Craniocerebral Gunshot Wounds in Civilian Practice

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NEUROSURGICAL understanding of missile injuries of the head is derived from information compiled during the four major wars of this century.1,4,8,12,18,20,22 Consequently, the concepts guiding the care and treatment of civilian gunshot wounds have, for the most part, been extrapolated from military experiences. The fundamental difference between military and civilian cranioencebral injury is related to the high velocity of the military missile compared to the low velocity in civilian injuries. Thus the broad extent of tissue damage noted in military practice is the result of the disruptive force caused by these exceptionally high levels of kinetic energy.7,20,25 This is rarely encountered in civilian practice.

Although the mechanism of tissue disruption by high velocity missiles is not completely understood, it has long been recognized that even small missiles at high velocity will cause extensive tissue damage.7,12,25 Kinetic energy varies with the square of the velocity and linearly with missile mass. If one considers power rather than kinetic energy, then another parameter is introduced and one may say that power, or the rate at which the energy is expended, varies with the cube of the missile velocity.7,25

Clinical evidence, compiled during wartime, corroborates these physical considerations. High velocity military wounds cause extensive tissue damage at great distances from the missile track.4,20 If left unattended, these wounds become devascularized, hemorrhagic, proteinaceous masses impregnated by foreign body fragments, all of which predispose to a suppurative process.2,22,28,33 If an infection does not develop, large giotic areas often result, which may become the nidus of epileptiform discharges. The two may occur together. The wars of this century have provided ample evidence that such military wounds must be treated by careful and extensive debridement coupled with pains-taking wound closure.4,20,26

The purpose of this study is to examine the cranioencebral injuries from relatively low velocity missiles encountered in civilian practice, to assess whether such injuries require the same surgical management outlined by the military neurosurgeon4,18,20 to evaluate the importance of adequate preoperative angiographic studies, and to analyze the results of a less radical treatment.4,8,20

Clinical Material

From January 1, 1964, through June 30, 1968, we studied 150 patients with cranioencebral gunshot wounds at Cook County Hospital in Chicago, Illinois. These patients constitute 93% of all those with such injuries treated at this institution during the period of our study; the remaining 7% were either admitted to nonsurgical services or their admission records have been lost in the interim. Patients dead on admission are not included in this series.

All patients with a Cook County Hospital admission diagnosis of gunshot wound of the head, whether seen first in another hospital or not, were initially evaluated in Cook County’s trauma unit. Each was examined and treated by a general surgical and a neurosurgical resident. Multiple injured patients with severe chest, cardiac, or hemorrhagic problems were treated in a team manner by the appropriate staff personnel.20

Patient Evaluation. We have divided the patients in this series into five stages according to the severity of their symptoms:

Stage I. These patients were alert, without history of unconsciousness, and with no neurological deficit. They were admitted for observation. If there was a depressed fracture, bilateral carotid angiography was performed to exclude a clot before the fractures were elevated.

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Stage 2. Although alert with no history of unconsciousness, these patients had a definite “localizing” neurological deficit. Bilateral carotid angiography was performed immediately.

Stage 3. Patients in this group were awake but somnolent, agitated, or confused, with a history of unconsciousness and often a definite personality change since the time of injury. We performed emergency tracheostomy on Group 3 patients who exhibited signs of respiratory difficulty, to avert the danger of acidosis secondary to the central respiratory depression caused by increased intracranial pressure.14-16 Bilateral carotid angiography was performed on all patients in this group.

Stage 4. These patients all were comatose, responding only to painful stimuli, or to verbal stimuli when reinforced with pain. Some required tracheostomy. Many deteriorated quickly to Stage 5, and most died immediately or in spite of removal of the precipitating intracranial clot.

Stage 5. In addition to being comatose, all of these patients showed decorticate or decerebrate responses to painful stimulation and all remained comatose until death.

Use of Angiographic Observations. In patients with depressed fractures without transdural penetration, when angiography revealed no subdural or intracerebral clot we did not open the dura if it was found intact. When angiography revealed a surgically amenable lesion beneath an intact dura, the dura was opened and the lesion attacked.

In patients with transdural penetration, no extensive debridement was done along the missile track. Deeper missiles were left in place if angiography revealed no shift of vessels to indicate either intracranial or extracerebral hematomas. When, on the other hand, angiography revealed the presence of a hematoma, either intracranial or extracerebral, then regardless of the patient’s normal neurological status the clot was removed.

