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Executive summary of the Brain Trauma Foundation Guidelines for the Management of Penetrating Traumatic Brain Injury, Second Edition

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BACKGROUND: New literature and military conflicts inspired the second edition of the Guidelines for the Management of Penetrating Traumatic Brain Injury (pTBI). In an effort to make the evidence-based guidelines more impactful to clinical practice, expert consensus and treatment algorithms were incorporated.

METHODS: The published pTBI guidelines were reviewed, and an executive summary of the recommendations specifically relevant to trauma and critical care were created. These include resuscitation, imaging including screening for vascular injuries, critical care management (intracranial pressure, antibiotics, seizure prophylaxis, and thromboembolic prophylaxis), timing of surgery, surgical technique, management of vascular complications, and prognosis.

RESULTS: A summary of the recommendations is provided including evidence-based guidelines (3 Level II, 10 Level III, and 15 Level IV) as well as expert consensus (Level C, 57 statements). Seven treatment algorithms are presented including a futility assessment tool.

CONCLUSION: The pTBI guidelines are intended to be used to assist the clinical care of a patient with pTBI. The clinical questions are addressed with published evidence when available and supplemented with expert consensus to guide the clinician caring for a patient with pTBI from admission, including resuscitation and imaging, surgical intervention, postoperative care and monitoring, and future screening and follow-up. (*J Trauma Acute Care Surg.* 2026;100: 371–379.

In our current era of evidence-based medicine, a multitude of clinical practice guidelines are available on a wide-ranging number of topics to help clinicians better care for patients. The management of the patient with traumatic brain injury (TBI) has been at the forefront of guideline development and promulgation.[1] The Brain Trauma Foundation (BTF) has led the conceptualization, development, and promotion of a number of essential, widely used guidelines (www.braintrauma.org). Indeed, implementation of the BTF prehospital and severe TBI guidelines has been demonstrated to improve mortality from TBI by approximately 50%.[2,3] Penetrating traumatic brain injury (pTBI) is unique for its complexity and typically presents providers with a multitude of challenges including but not limited to best practices with respect to prognostication, resuscitation, imaging, surgical interventions, and complications.

The previous pTBI guidelines were developed by a group distinct from the BTF and were not well disseminated. Although the guidelines addressed several pTBI issues, they lacked detailed recommendations to guide clinicians on the management of these complex patients. A new, more aggressive surgical approach used by the military in recent conflicts and a need to develop consensus around traumatic pseudoaneurysms were key inspirations for this update. New evidence on topics such as the type and duration of antibiotics, the use of thromboembolic chemoprophylaxis, and the screening and treatment of vascular complications led our group to revisit this difficult pathology. Additionally, we wished to revisit the previous guidelines' focus on prognosticators of poor outcome, which supported a collective view of this condition as fatal or resulting in a poor functional prognosis in a majority of patients.

A significant critique of modern guidelines has also been the strict reliance on published data to provide recommendations. Where there is a paucity of data, there remains a need to provide guidance for patient management. Several groups such as the Seattle International Severe Traumatic Brain Injury Consensus Conference (SIBICC) have responded by including expert consensus as part of their guidelines.[4] The second edition of the pTBI guidelines has followed this approach for recommendations to include rigorous literature review, when available, and an extensive expert consensus process to bridge the gap when data are lacking to best inform clinicians.

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Although the full guidelines have been published elsewhere,[5] this executive summary focuses the results of the larger set of recommendations and guidelines to specific recommendations appropriate to the daily medical and surgical care of these patients of particular interest to the readership of the *Journal of Trauma and Acute Care Surgery.*

MATERIALS AND METHODS

The methodology was established by the BTF and combines a rigorous literature review with expert opinion to yield evidence-based recommendations that are applicable to the bedside clinician. The SIBICC also provided a framework for the development of these guidelines.[4] In order to further assist the implementation of these recommendations in real-world scenarios, treatment algorithms and "toolkits" for conditions commonly seen in pTBI were also developed. The detailed methodology is fully described in the second edition text (Fig. 1)[5] but will be outlined briefly here.

A steering committee formulated the key questions (KQs), and the evidence-based search strategy was constructed and performed by the Pacific Northwest Evidence-based Practice Center, which worked independently from the steering committee and expert panelists throughout the process to avoid bias. Up to three panelists reviewed search results for each question and selected relevant papers. The Evidence-based Practice Center group then extracted data, determined risk of bias, and produced level of evidence along with associated recommendations and generated summary of evidence tables (Supplemental Digital Content, Supplementary Data 1, http://links.lww.com/TA/F40). All expert panelists reviewed these prior to a 3-day in-person meeting, and only the level of recommendation and wording was discussed to determine appropriate wording and whether any recommendation be upgraded on downgraded based on clinical effect size, patient acceptability, resource implications, and balance of benefits and harm.

