Management of Cerebrospinal Fluid Leaks

I. RECOMMENDATIONS
A. Standards
The available data are not sufficient to support a treatment Standard for management of cerebrospinal fluid (CSF) leaks in penetrating brain injury (PBI).

B. Guidelines
The available data are not sufficient to support a treatment Guideline for this topic.

C. Options
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 mater and prevent CSF leaks.

II. OVERVIEW
By definition, PBI violates the subarachnoid space and creates a potential CSF leak. In addition to leakage from entry or exit sites, a fistula may occur at a remote site because of skull fracture and a dural tear from a blowout mechanism. High-velocity missiles may create transients of extremely high intracranial pressure, which can produce fractures even in the base of the skull. The management of leaks at entry and exit sites requires surgical closure of wounds to the skin, fascia, and dura mater. Management of remote CSF leaks depends on recognition of the leak and prompt closure of the fistula either by a direct surgical approach or by CSF diversion when appropriate. The basic reason for addressing CSF leaks is the perceived correlation with infection.

III. PROCESS
A MEDLINE search from January 1966 to January 2000 using the search terms wounds, gunshot, and brain injuries or head injuries, when limited to human subjects, identified 382 articles published in peer-reviewed journals. Eighty-eight articles were rejected on the basis of clearly irrelevant titles. An additional 33 articles were then pulled from the bibliographies of reviewed articles. The primary selection process, therefore, identified 327 articles for further review. Two independent reviewers read the abstracts of all 327 and selected 65 for further inclusion. Articles were rejected on the basis of relevance to the topic (e.g., pediatric population, non-English language, case reports, irrelevance to project, atypical mechanisms of injury, and series of less than 10 subjects with no other unique reasons for inclusion). The 65 articles were then read in detail. During this process, additional articles were considered from the bibliographies of the 65 originally selected articles and rejected or added to the active list using the above algorithm. Of these 65 articles, 52 were directly relevant to the topics of surgical management, monitoring of intracranial pressure, and treatment of CSF leaks. The analysis of these articles forms the basis for these three sections. Independent reviewers found 17 articles to be appropriate for this particular section, of which 9 were analyzed in detail for this topic.

IV. SCIENTIFIC FOUNDATION
Infection is the most feared complication after PBI and is uniformly noted to be associated with increased mortality and morbidity. As such, its prevention is critical to optimizing outcome independently of management of the initial injury.

Factors considered determinants of infection include retained bone or metal fragments, time to surgery, use of antibiotics, and CSF leaks. Unfortunately, no studies have demonstrated that any of these factors are statistically significant predictors of infection independent of other factors. For instance, the presence of retained bone or metal is traditionally believed to be strongly correlated with the subsequent development of infection. Early authors uniformly stated that complete removal of such debris, including repeated surgery if necessary, was fundamental to proper management of PBI. As noted elsewhere in this document, however, studies that found a high correlation between retained fragments and infection report an extremely high degree of confounding by other risk factors for infection, such as CSF leaks, type of injury, or wound dehiscence.

Data on the association between infection and CSF leaks and retained bone, as shown in Table 1, suggest that risk factors, such as the presence of a CSF leak, are determinant of subsequent infection. The fact that 70% of infections in this series occurred around retained bone fragments suggests that the retained bone became infected secondarily because of the CSF leak.

Such data, combined with subsequent reports that note no increased incidence in infection resulting from surgical approaches that do not stress debridement of bone or metal fragments, strongly suggest that CSF leaks are the primary predictor of the development of intracranial infection. This finding is strongly supported by a recent study of 964 casualties from the Iran-Iraq War wherein retrospective, multivariate analysis of predictors of infectious complications strongly implicated CSF leaks, transventricular injury, and air sinus involvement as independent predictors of central nervous system infection.
As compared with their rather infrequent incidence in civilian PBI, CSF leaks have been reported to be unfortunately common in the military literature. The variable most highly correlated with intracranial infection in studies of infectious complications of military injuries is the presence of an acute or delayed CSF leak.\textsuperscript{1,6-10,13} In studies that included incidence data for CSF leaks in unselected populations, 49.5\% to 63\% of such patients became infected.\textsuperscript{1,10} The one published study that focused directly on CSF fistulae studied 101 patients with leaks of the 1,133 patients in the Vietnam Head Injury Study. They found that only 50\% of leaks were at the wound site, the others presumably caused by the fractures and dural rents resulting from the concussive effect of the projectile. Forty-four percent of the leaks closed spontaneously. Seventy-two percent of the leaks appeared within 2 weeks of injury. Mortality for patients with CSF leaks was 22.8\% versus 5.1\% among patients without leaks, although there was no control for confounding variables. The incidence of infection in this study was 49.5\% versus 4.6\% in the 1,032 casualties without CSF leaks.\textsuperscript{1}