Mortality. There was a direct relationship between the over-all mortality and the time lapse between injury, initial first aid, admission to a referring hospital, admission to Cook County Hospital, and definitive surgery. For ease of interpretation, we will refer to that group of patients first seen in other hospitals as Group A, and to that group seen only at Cook County Hospital as Group B. Upon cursory examination, it would appear that there is no significant difference between the mortality rates of the two groups. However, study of Table 1 illustrates the impressive changes in stage which occur before definitive surgical and medical treatments are begun.

Other factors than time contributed to the mortality:

1. The extent of injury to vital structures as reflected by the clinical “stage” of the patient on admission (Table 2).  
2. Logistical data. In contrast to military patients who undergo standardized evacuation procedures,20 civilians with gunshot wounds follow many courses en route to definitive therapy. In Chicago, the “nearest hospital” practice is followed. This entails the transportation of the injured patient to the nearest hospital, irrespective of any other considerations.

3. Age. The older the patient, the more fragile he is with respect to the injury.3

4. The effect of the number of Stage 4

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**TABLE 1**

Relation of mortality of Group A patients to delay in therapy

<table>
<thead>
<tr>
<th>No. of Patients</th>
<th>Stages</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>Patients at referring hospital</td>
<td>45</td>
<td>89</td>
</tr>
<tr>
<td>Patients on arrival Cook County hospital</td>
<td>36</td>
<td>83</td>
</tr>
<tr>
<td>Patients who died Cook County hospital</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>Patients operated on Cook County hospital</td>
<td>13</td>
<td>38</td>
</tr>
<tr>
<td>Operative deaths Cook County hospital</td>
<td>2</td>
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</tr>
</tbody>
</table>

Of course, this does not mean that these patients did not require hospitalization. Their condition was so grave that hospitalization was needed, regardless of the hospitalization time. The hospitalization time, however, may be a factor in the degree of recovery achieved by the patient.
and 5 operations on the overall surgical mortality.

5. Alcohol intoxication. From a study of intoxicated patients in our series, it would be difficult to cite alcohol as a factor seriously complicating craniocerebral gunshot wounds. Although the intoxicated patient may be put aside before completely objective evaluation of his problem has been assessed, this occurred only once in the 33 intoxicated cases of our entire series of 150 patients. Fifteen of these 33 patients required surgery.

**Fate of Patients with Residual Missile Fragments in Cerebral Tissues**

Cushing and Meirowsky stated that delay in wound closure contributes to poor prognosis. Even though some investigators writing on early World War II experiences pointed out the benign character of retained intracerebral metal fragments, Cairns, et al., and others later blamed such fragments as the primary cause of subsequent supplicative processes. The amount of peri-missile disruption was not considered the primary cause of the infection. The actual goal of the neurosurgical operation was the search for, and removal of, all retained fragments, and not solely the debridement of devascularized tissue.

Since the primary pathological difference between military and civilian wounds appears to be the area of tissue disruption, we have assumed, along with Maltby and Ascroft, that the adverse sequelae of retained fragments is a function of both widespread tissue disruption and foreign body fragments, not the latter alone.

We have analyzed our series with regard to the mortality and morbidity of patients with retained intracerebral missile fragments (Table 3). There were 25 patients in whom

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### Table 2

**Relation of mortality to surgery and clinical stage at admission**

<table>
<thead>
<tr>
<th>Patients</th>
<th>Stages</th>
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<td>1</td>
<td>2</td>
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<tr>
<td>Clinical stage on admission</td>
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<tr>
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<td>Over-all deaths</td>
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<td>% of total</td>
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</tr>
<tr>
<td>Patients operated on</td>
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<tr>
<td>number</td>
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<td>% of total</td>
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<td>Operative deaths</td>
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<tr>
<td>% of total</td>
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### Table 3

**Survival of patients with retained fragments**

<table>
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<tr>
<th>Cerebral Penetration</th>
<th>Operative Patients</th>
<th>Nonoperative Patients</th>
<th>Total Patients</th>
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<td>Multiple lobe</td>
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<tr>
<td>Total</td>
<td>14</td>
<td>13</td>
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</table>
missile fragments were retained, 14 after intracranial surgery and 11 with scalp debride-
ment but without intracranial surgery. All 25 are still alive with retained intracerebral
metal fragments. These patients have been followed for an average of 31 months post-
operatively, with the longest follow-up being 56 months and the shortest 20 months. Be-
cause no significant difference was noted be-
tween these groups over this period of time,
they have been assessed together.

Infection was the most serious sequela
noted in military cranioencephalic wounds with
retained missile fragments. In our se-
ries of patients with retained missile frag-
ments, however, the only infections were one
case of transient meningitis in a patient with
a basilar fracture and otorrhea, and one case
of superficial wound infection. Both of these
infections were cured with appropriate
wound care and antibiotic therapy. We have
not had a single case of cerebral fungus in-
fec tion or abscess formation in this group,
although we are aware that abscess forma-
tion from retained fragments has been re-
ported as late as 7 and 39 years after the in-
jury.

