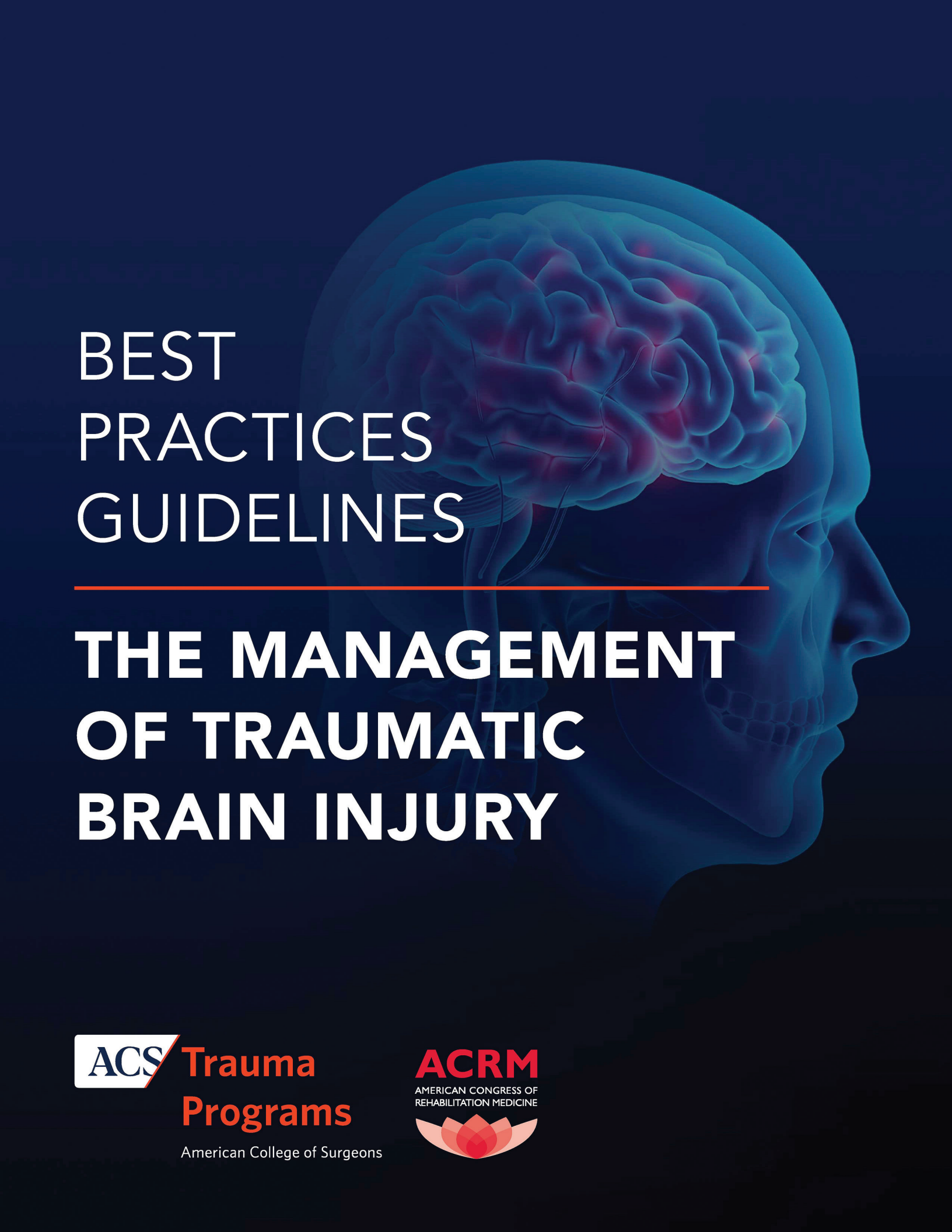

BEST PRACTICES GUIDELINES

THE MANAGEMENT OF TRAUMATIC BRAIN INJURY

ACS Trauma Programs
American College of Surgeons

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BASIC ASSESSMENT

KEY POINTS

- The GCS provides for the reliable assessment of level of consciousness. It requires a standardized assessment and reporting approach to assure reliability, accurate patient status communication between healthcare providers, and recording of changes over time.
- Assess and report each of the three GCS components (eye, verbal, and motor) for individual patients. Use GCS sum scores (e.g., 3–15) for patient group-level comparisons and injury classification.
- The pupillary light response provides diagnostic and prognostic information in patients with TBI.
- Quantitative pupillometry is a useful tool that provides more reliable and reproducible measurements than standard clinical assessment of pupillary reactivity.