The pTBI Expert Workgroup is a diverse group of military and nonmilitary clinicians and investigators who represent diverse geographic, medical disciplines, and clinical experiences. This group included neurosurgery, neurology, general/trauma surgery, orthopedic surgery, and craniofacial/plastic surgery as well as prehospital care, emergency medicine, neurocritical care, pediatrics, and rehabilitation medicine. A military medic and a patient with his family were included as well for input on lived experience. Workgroup members were divided into experts in Pre-Hospital and Emergent Management, Surgical Management, and Medical Management. A Steering Committee provided oversight for the project.

Figure 1. QR code for link to full supplement[5] at www.braintrauma.org.

Search Strategies

We conducted electronic searches in Ovid MEDLINE, Embase, and Cochrane CENTRAL up to August 31, 2022, but also included studies from recent world conflicts that were published after the search dates. The systematic reviews were queried for additional references.

Inclusion and Exclusion Criteria

The inclusion criteria reviewed patients of any age with pTBI defined as "a head injury that penetrated the dura and inflicted brain injury."[5] All study designs including case series and case reports were evaluated when no other evidence was available. The outcomes included accuracy, mortality, neurological function, and morbidity and needed to be reported within 1 year of injury. Satisfaction, quality of life, sleep, or determination of brain death outcomes were not included. All abstracts and full-text articles were independently reviewed for eligibility by multiple team members.

Bias and Strength of the Body of Evidence

The risk of bias for each study was assessed based on the Agency for Healthcare Research and Quality Methods Guide, the Cochrane Back and Neck Group, and the US Preventive Services Task Force.[6] The bias risk was determined to be low, moderate, or high, and the strength of evidence was assigned by two members of the research team as high, moderate, low, very low, or insufficient, as described in the Agency for Healthcare Research and Quality Methods Guide.

Evidence-based recommendations were assigned a level based on the quality of the body of evidence, applicability, and generalizability.

- Level I recommendations are based on high quality of the body of evidence.
- Level II recommendations are based on moderate quality of the body of evidence.
- Level III recommendations are based on low quality of the body of evidence.
- Level IV recommendations are based on very low quality of the body of evidence.
- Level C: Expert opinion recommendations are based on consensus.

The expert opinion was based on blinded consensus voting via SurveyMonkey© or at the in-person investigator meeting. An 80% threshold was necessary to formally ratify a consensus recommendation.

Selection of Summary Topics

The leadership and members of the Workgroup selected topics for presentation in this summary based on their clinical

utility to practicing providers involved in the care of patients with pTBI. These included KQs relevant to prognosis, surgical interventions, vascular injuries, and common medical interventions. It is intended to be a focused examination of the most impactful guidelines.

Of the 26 KQs addressed in the full guideline,[5] 18 KQs were selected for this review, which included the following topic areas:

- Initial management
- Diagnosis/diagnostic accuracy
- Intracranial pressure
- Prophylaxis in the ICU
- Timing of surgery
- Type of debridement
- Prevention of cerebrospinal fluid (CSF) leaks
- Cranioplasty/cranial surgery
- Traumatic cerebrovascular injury

RESULTS

A total of 6,078 references from all searches were reviewed, and 1,923 full-text papers were formally evaluated. A total of 125 studies in 135 publications were included. This included 29 nonrandomized studies, 85 single arm (case series) studies, and 11 case reports. Eighty-three studies (in 84 publications) were in civilian populations, 28 studies (in 36 publications) were in military populations, and 14 studies (in 15 publications) were both civilian and military populations. Of the consensus surveys, five online SurveyMonkey surveys were conducted prior to the in-person meeting and two online SurveyMonkey surveys were conducted subsequent to the in-person meeting. The recommendations for the selected KQs are presented here. Of note, no Level I recommendations were able to be made based on the available literature. A tabular version of the recommendations is available as Supplemental Digital Content (http://links.lww.com/TA/F40).

Initial Management

Key Question: In patients with pTBI, what are the benefits and harms of prehospital and emergency department resuscitation strategies (e.g., correction of coagulopathy, cardiopulmonary resuscitation, airway maneuvers, oxygen administration, cervical spine immobilization, specific fluid administration including hypertonic saline, mannitol administration, pain management, hyperventilation, posture), including the prevention of secondary injury (e.g., cerebral edema, diffuse axonal injury)?