Epileptic seizures were a problem in two
of our patients; one had intracranial surgery
and the other did not. Both had seizures
when initially admitted, but have subse-
quently been well controlled on anticonvul-
sant therapy. We are not able to correlate
this with retention of the fragments.

In this group with missile fragments (Ta-
ble 3), there are 10 who following intracra-
nial surgery remain alive and have no re-
tained missile fragments.

The single patient who died had all missile
fragments removed from the right frontal
lobe; because the entrance was via the fron-
tal sinus, a drain was left in place postopera-
tively and subsequent meningitis, cerebritis,
and ventriculitis resulted in death.

Nine patients who were operated on for
removal of intracerebral and subdural hema-
tomas and from whom the intracerebral mis-
siles were removed because of their easy ac-
sessibility were not included in the group
above because of the wide extent of debride-
ment accomplished in each case. Two of the
postoperative deaths in this group were the
result of widespread intracranial infection.
The three postoperative infectious deaths in
our entire series all followed procedures in
which the missile fragments were removed.
Six of these nine patients with wide cerebral
debridement are still alive; all have severe
neurological deficits including three with sei-
zure problems and four with incapacitating
hemiparesis. Five are in nursing homes.

Of the 14 patients who had intracranial
surgery and who retained missile fragments
postoperatively, one had seizures, one had
transient meningitis, two had a slight hemi-
paresis, and one was hemianopic. Of the 11
patients who did not have intracranial sur-
gery and who retained indriven missile frag-
ments, one was mildly hemiparetic and two
were hemianopic. None of these 25 cases re-
quired special nursing care and none was in-
stitutionalized.

We find in our series no evidence of predi-
lection to abscess formation or any other in-
fec t ous process if missile fragments are left
in the cerebrum. As yet, we have no evi-
dence to support the concept that such frag-
ments predispose to epileptic seizures.

The caliber of the missile, the degree of
penetration, the presence or absence of pow-
der burns, the site of entrance, all are factors
in the clinical outcome of each particular
case. Our series is not large enough to form
any conclusions concerning these factors,
but they may well be worth considering in
more extensive studies of this type. Table 4
is a tabular representation of many of these
parameters as observed in our series.

Discussion

Low velocity civilian cranioencephalic mis-
sile wounds are not uncommon. At Cook
County Hospital, they comprise 1.2% of the
"trauma" admissions.

Study of our 89 Group A patients re-
vealed that it took an average of 5.5 hrs for
each patient to be taken from the place of
injury to another hospital and subsequently
to be transferred to Cook County Hospital.
The mean injury-to-admission time for this
group was 5 hrs 15 min. Comparatively,
Group B patients had an average injury-to-
admission time of 2 hrs 15 min, with a mean
of 2.5 hrs, for a difference between the two
groups of approximately 3 hrs.

If one considers the clinical admission
stage of each Group A patient at both the
referring hospital and at Cook County Hos-
pital, he then has a clinical indicator of the
relative importance of the 3-hour delay (Ta-
Craniocerebral Gunshot Wounds

TABLE 4
Summary of clinical and ballistic factors related to deaths

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<tr>
<th>Ballistic Data</th>
<th>Total</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Stage 4</th>
<th>Stage 5</th>
<th>Total Deaths</th>
<th>Total Operations</th>
<th>Operative Deaths</th>
<th>Basilar Fracture</th>
<th>Linear Fracture</th>
<th>Depressed Fracture</th>
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</table>

It becomes evident that a significant degree of clinical deterioration does occur. Of the 89 patients, 37 became worse and 21 of these died.

Autopsies on these patients revealed that each of them had a significant but operable neurosurgical lesion. Only six of the 37 underwent surgery, of whom only two survived. The remaining patients had deteriorated to such an extent that surgical intervention was deemed futile. Not a single patient improved during the transfer process.

We observed that the earliest sign of an intracranial hematoma was respiratory distress. Of our 45 deaths, 39 patients demonstrated respiratory difficulty and 36 of these had a significant intracranial hematoma. Of the 66 patients in whom intracranial hematomas were found, both during surgery and at autopsy, 58 had significant respiratory distress. Of the 89 Group A patients transferred to Cook County Hospital, none had been tracheostomized and only two had endotracheal tubes in place. Our admission information indicated that 20, or 22.6%, of these patients were in moderate-to-severe respiratory distress, and that 19 of the 20, or 95%, died. Twelve of these 20 patients were awake and responding appropriately to verbal stimuli when they were first seen in the referring hospital.