### Direct CSF Leaks

If it is accepted that the necessity for radical removal of intracranial bone or metal fragments is optional, the care of the entry wound is not optional. In a study of injuries caused by \textit{.22} caliber bullets, Suddaby et al.\textsuperscript{14} limited treatment to closure of the entry wound in the emergency room for patients who had a high Glasgow Coma Scale score and no computed tomographic evidence of surgical pathology. Such an approach was not associated with an increased incidence of infection or other morbidity. Although this report does not include the details about the wound closure, it appears that wounds that are so minimal as to be amenable to such treatment could be simply cleaned up and closed without increasing the risk of CSF leak or infection. Whether using one or two layers, a watertight closure of the scalp should be accomplished.

For more complex entry wounds, local wound management requires more extensive surgical technique. Little literature is available to allow analysis of the various approaches in terms of CSF leak incidence or other outcomes. The most classic and most radical approach in the studies reviewed involved the following: extending the wound to allow vigorous debridement and closure without tension on the wound; complete excision of devitalized muscle, fascia, and periosteum; extension of the bony entry/exit site by craniectomy (simultaneously accomplishing debridement of the calvarium and exposure of the underlying dural and brain injury); and similarly generous debridement of the dural opening with watertight closure, using grafting as necessary.\textsuperscript{2-5,15} As noted in the section on surgical management of PBI, Rish et al.\textsuperscript{16} retrospectively performed a case-control study of craniectomy versus craniotomy for wartime injuries and found no obvious detriment to turning a bone flap and replacing it, as opposed to craniectomy. Unfortunately, this study was weakened because the authors were unable to control for the factors that initially led to the selection of the 63 patients for craniotomy rather than craniectomy.

The only article to directly address closure methods for CSF leaks through entry wounds concluded that autologous material is preferable as a graft, particularly fascia lata.\textsuperscript{17} Unfortunately, the authors presented no statistics or controls for confounding variables. The choice of closure material, therefore, remains at the discretion of the surgeon. The critical nature of achieving a watertight closure, however, does mandate that the necessity of grafting should be considered in any case where dural debridement interferes with secure closure without tension at the suture sites.

In the literature, the uniformly observed practices of CSF leak prevention and wound management for surgically treated patients include adequate debridement and thorough irrigation of necrotic and potentially nonviable scalp, skull, or dura prior to primary closure.\textsuperscript{1,3,5,6,9,10,13,18} The potential of blast effects from close range injury should be considered when deciding on the extent of debridement.

### CSF Leaks from Sites Remote from Entry or Exit Site

In the military situation, as many as 50\% of CSF leaks may occur at sites remote from entry or exit wounds, presumably caused by fractures and dural rents resulting from the concussive effect of the projectile.\textsuperscript{1} The management of such leaks requires identifying the presence of a leak, manifested by either rhinorrhea or otorrhea, and the necessity of closing the fistula. There is no literature to guide the precise techniques of surgical management of refractory otorrhea or rhinorrhea. The necessity of achieving closure, however, suggests that the surgical exploration and the vigor applied to closing the dural rents should not be restricted.

Meirowsky et al.\textsuperscript{1} produced the largest study of CSF leaks after PBI to date from the prospectively collected Caverness-Rish database from Vietnam. As previously noted, only 50\% of the leaks in this study were at entry or exit sites. In this series, 72\% of the leaks appeared within 2 weeks of injury, and 44\% of the leaks closed spontaneously. These authors thought that wounds associated with transventricular trajectories were most at risk of leaking, suggesting a course of CSF drainage in such cases.