Recommendations:

Level II: N/A

Level III: N/A

Level IV: N/A

Level C (with % consensus):

- Practitioners should adhere to the recommendations of the Prehospital Guidelines for the Management of Traumatic Brain Injury—Third Edition[7] and the BTF Fourth Edition TBI guidelines[8] concerning prehospital and emergency room resuscitation strategies. (100%)
- Cervical collars are not required in isolated penetrating brain injury in patients without clinical or computed tomography (CT) findings of cervical spine injury. (100%)
- In patients with signs of hemorrhagic shock or massive external hemorrhage, the primary focus should be on hemorrhage control and resuscitation using whole blood or equivalent blood products. (100%)
- Massive bleeding into the oropharynx often requires a definitive airway prior to packing the oropharynx with a hemostatic dressing or gauze packing. (93.3%)

Diagnosis/Diagnostic Accuracy

Key Questions:

- In patients with pTBI, what are the benefits, harms, and diagnostic accuracy of screening with cerebral angiography to diagnose traumatic intracranial arterial aneurysm (TICA) and cerebral vasospasm?
- In patients with pTBI, when should cerebral angiography best occur and is it preferred over computed tomography angiography (CTA)?
- In patients with pTBI, what are the benefits and harms of screening for delayed vascular complications?

Recommendations:

Level II: In patients with pTBI and a high index of suspicion for cerebrovascular injuries, digital subtraction angiography (DSA) should be performed as soon as feasible to detect traumatic aneurysms, as rupture is associated with worse outcomes.

Level III:

- Following pTBI, treatment of TICA detected by screening improves the likelihood of survival.
- Computed tomography angiography has the ability to detect some TICA as compared with the criterion standard, DSA, and should be used as an initial screening modality.
- As traumatic intracranial aneurysms may develop in a delayed fashion, vascular imaging should be repeated to improve outcomes by identifying such TICAs prior to rupture. There is insufficient evidence to indicate the optimal timing for either initial or repeat vascular imaging in order to rule out cerebral vascular injury.

Level IV: N/A

Level C (with % consensus):

CTA vs. DSA:

- If there is a high clinical suspicion for vasospasm, DSA should be considered over CTA to enable urgent endovascular treatment. (92%)
- DSA should be obtained in cases where vascular injury cannot be ruled out on CTA because of streak artifact from retained metallic fragments or where in-driven bone fragments or foreign bodies are adjacent to intracerebral vasculature. (100%)

DSA should be performed in patients with CTA confirmed vascular injury. (100%)

Timing:

- For patients with pTBI, a CTA should be ordered to evaluate for vascular injury at the time of initial CT on presentation. (100%)

In patients with pTBI, repeat vascular imaging should be obtained between 7 and 21 days postinjury or prior to patient discharge from hospital. (100%)

Benefits, Harms, Accuracy:

- The following characteristics are associated with higher risk of vascular injury and should be considered when deciding about urgency and prioritization of vascular imaging (wound trajectory through or adjacent to major brain vasculature, violation of multiple dural compartments, facio-orbito-pterional entry wounds, presence of intracerebral hematoma). (100%)

Intracranial Pressure Monitoring

Key Question: In patients with pTBI, what are the benefits and harms of intracranial pressure (ICP) monitoring?

Recommendations:

Level II: N/A

Level III: Pediatric and adult severe pTBI patients should be managed using ICP monitoring to reduce mortality, although it is associated with longer duration of intensive care.

Level IV: Intracranial pressure should be maintained below 22 mm Hg in pediatric and adult severe pTBI patients to reduce mortality and improve 6-month neurological outcomes.

Level C (with % consensus):

- Cerebral perfusion pressure (CPP) should be managed as per recommendations provided in the fourth edition adult coma guidelines[6] and the third edition pediatric guidelines for nonpenetrating TBI.[9] (92%):

o"The recommended target CPP value for survival and favorable outcomes is between 60 and 70 mm Hg. Whether 60 or 70 mm Hg is the minimum optimal CPP threshold is unclear and may depend upon the patient's autoregulatory status."
o"Age-dependent thresholds should be used for pediatric patients with a minimum CPP of 40–50 mm Hg, with infants at the lower end and adolescents at the higher end."

- Intracranial pressure monitoring can facilitate the detection of an expanding intracranial mass lesion following pTBI. (100%)

Prophylaxis

Key Questions:

- In patients with pTBI, what are the benefits and harms of seizure prophylaxis, either initiated or continued, in the critical care setting?
- In patients with pTBI, what are the benefits and harms of antibiotic prophylaxis, either initiated or continued, in the critical care setting?
- In patients with pTBI, what are the benefits and harms of deep vein thrombosis prophylaxis?

