Reducing intracranial pressure in patients with traumatic brain injury

Learn how to identify rising intracranial pressure early to promote appropriate interventions.

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TRAUMATIC BRAIN INJURY (TBI) refers to blunt or penetrating head injury that disrupts normal brain functioning, causing impaired thinking and memory, personality changes, and possible sensory and motor changes. Some people recover completely with no cognitive deficits; others remain in a persistent vegetative state.

TBI occurs in all age groups, and its incidence is increasing. It contributes to about 50% of all injury-related deaths and accounts for about 2.5 million emergency department (ED) visits annually. Although most TBIs cause only mild effects, roughly 290,000 patients are hospitalized for TBI annually; of those, about 51,000 die. However, over the past 3 decades, the overall mortality rate has declined from nearly 50% to approximately 25%.

TBI commonly leads to elevated intracranial pressure (ICP), which can have catastrophic consequences. ICP reflects the pressure of the cranial contents—cerebrospinal fluid (CSF), brain tissue, and blood. The cranial vault is a fixed structure, so it can’t enlarge when its contents expand. The sum of the volumes of brain tissue, CSF, and intracranial blood is constant; if one increases, one or both of the other two must decrease. Space-occupying conditions like tumors, infection, and edema compromise brain tissue when they expand, causing brain structures to alter shape, which can obstruct flow of CSF and blood.

CAUSES OF INCREASED ICP

All nurses need to be able to identify the factors that can increase ICP, which include:

- increased neuronal oxygen consumption from pain, anxiety, agitation, fever, and shivering (which increase metabolic demand)
- environmental light and sound
- bathing
- repositioning in bed
- seizures. Patients should receive seizure prophylaxis within the first week after TBI; however, early posttraumatic seizures aren’t associated with worse outcomes.

ICP MONITORING

We now know that not all the neurologic damage from TBI occurs at the time of injury. Some continues over several hours to days, so early recognition and treatment are crucial for optimizing patient outcome. Continuous ICP monitoring allows early identification of increased ICP. Not only does it reveal how the patient responds to routine activities, such as turning, bathing, and suctioning; it also promotes early interventions to treat rising ICP before it climbs dangerously high. The consensus recommendation is to treat ICP above 20 mm Hg. Pupillary changes can occur at ICP as low as 18 mm Hg; herniation, at ICP as low as 20 to 25 mm Hg. (See Assessment tools for patients with neurologic injuries.)

The Brain Trauma Foundation recommends ICP monitoring for all TBI patients who:

\* are capable of recovering

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Assessment tools for patients with neurologic injuries

Emergency medical responders in the field and clinicians in emergency departments and neurologic intensive care units use the Glasgow Coma Scale (GCS) to gauge the severity of neurologic injury. The patient’s score is based on the best eye opening, verbal, and motor responses. Ranging from 3 (deep coma) to 15 (fully awake), it’s obtained by totaling the best responses in all categories. GCS scores of 8 or lower indicate severe TBI; 9 to 12, moderate TBI; and 13 to 15, mild TBI. (Note: In the chart below, “NT” denotes “not testable.”)

<table>
<thead>
<tr>
<th>Score</th>
<th>Eye opening</th>
<th>Verbal response</th>
<th>Motor response</th>
</tr>
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<tbody>
<tr>
<td>NT</td>
<td>NT</td>
<td>NT</td>
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</tr>
<tr>
<td>1</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>To pressure</td>
<td>Sounds</td>
<td>Extension</td>
</tr>
<tr>
<td>3</td>
<td>To sound</td>
<td>Words</td>
<td>Abnormal flexion</td>
</tr>
<tr>
<td>4</td>
<td>Spontaneous</td>
<td>Confused</td>
<td>Normal flexion</td>
</tr>
<tr>
<td>5</td>
<td>NA</td>
<td>Oriented</td>
<td>Localizing</td>
</tr>
<tr>
<td>6</td>
<td>NA</td>
<td>NA</td>
<td>Obey commands</td>
</tr>
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</table>

**Rancho Los Amigos Scale**

The Ranchos Los Amigos Scale (also called the Rancho Los Amigos Level of Cognitive Functioning Scale) is used to monitor the patient’s readiness for rehabilitation after emerging from a coma following severe TBI. Levels range from 1 (coma) to 8 (oriented and appropriate). Levels 2 and 3 reflect emergence from coma; levels 4 to 6, confusion with nonpurposeful to purposeful behaviors. Patients usually enter rehabilitation at level 4. Levels 7 and 8 show continued improvement and insight approaching the patient’s pre-injury level of functioning.