We have not observed the widespread tissue damage encountered by the military neurosurgeon. Rarely have we seen significant brain swelling. In those cases where swelling was a significant problem, either the midbrain or the brain stem were in the missile track, or there was swelling about the pe-
r殆phy of an intracerebral hematoma or a contused lobe. The latter problem usually became significant 8 to 10 hours post injury.

The civilian missile, contrary to the military one, is relatively benign when imbedded in cerebral parenchyma. This fact is apparently due to the very limited area of permissile tissue disruption.\(^7\)\(^,\)\(^25\) It may be that the military decision to operate immediately and to remove all metal and bone fragments in such lesions\(^20\) was the result of the much higher velocity and therefore greater tissue disruption involved.

The rationale for the use of angiography rather than exploratory craniotomy or burr holes is that adequate angiographic studies provided precise information concerning the presence, location, and, in some cases, nature of intracranial surgical lesions such as contrecoup lesions,\(^19\) damage to arteries \(^14,\)\(^12,\)\(^23,\)\(^24,\)\(^26\) or dural sinus,\(^21,\)\(^31\) epidural hematomas, and false aneurysms.\(^8,\)\(^13,\)\(^27\) In addition to this, angiography helped in the evaluation of the operability of the lesion in the decision whether to perform surgery and how to do it. This information minimizes the number of those postoperative complications that are the result of preexisting lesions not suspected at the time of surgery.

We agree with Matson and Wolkin\(^19\) that metal fragments and foreign bodies in the brain should be removed at the time of primary debridement if readily accessible. However, if removal necessitates an approach through uninjured cerebral tissue and angiography reveals no peri-missile hematoma, the risks of increasing the neurological deficit, and the opening of new avenues for infection from contaminated wounds, outweigh the benefits to be gained; therefore, we recommend that such foreign bodies be left in place. In our series 25 patients were treated in this way, and the patients remain well today.

The vascular lesions caused by these missiles, however, are not benign. Hematomas in the extradural, subdural, intracerebral, and intraventricular compartments are often quite significant and can be life-threatening. The resultant hypercarbia and respiratory acidosis cause an increase in the intracranial pressure.\(^14-\)\(^16\) Interruption of the vicious cycle that results is mandatory. Timely tracheostomy and artificial respiratory assistance will slow, or even reverse, the rate of clinical deterioration. This is true for both military and civilian wounds.\(^20\)

Hooper pointed to preoperative delay as the most significant contributing factor in epidural hematoma deaths and further emphasized that over half of these delays occurred in the hospital. Two other parameters analyzed were the patient's state of consciousness at the time of surgery and his respiratory distress prior to surgery. Hooper concluded that depression of either of these parameters "foretold serious sequela."\(^10\)

Our series confirms these findings, and extends the observations to include all intracranial hematomas secondary to gunshot wounds, not simply extradural hematomas. In this respect our five-stage classification and the frequent use of emergency angiography have proven to be definite assets in diagnosing and treating the primary problem in civilian cranio-cerebral missile injuries, namely, intracranial hematomas.

**Summary**

We have studied 150 consecutive civilian cranio-cerebral gunshot wound victims treated at Cook County Hospital from January 1, 1964, through June 30, 1968. Each patient was assessed according to the degree of his injury, as indicated by an arbitrary five-point scale, both at referring hospitals and upon admission to Cook County Hospital. Timetable studies done concurrently indicate that taking patients to the nearest hospital, and subsequently transferring them to Cook County Hospital, was responsible for a 3-hour delay in the initiation of definitive therapy. Significant increases in mortality rates were found in those patients who had delayed therapy as compared with those who were admitted directly to Cook County Hospital.

Multiple clinical parameters were monitored in each patient, the most significant of which was depression in either the respiratory status or the level of consciousness. Intracranial hematomas, rather than the missiles themselves, were found to be responsible for the greatest threat to these patients. It was deemed essential that these lesions be evaluated and treated as accurately and rapidly as possible. Cerebral angiography proved an invaluable aid in this respect.

Contrary to military reports where wide areas of cerebral tissue disruption were com-
monplace, civilian missiles were found to produce little tissue damage other than hematoma formation. The therapy, therefore, was based upon the removal of intracranial hematomas and surface debridement, leaving missile fragments in place if removal necessitated an approach through uninjured cerebral tissue and angiography revealed no peri-missile hematoma. Twenty-five patients thus treated retained indriven missile fragments after therapy and none has developed significant adverse sequelae referable to the retained missile fragments.

References