Recommendations:

Level II: N/A

Level III: Prophylactic antibiotics in patients with pTBI can be considered.

Level IV: Early initiation of pharmacological venous thromboembolism (VTE) prophylaxis within 48 hours of injury may be considered in adult patients with penetrating TBI who have not suffered an increase in incident hemorrhage volume without increasing the risk of consequent intracranial hemorrhage, emergent reoperation, or death. There is, however, insufficient evidence of efficacy and insufficient evidence to make recommendations about the choice of pharmacologic agent, time to initiation, dosage, and duration for VTE prophylaxis.

Level C (with % consensus):

Seizure Prophylaxis

- Antiseizure prophylaxis is indicated for 7 days or longer in patients with pTBI to reduce the risk of posttraumatic seizures. (96.7%)

No specific anti-epileptic drug can be recommended as being superior for the prevention of early posttraumatic seizures. (100%)

Antibiotics

- It is reasonable to treat pTBI patients who have violation of the dura or who are undergoing invasive procedures with prophylactic antibiotics. (87.5%)

It is reasonable to treat patients with pTBI related to blasts, air sinus penetration, retained bone fragments, or grossly contaminated objects with prophylactic antibiotics, as these are at higher risk of infections. (95.8%)

In pTBI patients at higher risk of intracranial infections, it is reasonable to administer broad-spectrum antibiotic (95.8%) including anaerobic coverage (81.8%) for up to 5 days (91%).

In patients who are not at higher risk of intracranial infections, it is reasonable to administer antibiotic prophylaxis (87.5%) for duration of up to 3 days (100%).

When prophylactic antibiotics are administered, they should be administered as soon as possible after injury. (100%)

VTE Prophylaxis

- Mechanical VTE prophylaxis should be considered for all adult patients with pTBI. (100%)

VTE chemoprophylaxis may be considered for all adult patients with pTBI 24 to 48 hours after cranial surgery and/or stable hemorrhage on CT scan. (96.7%)

Timing of Surgery

Key Questions:

- In patients with pTBI who are neurologically stable, what are the benefits and harms of delaying surgery for better operative conditions?
- In patients with pTBI, what are the benefits and harms of urgent surgical decompression/craniectomy versus a period of observation prior to decompression?

Recommendations:

Level II: N/A

Level III: N/A

Level IV: In severely injured pTBI patients, we recommend performing a craniectomy or craniotomy early when indicated to reduce the likelihood of death or poor outcome.

Level C (with % consensus):

- Patients with pTBI who are medically salvageable with a surgical indication should undergo urgent surgery to reduce morbidity and mortality. Surgical planning should be individualized, and the availability of resources needed for safe surgery must be ensured. (100%)

- Patients with penetrating brain injury who are neurologically stable should be transferred to a facility with neurosurgical expertise as soon as feasible. (100%)

Type of Debridement

Key Question: In patients with pTBI, what are the benefits and harms of radical (brain debridement, deep fragment removal) versus conservative debridement (local irrigation and closure)?

Recommendations:

Level II: N/A

Level III: Conservative debridement involving less dissection of the brain is preferred over radical debridement, as the latter approach is not associated with superior outcomes and risks greater injury to the brain.

Level IV: N/A

Level C (with % consensus): N/A

Prevention of CSF Leaks

Key Question: In patients with pTBI, what are the benefits and harms of water-tight closure of the dura, with or without graft, to prevent CSF leak in the setting of exposure of cisterns or the ventricular system?

Recommendations:

Level II: Cerebrospinal fluid fistulae should be surgically repaired following pTBI to reduce the risk of infection and poor outcome.

Level III: N/A

Level IV: N/A

Level C (with % consensus): In the presence of a pTBI, it is recommended to prophylactically repair the violated dura directly or by application of an autograft (tensor fascia lata, pericranium, temporalis fascia) or allograft to prevent CSF leaks and prevent deep central nervous system (CNS) infections and mortality. Cerebrospinal fluid drainage can be considered as an adjunctive measure. (93.3%)

Cranioplasty/Facial Surgery

Key Question: In patients with pTBI, what are the benefits and harms of early versus delayed cranioplasty?

Recommendations:

Level II: N/A

Level III: N/A

Level IV: Cranioplasty, irrespective of its timing, is indicated in order to optimize outcome following pTBI.