- have Glasgow Coma Scale (GCS) scores of 3 to 8
- have abnormal head computed tomography (CT) scans.

ICP monitoring also is recommended for all severe TBI patients with normal head CT scans who are older than age 40 and show motor posturing (decorticate, decerebrate, or both) and systolic blood pressure below 90 mm Hg. In conjunction with mean arterial blood pressure (MAP) monitoring, ICP monitoring is used to calculate cerebral perfusion pressure (CPP), an indirect measure of cerebral perfusion. (See Calculating cerebral perfusion pressure.)

**Methods for reducing ICP**

ICP should be reduced in a stepwise fashion, starting with noninvasive and conservative measures and progressing to other measures as needed. Some interventions may occur simultaneously, depending on the patient’s specific needs and severity of increased ICP.

**First steps: Noninvasive and conservative measures**

- Elevate the head of the patient’s bed 30 to 45 degrees and ensure venous outflow isn’t obstructed from a kinked neck, constricting tape, or cervical collar.
- Take steps to prevent shivering, which increases ICP.
- Avoid hyperthermia, which can increase metabolic demand as much as 10% per degree C. (Fever is a marker of poor outcome in TBI patients.) Be aware that vasodilation from fever increases CPP, which in turn raises ICP. Increased air circulation blankets, cooling catheters, and antipyretics can be used to decrease fever.
- Take measures to optimize the patient’s blood pressure, avoiding both hypotension and hypertension.
- Know that aggressive fluid resuscitation to drive CPP above 70 mm Hg puts patients at risk for acute respiratory distress syndrome. To avoid hypoxia, strive for an oxygen saturation above 90% or a partial pressure of arterial O2 (Pa O2) above 60 mm Hg.
- Catecholamine stress response in TBI patients can lead to hyperglycemia, which typically warrants supplemental insulin. Untreated hyperglycemia (blood glucose level above 200 mg/dL) is associated with worse neurologic outcomes. Prolonged hypoglycemia also is dangerous because it can reduce the brain’s glucose supply, leading to neurologic deterioration. Experts recommend starting blood glucose monitoring at admission and striving for normoglycemic status. The American College of Neurological Surgeons and the American Association of Neurological Surgeons recommend a target blood glucose level of 80 to 150 mg/dL. (See Blood glucose monitoring.)
Calculating cerebral perfusion pressure

In patients with traumatic brain injury, cerebral perfusion pressure (CPP) is an important parameter because reduced CPP increases cerebral hypoxia risk. Optimal CPP ranges from 50 to 70 mm Hg. CPP below 50 mm Hg is linked to a poor patient outcome. CPP is calculated using this equation:

\[ \text{CPP} = \frac{\text{mean arterial pressure (MAP)}}{\text{intracranial pressure (ICP)}} \]

Surgeons recommends a blood glucose range between 80 and 180 mg/dL. However, optimal hyperglycemia treatment in severe TBI remains controversial.

**Second steps: Pharmacologic interventions**

If the patient's increased ICP doesn't respond to first steps, pharmacologic interventions are added.

- To optimize blood pressure and improve cerebral perfusion, the patient may require vasopressors and I.V. fluid boluses to keep systolic pressure above 90 mm Hg. Stay alert for side effects; depending on the agent used to support blood pressure, the patient may experience tachycardia, peripheral vasoconstriction, arrhythmias, platelet inhibition, hyperglycemia, thrombocytopenia, and increased myocardial dysfunction.

- After TBI, patients may have a stress response marked by hypertension, which may warrant antihypertensive agents. Clinicians should choose agents with the least possible impact on ICP. Be aware that such antihypertensives as nitroglycerin, nitroprusside, and nicardipine can cause side effects that increase ICP—namely, orthostatic hypotension, dizziness, nausea, vomiting, headache, reflex tachycardia, preferential peripheral vasodilation before cerebral vasodilation, thiocyanate toxicity, and platelet dysfunction.

- As needed and ordered, provide interventions for pain, anxiety, and seizures.

- To monitor for nonconvulsive seizures, the physician may consider continuous electroencephalography if ICP rises inappropriately. If ICP remains elevated after antiseizure measures, the patient may require some of the interventions described next.

**Third steps: Continuous sedation**

If elevated ICP persists despite conservative and pharmacologic measures, continuous sedation may be tried; this technique may reduce ICP by eliminating agitation and pain.

- Opioids or benzodiazepines may be used for sedation; agitated patients also may receive hypnotic or paralytic agents. These drugs may be given individually or in combination. To minimize hypotensive side effects, ensure the patient has normal fluid volume and use smaller doses of opioids, benzodiazepines, or hypnotics, as ordered.