There is no solid evidence on which to base the decision of how to treat CSF leaks after PBI. For leaks developing at entry or exit sites, immediate reexploration and...
watertight closure would probably be the treatment of choice, although CSF diversion might be an option in selected cases. In the case of otorrhea or rhinorrhea after PBI, a course of CSF diversion should be considered. In the absence of evidence to the contrary, treatment algorithms similar to those developed to treat otorrhea or rhinorrhea after closed TBI would be reasonable as guides to the details of such management. Similar to the case of closed TBI, the presence of mass effect should be eliminated prior to considering lumbar drainage over ventriculostomy as the diverting technique.

**Air Sinus Injuries Associated with CSF Leaks**

PBI that involves air sinuses appears to have a high risk of developing CSF leaks that are correlated with subsequent intracranial infection. In a study specifically focused on such injuries, Arendall and Meirowsky reported a 28% instance of CSF leaks. Although they did not report on the overall incidence of infection associated with such leaks, it was noted that 10 of the 26 patients with CSF leaks that persisted after surgery became infected (38%). They stressed that expeditious exenteration of the affected sinus and watertight closure of any dural rents, coupled with vigilance for missed or incompletely treated sources of CSF leaks, should optimize outcome in this group of patients.

**V. 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. Only in the case of injuries involving air sinuses does the literature report that the failure of surgical treatment to control CSF leakage is associated with an increased incidence of subsequent infection. Nevertheless, it is important to stress the rapid and effective management of CSF leaks as an important early component of PBI management.

The management of superficial wounds without computed tomographic evidence of intracranial complications of the injury can be performed via local debridement and simple closure. More complex wounds associated with CSF leaks need to be more extensively explored in order to allow watertight closure, either by direct closure of dural defects or by using grafting materials. The management of CSF leaks remote from the point of entry or exit also appears important, but there is no evidence to suggest the superiority of direct exploration and closure over temporary CSF diversion.

**VI. KEY ISSUES FOR FUTURE INVESTIGATIONS**

A major area for future investigation is the potential for prophylactic antibiotics to reduce the incidence or virulence of infection in the management of CSF leaks or air sinus injuries in PBI. The role of CSF diversion and details of its optimal timing and management in treating CSF leaks arising because of PBI is also worthy of study.

### VII. Evidentiary Table: Management of CSF Leaks

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<thead>
<tr>
<th>Authors, Year</th>
<th>Description of Study</th>
<th>Data Class</th>
<th>Conclusions</th>
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<tr>
<td>Aarabi et al., 1998&lt;sup&gt;12&lt;/sup&gt;</td>
<td>Military (n = 964). Surgical experience with casualties from the Iran-Iraq War. Retrospective study of infectious complications in 105 patients with univariate and multivariate analysis of predictors of intracranial infection in the entire group, including projectile type, injury mode, air sinus involvement, number of involved lobes, transventricular injuries, location of exploration, CSF leak, GCS score, retained bone, and retained metal.</td>
<td>III</td>
<td>Clinical infection in 105 patients, 82 meningitis, 20 abscess. Causative organisms, 45% gram-negative and 15% gram-positive. Features related to infection were mainly CSF leaks, transventricular injury, and paranasal sinus injury.</td>
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<td>Arendall and Meirowsky, 1983&lt;sup&gt;13&lt;/sup&gt;</td>
<td>Military (n = 163). Evaluation of casualties from the Korean War with air sinus injuries. CSF fistula was noted in 28% of the patients associated with high incidence of infection. The authors recommend exenteration of the sinuses and watertight repair of basal dura with graft.</td>
<td>III</td>
<td>28% instance of CSF leaks. Ten of 26 patients with CSF leaks persisting after surgery became infected (38%). Stressed that expeditious exenteration of the affected sinus and watertight closure of any dural rents, coupled with vigilance for missed or incompletely treated sources of CSF leaks, should optimize outcome in this group of patients.</td>
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<tr>
<td>Gonul et al., 1997&lt;sup&gt;10&lt;/sup&gt;</td>
<td>Military (n = 148). Evaluation of immediate and long-term surgical complications (infections, CSF leaks, retained bone fragments) and mortality in casualties with penetrating craniocerebral wounds.</td>
<td>III</td>
<td>The variable most highly correlated with intracranial infection was the presence of an acute or delayed CSF leak, which had a 63% infection rate. Stressed vigorous effort to counter CSF fistulas with tight dural closure. No need to retrieve retained bone and metal fragments.</td>
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REFERENCES


