fragments is seen.

series closely parallels that reported by Barnett and Meirowsky for wounds in the Korean War and that recorded by Raimondi and Samuelson in a civilian population in the pre-CT scan era. This is somewhat surprising with regard to the military wounds, since the missiles most often involved were shell fragments rather than bullets, and were “low velocity” by military standards. However, these projectiles still had velocities as high as 1000 to 1500 m/sec, speeds much higher than the muzzle velocities of civilian handguns. While this relatively high incidence of intracranial hematomas awaits confirmation, it may be due in part to the short interval between wounding and evaluation, and improved diagnosis now available with CT scanning. The routine use of CT has had a significant impact upon the management of these wounds. Much of the pre-CT era literature on this subject was devoted to the importance of detecting the presence of intracranial hematomas. Now CT scanning provides a quick noninvasive method of assessing the intracranial contents, and its use in the management of civilian craniocerebral gunshot wounds has recently been reviewed. Although the artifact caused by metallic fragments is occasionally bothersome (Fig. 1), CT scanning is currently the procedure of choice in evaluating these injuries. Because of these occasional metallic artifacts, we obtain routine skull radiographs in these patients: while they usually do not aid our decision of whether to intervene surgically once this decision has been made, they are invaluable in planning the surgical approach.

The occurrence of ventricular injury in this series was also a predictor of a poor outcome. This is consistent with earlier reports that patients with ventricular wounds carry the highest mortality. However, the latest report on these injuries of which we are aware is derived from the military experience in the Korean War by Wannamaker. Diagnosis of ventricular wounding in his series was based on actual visualization of the opening into the ventricle at surgery, and he reported a mortality rate of only 10.47%. Unfortunately, this does not give a complete picture of the gravity of violation of the ventricular system. The fact that 89.7% of the patients in our series with ventricular involvement experienced a poor outcome (GOS Grade 3, 4, or 5) is *prima facie* evidence of the seriousness of these wounds. The incidence of wounds of the ventricular system in the present study was based upon the CT demonstration of a bullet trajectory through the ventricles (Fig. 1) plus visualization at surgery. It is, therefore, difficult to account for the tremendous differences in the data between Wannamaker’s military experience and the present study. Some of this difference may be due to the increased sensitivity of the CT scan and the fact that the military series was from a second-echelon hospital. In addition, if ventricular wounds are as devastating as our data would indicate, a combination of the longer intervals between wounding and definitive neurosurgery seen in wartime and the possible mortality attributable to this time interval could account for a lower percentage of these wounds being seen in a second-echelon hospital.

A final factor that was of prognostic significance was involvement of both cerebral hemispheres. In contrast to the military experience where the great majority of wounds (82%) were confined to one cerebral lobe, 55% of the wounds in the present series were bihemispheric and 85.7% of these patients experienced a poor outcome. While it must remain speculative, one might suspect that the high proportion of attempted suicides (46%) and resultant point-blank range could account for some of this difference.

Since the turn of the century, consumption of alcohol has been recognized as being associated with one-third to one-half of all cases of violent death, but until recently this involvement had not been systematically explored. A recent study has reported that 45.2% of homicides and 35.4% of suicides had positive blood ethanol levels. Our data show that 39.4% of homicides and 23.5% of suicides had positive blood ethanol levels, but the presence of ethanol was not an aid in predicting outcome, nor was there any statistically significant difference in ethanol use between the homicide and suicide groups.

There was a preponderance of small-caliber weapon wounds in this series (70.9%). The tendency was for patients wounded with a larger-caliber weapon to have a worse outcome: 78% of large-caliber wounds were fatal compared to a fatality rate of 54.5% with small-caliber weapons. This is consistent with earlier findings, but was not statistically significant. Nonetheless, it is interesting to note the differences in the CT scan
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Fig. 2. Computerized tomography scans showing wounds from a small-caliber weapon (left) and a large-caliber weapon (right).

appearance of the wounds with large- and small-caliber weapons (Fig. 2).

In spite of sophisticated preadmission, perioperative, and postoperative care, it is somewhat frustrating to note our general lack of improvement in the morbidity or mortality rates associated with civilian craniocerebral gunshot wounds. In general, it would appear that the most important factors for prognostication are the GCS score at the time of initial assessment, and factors directly related to the wound, such as the presence of intracranial hematomas, ventricular injury, or bitemporal injury. Based on these results, we advocate a conservative approach to the management of these wounds as outlined earlier, and currently believe that surgical intervention is probably not indicated in patients with a GCS score of 3.

Standardized scales for the assessment of level of consciousness and outcome should be adopted in order to allow collection of larger amounts of data and provide comparative information that might serve to improve upon our current strategies of treatment.

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References


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