Level C (with % consensus): Cranioplasty can be performed as soon as medically and surgically feasible. (88.5%)

Traumatic Cerebrovascular Injury

Key Questions:

- In patients with pTBI, what are the benefits and harms of endovascular coil occlusion to reduce risk of rupture, in the setting of a traumatic aneurysm?
- In patients with pTBI, what are the benefits and harms of surgical or endovascular management of venous sinus injuries to prevent venous infarction?
- In patients with pTBI, what are the benefits and harms of surgery to reduce risk of rupture, in the setting of a traumatic aneurysm?

Recommendations:

Level II: N/A

Level III: N/A

Level IV:

- Endovascular treatment of TICA, which often require retreatment, is recommended as a means of reducing the risk of aneurysmal rupture and the associated high rate of morbidity and mortality. There is, however, insufficient evidence to support superiority of endovascular aneurysm occlusion over open surgical parent vessel sacrifice despite a theoretical reduced risk of iatrogenic stroke.
- Open surgery may be considered in the setting of TICA resulting from pTBI to reduce chance of rupture and improve outcome.
- Sinus injuries should be repaired by open surgery when exsanguination or death from herniation would be more likely to occur in the absence of intervention to improve survivability.

Level C (with % consensus):

- A multidisciplinary approach to vascular sequelae of pTBI (TICA, A-V fistula, vasospasm, etc.) for patients with traumatic vascular injury(ies) is preferred when feasible. (100%)
- It is recommended that TICAs, which increase in size, be treated with either open or endovascular means because of a presumed elevated risk for rupture. (87.5%)

It is recommended that larger TICAs should be more strongly considered for treatment because of a presumed elevated risk for rupture. There is insufficient evidence or expert consensus to recommend a size threshold, however. (80.5%)

- It is recommended that TICAs treated endovascularly should be reassessed with cerebral angiography within 8 weeks of initial treatment because of a risk of treatment failure (i.e., aneurysm recurrence or regrowth) for which further therapeutic procedures may be necessary. (95%)
- In certain circumstances, it may be permissible for TICAs to undergo a short period of conservative management in hopes of achieving spontaneous regression. Close observation is required if such an approach is attempted. Reasons for observation may include the lack of available neuroendovascular expertise or a perceived unfavorable risk-benefit ratio inherent to treatment. (95%)

Prognosis

Following extensive debate, a toolkit for futility was created (Fig. 2) and achieved 100% consensus from panelists. The purpose of the Futility Assessment Toolkit is to encourage initial, time-sensitive, neurosurgical, and other clinical decision making in patients with pTBI to be aggressive, excluding those circumstances where intervention is considered medically futile.

Key differences between the first[4] and second edition to the guidelines are highlighted in Table 1.

DISCUSSION

Penetrating TBI is a complex condition that requires sophisticated management decisions at all stages of the patient's care. To assist in this process, under the leadership of the BTF, the pTBI Expert Workgroup has published guidelines answering the most challenging questions in the care pathway. Frequently,

