Penetrating Brain Injury Guidelines

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**Introduction**

- 1995, evidence-based *Guidelines for the Management of Severe Head Injury*
- However, these guidelines did not address the management of patients injured by penetrating objects.
- 1998, the International Brain Injury Association, the Brain Injury Association, USA, and members of the American Association of Neurological Surgeons and the Congress of Neurological Surgeons began work on this task.
- The following guidelines are based on the Guidelines for the Management Of Penetrating Brain Injury presented in The Journal of Trauma Injury, Infection & Critical Care, August Supplement 2001, Volume 51, Number 2. The have been modified and expanded to address issues specific to University Mississippi Medical Center and also reflect approaches to certain issues not addressed in the guidelines.

**I. Neuroimaging in the Management of PBI Patient**

- CT scanning of the head is strongly recommended. (CT scanning provides improved identification of in-driven bone, fragments, missile trajectory, extent of brain injury, and detection of hematomas and mass effects.)
- Angiography is recommended in PBI where a vascular injury is suspected.
- MRI seldom indicated
- CT Angio should be ordered for any wound tract that crosses paraclinoid region, midline or sylvian fissures

**II. Vascular Complications of PBI**

- CT angio and/or conventional angiography should be used to identify a traumatic aneurysm or AV fistula in patients with a PBI involving an orbitofacial or pterional injury, particularly in patients harboring an intracerebral hematoma. Substantial unexplained SAH or delayed hematoma should raise suspicion of a vascular injury.
- When a traumatic aneurysm or AV fistula is identified, surgical or endovascular management is recommended.

**Subarachnoid Hemorrhage**

- The incidence of SAH after PBI ranges from 31% to 78%, on the basis of CT scan data.
- The presence of SAH after PBI has been shown to correlate significantly with mortality.
**Vasospasm**
- Patients with SAH may exhibit cerebral vasospasm on transcranial Doppler.
- No differences in outcome (3-month Glasgow Outcome Scale) were found in PBI patients with or without vasospasm.
- When these are detected, therapeutic measures analogous to those used outside the setting of trauma are indicated. These include Triple H therapy (hypertension, hypervolemia, and hemodilution) and selective angioplasty.

**Vascular Complications – SUMMARY**
- In PBI, physicians should maintain an index of suspicion for the presence of vascular injury, traumatic SAH, and vasospasm. This is based upon bullet track, delayed hematoma formation and new neurological findings.
- When these are detected, therapeutic measures analogous to those used outside the setting of trauma are indicated.
- However, outcome data to judge the efficacy of these interventions are limited and do not support recommendations stronger than treatment options.

**III. ICP Monitoring**

- Early ICP monitoring is recommended when the clinician is unable to assess the neurologic examination accurately; the need to evacuate a mass lesion is unclear; or imaging studies suggest elevated intracranial pressure.
- The role of ICP monitoring and its application in PBI have been incompletely studied especially with civilian data.
- Intracranial hypertension appears to be common after PBI and, when present, is predictive of less favorable outcome.
- Unfortunately, there is little data to reveal whether or how successful management of intracranial hypertension improves outcomes in patients with PBI.
- However, some aspects of ICP management discussed in the literature on nonpenetrating TBI can be generalized and applied logically to PBI, even though all information is derived from Class III data.
- Threshold to begin institution of primary tier therapy for ICP control is 20mmHg.
IV. Surgical Management

- Treatment of small entrance wounds with local wound care and closure in patients whose scalp is not devitalized and have no “significant” intracranial pathologic findings is recommended.
- In the presence of significant mass effect, debridement of necrotic brain tissue and safely accessible bone fragments is recommended.
- Evacuation of intracranial hematomas with significant mass effect is recommended.
- Attempts should be made to operate within 12 hours of injury to prevent infection
- Unlike previous trends toward aggressive debridement; routine surgical removal of fragments lodged distant from the entry site and re-operation solely to remove retained bone or missile fragments are not recommended.
- Repair of an open-air sinus injury with watertight closure of the dura is recommended. Clinical circumstances dictate the timing of the repair.

Surgical Management- SUMMARY
- Currently, surgical management of PBI clearly tends toward minimizing the degree of debridement and watertight dural closure.
- There are no controlled studies that have examined the relative efficacy of various degrees of debridement to prevent infection and minimize the development of seizure disorders.
- Any patient with salvageable exam and MLS>5mm where MLS is greater than width of associated SDH/EDH should be considered for decompressive craniectomy.

V. Management of Cerebrospinal Fluid Leaks

- Surgical correction is recommended for CSF leaks that do not close spontaneously, or are refractory to temporary CSF diversion.
- During the primary surgery, every effort should be made to close the dura and prevent CSF leaks.
- It appears that minimal wounds could simply be locally débrided and repaired without increasing the risk of CSF leak or infection.
- Whether using one or two layers, a watertight closure of the scalp should be accomplished.