- Paralytics may be given if posturing and agitation increase ICP. Know that if the patient is paralyzed and sedated, a neurologic exam may be difficult or impossible to conduct; you won't be able to assess mental status, sensation, or movement or obtain a GCS score. Instead, monitor pupillary response and ICP for changes.

- Serial head CT scans may reveal evolving or resolving abnormalities, such as bleeding or swelling.

- The EVD may be used to drain off 3 to 5 mL of CSF.

**Fourth steps: Barbiturates, osmotics, hyperventilation, therapeutic hypothermia, and surgery**

Patients with refractory ICP elevation may require the additional interventions below.

- **Barbiturates.** These drugs reduce cerebral metabolic demand and blood flow, providing cerebral protection. The most commonly used barbiturate is pentobarbital. If ICP doesn't decrease within the first 4 hours after this drug is given, it's unlikely to lower ICP unless given in combination with other drugs. Know that patients on barbiturates won't have a pupillary response, so you'll need to rely on ICP monitoring for evidence of brain herniation. Keep in mind that early changes in pupillary response may indicate early herniation.

- **Osmotics.** For patients with persistently elevated ICP, osmotic therapy may be used to expand blood volume by shifting fluid from the brain's extracellular to intravascular spaces. Osmotics also reduce blood viscosity, which raises CPP and lowers ICP. (See Understanding osmotic therapy.)

- **Hyperventilation.** The goal of hyperventilation is to reduce PaCO₂, a potent cerebrovascular vasodilator that increases ICP. Hyperventilation reduces ICP by lowering PaCO₂, which causes vasoconstriction. The respiratory therapist induces hyperventilation by adjusting ventilator settings as ordered and monitoring arterial blood gases (ABGs). Usually, PaCO₂ should be decreased no lower than 30 mm Hg. However, in patients with refractory increased ICP (above 20 mm Hg), hyperventilation may be used to reduce PaCO₂ from 35 to 29 mm Hg, which typically lowers ICP 25% to 35%. Hyperventilation isn't recommended as first-line therapy because it leads to cerebral vasoconstriction at a time when cerebral blood flow already is reduced. It's used intermittently and for several minutes at a time—and never when ICP is within normal limits or as continuous therapy. It must be avoided during the first 24 hours after injury because it can further
Understanding osmotic therapy

Patients with increased intracranial pressure (ICP) commonly receive bolus or continuous infusions of I.V. mannitol or hypertonic saline solution for osmotic therapy. Mannitol promotes osmotic diuresis, whereas hypertonic saline solution is more likely to maintain plasma volume. The goal of giving hypertonic saline solution is to raise the serum sodium level to 150 or 155 mEq/L, which increases serum osmolality and in turn reduces water in the brain.

During osmotic therapy, be sure to monitor your patient’s serum osmolality. Normally, it ranges from 285 to 295 mOsm/L; patients with elevated ICP usually are treated to a range of 300 to 320 mOsm/L. Know that although levels above 320 mOsm/L lower ICP, higher serum osmolality levels with mannitol use can cause profound diuresis, possibly leading to rebound cerebral edema.

Use hypertonic saline solution cautiously in patients with heart failure or a low ejection fraction, as it can increase the risk of acute rapid-onset (flash) pulmonary edema. Be aware that mannitol can cause electrolyte disturbances in patients with renal failure.

compromise cerebral perfusion. It shouldn’t be used as preventive therapy.

- **Therapeutic hypothermia.** This technique has been shown to reduce ICP but not to consistently improve outcomes. Limiting cooling to less than 48 hours can minimize complications, such as cardiac dysfunction and abnormal O₂ delivery. Although cooling protocols vary, body temperature shouldn’t be decreased below 89.6° to 91.4° F (32° to 33° C).

- **Surgical options.** Surgery may reduce ICP by allowing the brain to swell. Craniectomy removes a large section of bone, which is stored for later replacement. But such decompressive surgery is controversial: Although it lowers ICP, it doesn’t change overall mortality. Also, some experts speculate that axonal stretch and altered cerebral blood flow may cause neural injury in craniectomy patients.

Timing of surgical intervention may vary. A TBI patient with an expanding hematoma that’s causing brain herniation is likely to undergo surgical decompression as soon as possible after arriving at the ED. If the patient doesn’t have a hematoma or evidence of cerebral edema, clinicians may decide to monitor ICP and try conservative measures first. Preexisting illness, age, and patient wishes also should be considered before surgical intervention.

**TBI case study**

The following case study illustrates the possible course of a hospital stay for a patient with TBI.