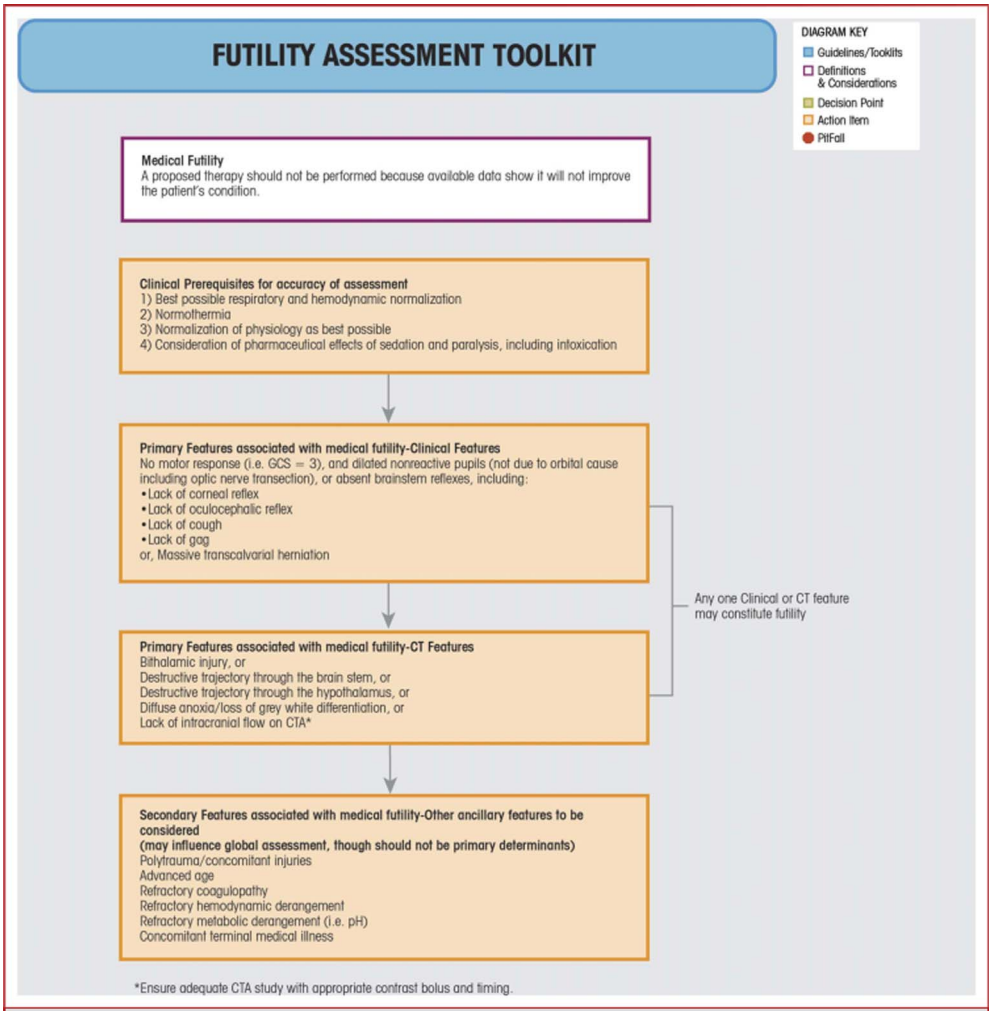

Figure 2. Futility Assessment Toolkit: clinical and radiographic indicators of futility.

guidelines suffer from too little data to support the stated recommendations or rely so heavily on evidence-based medicine that the practical aspects of care are neglected. To address these pitfalls, the current second edition of the pTBI guidelines incorporates data-driven recommendations and expert consensus. Members of the Workgroup have further focused the guidelines on those immediately relevant to the traumatologist at the bedside in this executive summary.

To further emphasize the practical nature of these guidelines, we have chosen to summarize the care pathway of a typical pTBI patient. When any suspected pTBI patient is encountered at the scene or in the emergency department, the initial resuscitation should involve the recommendations from the Prehospital Guidelines for the Management of Traumatic Brain Injury[7] and the BTF Severe TBI Guidelines.[8] Excessive bleeding or hypovolemic shock should be managed with local hemostatic measures and transfusions of whole blood or balanced blood products prior to imaging. If a facial trajectory compromises the airway, then definitive surgical airway may be needed prior to packing of the wounds as well. Cervical collars should be avoided in these patients, as this may worsen outcome, and the incidence of unstable cervical spine injuries concomitant with pTBI is incredibly low in the absence of additional injury mechanisms.

Following resuscitation, imaging including CT, CTA, and computed tomography venogram are appropriate. In the presence of a post resuscitative examination and imaging, an initial understanding of prognosis is needed to guide therapies. We emphasize that aggressive treatment of pTBI is appropriate in many cases, and overly nihilistic approaches should be avoided. However, certain imaging findings have a high correlation with mortality and thus futile care including:

- trajectories through the brainstem
- bilateral thalami
- bilateral hypothalami (zona fatalis)
- diffuse loss of gray-white differentiation
- lack of intracranial flow noted on CTA

From the clinical standpoint, the following features are considered poor prognostic signs:

- no motor response after resuscitation and without any sedation

TABLE 1. Key Differences Between the First and Second Edition of the pTBI Guidelines