Management of CSF leaks remote from the entry site
- CSF diversion should be considered.
- Similar to the case with closed TBI, the presence of a mass effect and MLS should be eliminated prior to considering lumbar drainage over ventriculostomy.
- 10 of 26 patients with CSF leaks that persisted after surgery became infected (38%).
CSF Leaks – SUMMARY
- CSF leaks after PBI seem to be highly predictive of the development of infectious complications.
- Although it seems logical to assume that early, effective management or prevention of CSF leaks should minimize infectious complications, this has not been well documented in the literature.
- Debridement of the dural opening and watertight closure are recommended
- Autologous materials such as graft (fascia lata / pericranium) are preferred.
- It is important to stress the rapid and effective management of CSF leaks as an important early component of PBI management
- The management of CSF leaks remote from the entry site also appears important but there is no evidence to suggest that direct exploration is better than CSF diversion.
- In our experience when significant disruption of the anterior fossa and/or sinuses is present early tracheostomy should be considered
VI. Antibiotic Prophylaxis for Penetrating Brain Injury

- Use of prophylactic broad-spectrum antibiotics is recommended for patients with PBI.

**Infection Rate**
- The risk of intracranial infection among patients with PBI is high.
- The presence of air sinus wounds or cerebrospinal fluid (CSF) fistulae may further increase the risk of infection.
- The rate of infection reported in series of patients with PBI varies directly with the use of broad-spectrum antibiotics early in the management of these patients.

**Antibiotic Prophylaxis – SUMMARY**
- Although there is a paucity of evidence regarding causative agents of infection in PBI, data available suggest that a wide variety of organisms may act as agents of infection in these patients.
- This diversity supports the use of a broad-spectrum antibiotic regimen.
- The significantly lower rate of infection in later series, as compared with earlier studies during World War II and prior to World War II, supports the indication for routine prophylactic antibiotics. (Table 1.)

### Table 1 Rate of Infection with the Use of Broad-Spectrum Antibiotics

<table>
<thead>
<tr>
<th>Era and Population</th>
<th>Authors, Year</th>
<th>Drug</th>
<th>Rate of Infection (%)</th>
<th>Brain Abscess (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preantibiotic; WWI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Military</td>
<td>Whitaker, 1916</td>
<td>None</td>
<td>58.8</td>
<td></td>
</tr>
<tr>
<td>Transitional; WWII</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Military</td>
<td>Slemmon, 1945</td>
<td>Sulfa</td>
<td>21-31</td>
<td></td>
</tr>
<tr>
<td>Military</td>
<td>Slemmon, 1945</td>
<td>Penicillin</td>
<td>5.7-13</td>
<td>8.5</td>
</tr>
<tr>
<td>Antibiotics: after</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WWII</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Military</td>
<td>Aarabi, 1998; 4 1987; 10 1990; Rish et al., 1961; Taha et al., 1991</td>
<td>Broad-spectrum antibiotics</td>
<td>4-11</td>
<td>1.6-3.1</td>
</tr>
<tr>
<td>Military</td>
<td>Benzel et al., 1991; Byrnes et al., 1974; Helling et al., 1992; Hubschman et al., 1979; Lilard, 1978; Najib et al., 1986; Suddaby et al., 1987</td>
<td>Broad-spectrum antibiotics</td>
<td>1-5</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Civilian</td>
<td></td>
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</tbody>
</table>
VII. Anti-Seizure Prophylaxis for Penetrating Brain Injury

- Anti-seizure medications in the first week after PBI are recommended to prevent early posttraumatic seizures in patients with PBI.
- Prophylactic treatment with anticonvulsants beyond the first week after PBI has not been shown to prevent the development of new seizures, and is not recommended.

VIII. PROGNOSIS IN PENETRATING BRAIN INJURY

- **DEMOGRAPHIC FACTORS: AGE**
  - Increasing age correlates with increased mortality after penetrating brain injury

- **EPIDEMIOLOGY: CAUSE OF INJURY**
  - Suicide is correlated with a higher rate of mortality than other

- **EPIDEMIOLOGY: MODE OF INJURY**
- Perforating injuries correlate with a poorer outcome.
- PBIs are differentiated into the following categories:
  - **Penetrating** (a foreign object penetrates skull and dura and remains lodged within the intracranial cavity)
  - **Tangential** (a foreign object glances off the skull, often driving bone fragments into the brain)
  - **Perforating** (a ‘through-and-through’ injury, characterized by entry and exit wounds). Debris and bone fragments commonly are present within the brain in this latter type of injury.

- **EPIDEMIOLOGY: CALIBER OF WEAPON**
  - The effect of weapon caliber on outcome, independent of total kinetic energy, was not demonstrated in the published data.
  - The caliber of a missile is defined as the inner diameter of the barrel of the weapon
  - The amount of energy transmitted from a missile striking the head is dependent on its mass and velocity according to the formula: \( E = \frac{1}{2} MV^2 \).
  - Therefore, the velocity of a bullet will have a greater effect on the transmission of kinetic energy to the brain than its mass or caliber

- Hypotension is associated with increased mortality
- Coagulopathy is associated with increased mortality.
- Respiratory distress is associated with increased mortality in PBI
- Low GCS correlates with higher mortality and unfavorable outcome
- High ICP is predictive of higher mortality.
Features on CT that correlate with poorer prognosis
- Bihemispheric lesions
- Multilobar injuries
- Ventricular involvement
- Cisternal effacement

The presence of large contusions on CT scans does correlate with increased mortality.

Intracerebral hematoma appears to increase mortality, but study design flaws in the various articles prevent definitive conclusions.

Intraventricular hemorrhage is strongly correlated to increased mortality.

Subarachnoid hemorrhage in PBI is also correlated to increased mortality.