Anna S, age 17, experiences seizures and loss of consciousness after suffering head trauma in a sports injury. In the field, emergency medical technicians determine her initial GCS score is 3 (eye opening 1, verbal response 1, motor response 1), which warrants intubation. They transport her to the ED, where an initial head CT shows areas of hemorrhage. Subsequent magnetic resonance imaging confirms diffuse axonal injury.

Here’s a summary of Anna’s condition and medical care during her 4-week hospitalization:

**Day 1:** A parenchymal catheter is placed for ICP monitoring. Anna’s ICP is 10 mm Hg.

**Day 4:** Anna’s ICP increases intermittently up to 30 mm Hg. The physician orders sedation and intermittent boluses of hypertonic saline solution.

**Day 5:** Anna’s temperature rises to 104°F (40°C). A cooling catheter is placed to keep her temperature at 98.6°F (37°C). When her ICP monitor wire fails, the parenchymal catheter is removed and an EVD is placed for continued ICP monitoring and CSF drainage.

**Day 14:** Anna opens her eyes spontaneously and looks around.

**Day 16:** Anna is extubated; she responds purposefully to noxious stimulation.

**Day 18:** Anna’s GCS score is 10 (eye opening 4, verbal response 1, motor response 5). Her Rancho Los Amigos Scale score is 2 with emerging 3, as she begins to wake up and respond to her environment. Her ICP drops below 10 mm Hg and her EVD is discontinued.

**Day 25:** Anna is able to follow commands, converse, and eat. Her Rancho Los Amigos Scale score is 4.

**Day 28:** Anna is discharged to a rehabilitation facility for patients with brain injury.

**Team approach to TBI**

Managing increased ICP in patients with TBI calls for a team approach to optimize outcomes. bedside nurses are better positioned than other clinicians to identify rising ICP early to ensure appropriate interventions. Use your critical thinking skills and start conservative measures while anticipating next steps during communication with care providers.

**Selected references**


Brain Trauma Foundation; American Association of Neurological Surgeons; Congress of Neurological Surgeons; Joint Section on Neurotrauma and Critical Care, AANS/CNS; Bratton SL, Chestnut RM, Ghajar J. Guidelines for the management of severe traumatic brain injury. Antiseizure prophylaxis. J Neurotrau-


6. Which statement about neurologic assessment tools is correct?
   a. With the GCS, the patient’s score is based on best eye opening, verbal, and sensory responses.
   b. With the GCS, the patient’s score is based on best eye opening, verbal, and motor responses.
   c. The Ranchos Los Amigos Scale is inadequate for monitoring a patient’s readiness for rehabilitation.
   d. Scores on the Ranchos Los Amigos Scale range from 0 to 18.

7. To help avoid increased ICP, you keep the head of Mark’s bed at:
   a. 0 to 10 degrees.
   b. 20 to 25 degrees.
   c. 30 to 45 degrees.
   d. 60 to 90 degrees.

8. Which statement should you consider when managing Mark’s temperature?
   a. Temperature elevation is a positive prognostic sign.
   b. Fever can increase metabolic demands as much as 25% per degree C.
   c. Fever can increase metabolic demands as much as 10% per degree C.
   d. Vasodilation from fever reduces CPP.

9. An expected treatment goal for Mark is to:
   a. Avoid antipyretics for managing fever.
   b. Keep his oxygen saturation above 90%.
   c. Keep his blood pressure slightly below normal.
   d. Keep his partial pressure of arterial O₂ (PaO₂) above 50 mm Hg.

10. Mark is started on nitroprusside to control his high blood pressure. Which of the following is a potential side effect you should watch for?
    a. White blood cell dysfunction
    b. Orthostatic hypertension
    c. Reflex bradycardia
    d. Thiocyanate toxicity

11. Mark’s increased ICP resists treatment, so clinicians decide to start him on osmotic therapy. Which statement about this therapy is correct?
    a. Continuous infusion of hypotonic saline solution is a common choice.
    b. The goal is to achieve a serum sodium level of 125 to 135 mEq/L.
    c. Bolus infusion of hypotonic saline solution is a common choice.
    d. The goal is to achieve a serum sodium level of 150 to 155 mEq/L.

12. If the physician decides to add hyperventilation to Mark’s regimen, which of the following should you keep in mind?
    a. It’s not recommended as a first-line therapy.
    b. It can cause vasodilation.
    c. It’s administered over a period of several hours.
    d. It’s used on a continuous basis.

13. Which statement about the use of barbiturates in treating patients with TBI is correct?
    a. They aren’t useful if ICP doesn’t drop over the first 2 hours.
    b. They increase cerebral metabolic demand.
    c. Pentobarbital is the most commonly used barbiturate.
    d. Patients continue to have a pupillary response.