	Key Differences Between the First and Second Editions
Initial management	• The previous version of these guidelines did not address the benefits or harms of resuscitation strategies or the impact on the prevention of secondary injury in pTBI patients. • 2nd Edition of these guidelines refers the reader to the 3rd Edition of the Prehospital Guidelines for the Management of Traumatic Brain Injury[7] and the BTF 4th Edition TBI guidelines,[8] which had not been published prior to the 1st Edition of the pTBI guidelines.
Diagnosis/diagnostic accuracy	• The prior penetrating head injury guidelines addressed "Neuroimaging in the Management of Penetrating Brain Injury" and "Vascular Complications of Penetrating Brain Injury." • In the prior edition, only two articles included addressed the utility of DSA. The routine performance of CTA was not addressed. The guidelines supported the use of DSA when vascular injury is suspected. It also highlighted high-risk wound trajectories. • The 2nd Edition describes the utility of CTA as a screening modality but does not recommend replacing DSA. • The 2nd Edition also focuses on the importance of repeat imaging to detect the delayed development of TICA.
ICP monitoring	• The prior guidelines made a level III/IV recommendation for early monitoring if a clinician is unable to assess the neurological status. No studies were available at that time to make recommendations based on studies in patients with pTBI. • The 2nd Edition makes clear recommendations for use of ICP monitoring based on low-level evidence. • Similar to the previous edition, the current guideline extrapolates the recommendations in blunt TBI[8] to the pTBI patient population.
Prophylaxis	Seizure prophylaxis • The prior edition of the guidelines made clear recommendations about seizure prophylaxis. These recommendations were derived from studies in blunt TBI. • The prior guideline made a Level IIA recommendation for the use of phenytoin based on available literature. • The current edition made only Level C Expert Consensus recommendations because of a paucity of literature in the pTBI patient population and makes no specific recommendation for choice of anti-epileptic medication. Antibiotics • The prior edition made a Level III/IV recommendation for the use of prophylactic broad-spectrum antibiotics for patients with pTBI. • The available literature for the 2nd Edition recommendations was not of high enough quality to make a firm recommendation above suggesting at a Level II that prophylactic antibiotics "can be considered." • The current edition, however, makes several statements at the level of expert opinion about high-risk patients, timing of initiation, and duration of therapy in lower risk patients. VTE prophylaxis • The prior edition of the pTBI guidelines did not report on VTE prophylaxis. • The current edition highlights the importance of early initiation of VTE prophylaxis.
Timing of surgery	• The 1st Edition recommended, as an option, surgery "as soon as the indications…are recognized." Limited data were available at that time. • The current edition recommends early surgery based on six studies as a Level IV recommendation. • Expert consensus from the current guideline suggests that urgent surgery is preferable in medically salvageable patient and that expeditious referral to neurosurgical expertise be made.
Type of debridement	• The 1st Edition of these guidelines addressed the question of extent of debridement in detail. Limited conclusions were able to be drawn because of the available data quality. The authors did recommend against aggressive removal of bone and foreign bodies because of the increased risk of complications. • The current guidelines similarly favor conservative debridement as a Level III recommendation.
Prevention of CSF leaks	• Surgical correction was recommended for CSF leaks in the previous edition of these guidelines. • Additional data available for the 2nd Edition allowed for a moderate strength Level II recommendation about surgical repair of CSF leaks.
Cranioplasty/facial surgery	• The prior edition of the pTBI guidelines did not provide a recommendation on timing of cranioplasty. • The current edition supports a Level IV recommendation to perform cranioplasty, but no data support an evidence-based recommendation on timing. • The 2nd Edition Expert Consensus recommendation is for cranioplasty to be performed as soon as "feasible."
Traumatic cerebrovascular injury	• The prior pTBI guidelines addressed "Vascular Complications of Penetrating Brain Injury" directly. No Level I or Level II recommendations on this subject were provided in the prior edition, but Level III/IV recommendations stated that surgical or endovascular management of TICAs or AVF was recommended. • In the current edition, it was acknowledged that significant advances have been made in endovascular management of aneurysms since the 1st Edition. Level IV recommendations about endovascular versus open approaches are presented with endovascular approaches being considered a viable option for treatment of TICA. • Several additional Expert Consensus recommendations are made in the current guideline to help guide decision making about which vascular lesions may benefit from intervention.
Prognosis	• The previous version of the guidelines did not investigate specific instruments and models to predict outcomes. However, an extensive section of the 1st Edition of these guidelines described multiple variables (i.e., age, intentionality, anatomic wounding trajectory, hypotension, coagulopathy, respiratory distress, low GCS score, presence of fixed dilated pupils, elevated ICP, and anatomical features of injury on CT) found to correlate with mortality and/or poor functional outcome. • The 2nd Edition of these guidelines performed a comprehensive review of available prediction tools and instruments. Several were noted to perform accurately, but it was noted that all are imperfect, especially when predictions for a single patient are considered. • As it was the considered and universal opinion of the authors of the 2nd Edition that decision making based on risk of death, informed by retrospective studies contaminated by nihilistic care that do not inform natural history, was potentially detrimental. • It was subsequently concluded, with the support of a formal consensus vote, that initial decisions concerning intervention or nonintervention should be made based on medical futility of any proposed intervention. • Therefore, the authors created the Futility Assessment Toolkit: clinical and radiographic indicators of futility (Fig. 2).

AVF, arteriovenous fistula; GCS, Glasgow Coma Scale.