Pupillary Reactivity and Pupillometry

The pupillary light response is an important element of the neurologic exam because it provides useful diagnostic and prognostic information. Some degree of pupillary asymmetry may be normal, but the development of new pupillary asymmetry can indicate compression of the brainstem with impending uncal herniation, triggering the need for further evaluation and intervention. In uncal herniation, the parasympathetic fibers on the surface of the third cranial nerve are compressed, leading to a slowly reactive—or eventually unreactive—pupil. A unilateral unreactive pupil is consistent with an ipsilateral mass lesion, while bilaterally fixed and dilated pupils portend a poor overall prognosis for functional recovery.

Older Adults: In older adults, evaluation of the pupillary response may be confounded by preexisting chronic ophthalmic diseases (e.g., glaucoma or cataract disease). Quantitative pupillometry may be of limited value in patients with postsurgical pupils (i.e., after cataract surgery), however, this does not influence pupillary light reflex parameters measured by automated pupillometry.[9,10] In these patients, a medical history is essential to correctly interpret physical examination findings such as an abnormal pupillary light reflex, anisocoria, or oculomotor palsy.

Quantitative Pupillometry: Both the inter-rater and intra-rater reliability of the standard clinical determination of pupillary size and reactivity are relatively poor. Quantitative pupillometers provide increased reliability and consistency of pupillary measurements.[11–13] The quantitative pupillometer is a small handheld device that uses both visible and infrared light to measure a pupil, capture its response to a light stimulus, and quantify the pupil's characteristics. It has six items measured (see Box 1). In pediatric patients, however, developmental changes in myelination during infancy can alter the normal latency observed, potentially limiting the application of a priori thresholds.[14,15]

Box 1. Output from Quantitative Pupillometer

- Starting diameter (mm)
- Ending diameter (mm)
- % Change
- Latency (s)
- Average constriction velocity (mm/s)
- Average dilation velocity (mm/s)

Clinical experience shows that quantitative pupillometry can facilitate a more accurate clinical assessment by providing an objective and reliable assessment of pupillary reactivity. Pupillary changes may be detected before a provider's clinical assessment of pupillary size and reactivity, thus providing an early warning sign. Quantitative pupillometry can assess reactivity even when opioids and other drugs result in small pupils, which make clinical assessment difficult. Moreover, the pupillometry output can be directly entered into the patient's electronic medical record.

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NEUROMONITORING

KEY POINTS

- Serial clinical assessment of neurological status in regular intervals provides the foundation of neuromonitoring in TBI patients.
- Neuromonitoring, beyond monitoring of ICP in isolation, can help establish individualized patient care goals and therapy.
- Assessment of cerebral autoregulation can help establish CPP goals in individual patients. Consider performing neuromonitoring in patients who do not respond to initial (Tier One) therapies to decrease ICP.
- Impaired cerebral oxygenation can occur with both normal or increased ICP. Consider treatment of brain tissue hypoxia based on the underlying pathophysiology and a tiered approach of escalating therapies.
- Continuous electroencephalography (EEG) assists in seizure detection and management, especially for nonconvulsive seizures.

Repeated clinical assessment of neurological status provides the foundation of neuromonitoring in TBI. It can be supplemented by noninvasive methods, such as the use of quantitative pupillometry at set intervals to quantify the pupillary light reflex (see the Basic Assessment section on page 10). While ICP monitoring is most commonly used to supplement clinical assessment, other techniques can supplement clinical assessment as well (see Intracranial Pressure Monitoring on page 22).

TBI is a complex disease with substantial heterogeneity. ICP monitoring alone cannot detect all potential insults to the brain, nor does it allow for patient-specific individualized care based on factors such as the presence or absence of autoregulation. Cerebral pressure autoregulation is the brain's intrinsic ability to maintain constant CBF over a range of systemic blood pressures. This mechanism protects the brain from cerebral ischemia due to hypotension and from excessive blood flow that can lead to elevated ICP. The SIBICC algorithm recommends assessment of autoregulation status in patients who do not respond to initial therapy to reduce elevated ICP (see Tier One in Box 3 on page 26).[1]

Assessment of Cerebral Autoregulation

Mean arterial pressure challenge: Cerebral autoregulation can be assessed at the bedside in the ICU by performing a MAP challenge while monitoring ICP in the closed cranium. This challenge is performed by initiating or increasing a vasopressor infusion in euvolemic patients to increase the MAP by 10–15 mm Hg for no more than 20 minutes. Perform a MAP challenge under the direct supervision of a bedside provider experienced in performing the challenge so that patient response and safety are assured. Perform no other therapeutic adjustments during the MAP challenge.