- bilateral dilated and nonreactive pupils (nonpharmacologic, not associated with orbital injury)
- absent brainstem reflexes
- massive transcalvarial brain herniation.

If these are not present, then aggressive interventions are appropriate and should be undertaken.

While the workup and resuscitation are being performed, several medical therapies should be initiated. Antiepileptic drugs (AEDs) and broad-spectrum antibiotics should be considered immediately. No specific AED can be recommended as being the most effective for the prevention of early posttraumatic seizures. Broad spectrum antibiotics should be continued for 3 days in low-risk patients and 5 days for high-risk patients, such as those with grossly contaminated wounds, trajectory through air sinuses, and prolonged delay to definitive care. Mechanical VTE prophylaxis should begin immediately as well.

After imaging, virtually all pTBI patients require some form of surgical or procedural intervention. In patients with fatal injuries or with focal lesions, closure of the open wounds and wrapping of the head are needed to avoid continued transcalvarial herniation. In surgical patients, the panelists recommend performing a craniectomy or craniotomy early when indicated to reduce the likelihood of death or poor outcome or the immediate transfer to facilities with this capability. In the presence of TICA on the CTA, a diagnostic angiogram and treatment may be appropriate prior to open surgical intervention.

At the time of surgery, conservative debridement involving less dissection of the brain is preferred over radical debridement, and all potential CSF fistulas should be surgically repaired to reduce the risk of infection and poor outcome. Other forms of CSF diversion including ventriculostomy catheters and lumbar drains may be used to supplement the surgical repair. Finally, an ICP should be placed in all severe TBI patients with concern for cerebral edema.

After initial resuscitation, imaging, and surgical intervention, complication and secondary injury avoidance are the mainstays of treatment. The patients are admitted to an ICU setting with ICP management consistent with the BTF guidelines including maintaining ICP below 22 mm Hg and CPP values between 60 and 70 mm Hg in adults. Age-dependent thresholds should be used for pediatric patients. The decision to remove the monitor should be based on the patient's examination, imaging, and clinical course. The SIBICC guidelines may also provide assistance in this management.[4] Antibiotics are continued for 3 to 5 days, AEDs are continued for 7 days in the absence of seizures, and pharmacological VTE prophylaxis within 48 hours of injury may be considered. Monitoring for CSF leakage and wound related complications is also essential for the care of these patients.

Vascular complications are a relatively unique consideration in pTBI. The initial CTA is appropriate for screening immediately after injury, but in patients with pTBI and a high index of suspicion for cerebrovascular injuries, DSA should be performed as soon as feasible. These high-risk factors include patients with pseudoaneurysm on CTA, streak artifact from the bone fragments and foreign bodies, and certain anatomic features, including wound trajectory through or adjacent to major brain vasculature, violation of multiple dural compartments, facio-orbito-pterional entry wounds, and presence of intracerebral hematoma.

A traumatic pseudoaneurysm is a defect in the wall of a cerebral vessel, which is protected only by clot. Rupture of a traumatic pseudoaneurysm carries a high mortality rate, and these lesions often develop in delayed fashion after a pTBI. In the presence of a pseudoaneurysm, endovascular treatment, which often requires retreatment, is recommended as a means of reducing the risk of aneurysmal rupture and the associated high rate of morbidity and mortality. This is particularly true of large or expanding aneurysms. Observation is discouraged but is an option for select small lesions in eloquent areas, but frequent monitoring is needed if initial conservative management is pursued. In the absence of pseudoaneurym/TICA, it is recommended to repeat vascular imaging between 7 and 21 days postinjury or prior to discharge from the hospital to detect those which develop in a delayed fashion. Traumatic intracranial arterial aneurysms treated endovascularly should be reassessed with cerebral angiography within 8 weeks of initial treatment because of a risk of treatment failure. Vasospasm is a risk for pTBI patients and therefore should be monitored and treated as consistent with institutional protocols as well.

Following the acute period, provision of acute rehabilitation is appropriate. However, cranioplasty can be performed as soon as medically and surgically feasible. The outpatient follow-up may be done as consistent with other patients with TBI with special consideration for future screening of vascular complications as previously outlined.

CONCLUSION

The complex nature of pTBI requires a multidisciplinary team and complex care pathways. The pTBI Guidelines, Second Edition, seeks to provide expert and data driven recommendations to allow for the best outcome for this challenging disease. The reader of this executive summary is referred to the full second edition guidelines for the complete recommendations, evidentiary summaries and rationales, and discussion.[5]

AUTHORSHIP

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DISCLOSURE

Conflicts of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/F39).

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