Record key physiological parameters (MAP, ICP, CPP, $PbtO_2$) before and after the MAP challenge. Patients with a closed cranium in whom ICP increases with a MAP challenge are considered to have impaired autoregulation, and they may benefit from a lower CPP goal. Conversely, patients with a closed cranium in whom ICP decreases or does not change significantly with a MAP challenge are considered to have intact autoregulation, and these patients—particularly those with decreasing ICP in response to the MAP challenge—may benefit from a higher CPP goal.

Cerebrovascular pressure reactivity index: Another ICP-based method used to continuously assess cerebral autoregulation status is to follow the cerebrovascular pressure reactivity index (PRx). The PRx is defined as the slope of the regression line relating MAP and ICP, and it can be used to establish patient-specific CPP thresholds. For patients with impaired cerebral autoregulation (PRx slope > 0.13), a lower CPP (50–60 mm Hg) may be considered as an option for treatment. Patients with intact autoregulation (PRx slope < 0.13) may benefit from a higher CPP (60–70 mm Hg). Of note, assessment of the PRx requires specialized technical expertise and additional hardware and software, which are commercially available.

Brain tissue oxygen tension: Autoregulation status may also be assessed by following $PbtO_2$, as long as systemic oxygenation (PaO_2) is maintained at a constant level. Verify this by checking the arterial blood gas before and after the MAP challenge.

Table 10. Traumatic Brain Injury Management PI Recommendations

Performance Improvement Recommendations	Outcome Measure and Threshold
Documented facility guidelines for neurosurgical urgent evaluation	Neurosurgical evaluation must occur within 30 minutes of request for the following injuries[1]: • Severe TBI (GCS < 9) with head CT evidence of intracranial trauma • Moderate TBI (GCS 9–12) with head CT evidence of potential intracranial mass • Neurologic deficit due to potential spinal cord injury
Consider prehospital transport of patients meeting listed criteria to the most appropriate trauma center with neurosurgical capability[2]	• GCS motor score < 6 • Skull deformity or suspected skull fracture • Signs of basilar skull fracture • Penetrating head injury • Caregiver-reported change from baseline behavior in an infant/child following injury
Consider transferring patients meeting listed criteria to a trauma center with neurotrauma expertise, where available (see Triage and Transport section on page 6)	• Significant intracranial injury (e.g., large SDH, EDH, IPH, IVH) • Displaced skull fracture • Suspected TBI (GCS score ≤ 15) **and** moderate to severe extracranial anatomic injuries, **and/or** inability to monitor for neurological deterioration when intracranial injury is present or suspected
Neurotrauma contingency plan is in place	Must be implemented when neurosurgery capabilities are encumbered or overwhelmed
Monitoring of neurotrauma diversion is reported at least quarterly as part of the PIPS program, if neurotrauma diversion occurs	Diversion initiation (date/time) and discontinuation (date/time) are monitored and reported quarterly as part of the PIPS program
Use of GCS individual components (eye, verbal, and motor scores) as the preferred method of measuring neurological status in TBI patients	Use of individual components of GCS in the prehospital and hospital settings, with frequent serial assessments and notation of changes
Documentation of individual GCS score components (eye, verbal, and motor scores) in the patient care report	All GCS individual components are documented
Pupil assessment documentation	• Clinical assessment is required • Consider use of quantitative pupillometry • Assessments repeated frequently and documented
Hemodynamics assessment documentation	• Age-specific measurement of hemodynamic status (blood pressure management) following acute TBI is required • Assessments repeated frequently and documented
Ongoing standardized neurological assessment and documentation	• Standardized neurological assessment and documentation • Assessments are repeated frequently and documented
Repeat imaging	• Urgent repeat head CT scanning is indicated for a patient of any age with worsening changes on neurologic exam • Repeat head CT is indicated in 6–12 hours after initial imaging when a patient of any age has a persistently altered mental status and initial CT showed traumatic abnormality
Appropriate timeliness and coordination of monitoring during imaging	Per individual facility
Consideration of blood-based biomarker testing for patients to reduce unnecessary CT imaging	Applies to patients ≥ 18 years of age with suspected TBI and a GCS of 13–15 within 12 hours of injury