

Increased Icp and Herniation

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THE STORY IN ONE SENTENCE

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“High brain pressure? Raise the head of the bed 30 degrees. Give hypertonic saline or mannitol to pull fluid out of the brain. Keep the patient calm and quiet. Watch pupils and breathing every hour. Brain surgery may be needed fast to remove the mass or drain fluid.”

Normal anatomy — the body's job

Inside the skull sit three things: brain tissue (the squishy gray and white matter), blood (flowing through arteries and veins), and cerebrospinal fluid or CSF (clear liquid made by the choroid plexus in the brain's fluid chambers, called ventricles, that cushions the brain and washes away waste). The skull is a rigid bone box that cannot stretch. Normally these three volumes balance each other—if one goes up a little, another goes down a little—so pressure stays steady around 5 to 15 mm Hg. This balance is called the *Monro-Kellie doctrine*.

BODY'S JOB

The brain's job is to think, move your body, and keep all organs running. Blood delivers oxygen and sugar (glucose) that brain cells burn for energy every second; if blood flow drops even briefly, cells start to die. CSF cushions the brain against bumps, carries away waste, and flows in a loop: made in the ventricles, it flows through narrow passages, then out over the brain's surface, and finally gets absorbed into the bloodstream through arachnoid granulations (tiny one-way valves). This flow keeps pressure steady and the brain clean.

1. Blood enters through carotid and vertebral arteries at the base of the skull, branches into smaller vessels, and delivers oxygen and glucose to every brain cell.
2. Brain cells use that oxygen and glucose to make energy (ATP) so they can fire signals, think, and control the body.

3. Veins drain used blood—and the waste carbon dioxide—out of the skull through jugular veins in the neck.
4. At the same time, the choroid plexus (a spongy tissue in the ventricles) filters blood and makes about 500 mL of clear CSF every day.
5. CSF flows from the lateral ventricles through the foramen of Monro into the third ventricle, then through the aqueduct of Sylvius into the fourth ventricle, then out through small openings (foramina of Luschka and Magendie) to bathe the brain and spinal cord.
6. Finally, arachnoid granulations (tiny bumps on the brain's surface) absorb CSF back into the bloodstream, keeping the total volume constant.
7. Because the skull cannot expand, any increase in brain tissue, blood, or CSF must be balanced by a decrease in another, or pressure will climb.

What breaks

Something adds extra volume inside the skull—a tumor, swelling (edema), a blood clot (hematoma), or blocked CSF drainage (hydrocephalus)—and the skull cannot stretch to make room. Pressure climbs. At first the body pushes out some CSF and blood to compensate, but once that safety margin runs out, pressure spikes fast. The rising pressure squeezes blood vessels, cutting oxygen delivery, and pushes the brain downward toward the only opening at the skull base, crushing the brainstem.

CLINICAL TERM

Increased intracranial pressure (ICP) and herniation. Normal ICP is 5–15 mm Hg; pressure above 20 mm Hg is abnormal, and sustained pressure above 30 mm Hg causes brain injury. Common causes include mass lesions (tumor, abscess, a pooled collection of blood (hematoma)), cerebral swelling (edema) (from trauma, stroke, infection, or liver failure), hydrocephalus (blocked CSF flow), and with no known cause (idiopathic) intracranial high blood pressure (hypertension). When ICP rises, cerebral blood flow (perfusion) pressure (CPP = mean arterial pressure minus ICP) falls; if CPP drops below 50–60 mm Hg, brain cells do not get enough oxygen and start to die (ischemia). Herniation occurs when rising pressure forces brain tissue through rigid openings: uncal herniation (medial temporal lobe pushes through the tentorium, compressing cranial nerve III and the brainstem), central transtentorial herniation (both hemispheres push down, compressing the diencephalon and midbrain), tonsillar herniation (cerebellar tonsils push through the foramen magnum, compressing the medulla), and subfalcine herniation (cingulate gyrus pushes under the falx cerebri, compressing the anterior cerebral artery). Herniation is immediately life-threatening.

How the body compensates

At first the body tries to protect the brain by pushing CSF and venous blood out of the skull to make room for the extra volume. This keeps pressure normal for a while—so vital signs look okay and the patient seems stable. But this compensation has a limit. Once the safety margin runs out, the pressure-volume curve turns steep: a tiny bit more swelling causes a huge pressure spike. The patient's level of consciousness drops, pupils dilate, and vital signs swing wildly. The danger is that the team may miss the tipping point because early signs are subtle. You must watch trends—worsening headache, growing drowsiness, slowing heart rate, rising blood pressure—not just one snapshot, because once herniation starts the window to reverse it closes in minutes.

1. The brain pushes cerebrospinal fluid out of the skull and down into the spinal canal, lowering the CSF volume inside the head and buying a little space.
2. Veins inside the skull collapse and squeeze blood out into the neck veins, further lowering intracranial volume and keeping pressure steady.
3. These two changes can absorb 60 to 100 mL of extra volume without raising pressure much—this is the flat part of the pressure-volume curve, and the patient may have only mild headache or fatigue.
4. Once that reserve is exhausted, the curve turns steep: every extra mL now causes a large jump in pressure. The patient becomes confused, then drowsy, then unresponsive as blood flow (perfusion) drops.
5. The body tries one more trick—Cushing's reflex—raising blood pressure to force blood into the squeezed brain and slowing the heart rate to protect against the high pressure. You see a wide pulse pressure (high systolic, low diastolic) and a slow heart rate (bradycardia). This triad (hypertension, a slow heart rate, irregular breathing) is a late sign that herniation is starting.
6. The rising pressure pushes the brain toward the only exit—the foramen magnum at the skull base—and brain tissue herniates through rigid edges (the tentorium or the foramen magnum), crushing the brainstem and cutting off breathing and consciousness.
7. Once herniation begins, blood flow (perfusion) collapses, cells die, and the patient stops breathing. Without immediate intervention—hyperventilation, hyperosmolar therapy, or surgery—death follows in minutes.

Domino effect

1. A mass (tumor, a pooled collection of blood (hematoma), abscess), cerebral swelling (edema) (from trauma, stroke, infection), blocked CSF drainage (hydrocephalus), or venous clot adds volume inside the rigid skull. — The skull is a closed box that cannot stretch. Extra volume has nowhere to go, so intracranial pressure (ICP) begins to climb. At first the body compensates by shifting CSF and blood out, keeping pressure normal and symptoms mild—maybe just a dull headache or mild confusion.
2. As the mass or swelling grows, compensation runs out. Pressure spikes. Blood vessels get squeezed, cutting oxygen delivery to brain cells (ischemia). — Cerebral blood flow (perfusion) pressure (CPP) equals mean arterial pressure minus ICP. When ICP rises above 20–30 mm Hg, CPP falls below the 50–60 mm Hg needed for cells to survive. Starved of oxygen, cells swell further (secondary swelling (edema)), creating a vicious cycle: more swelling raises pressure, which cuts flow, which causes more swelling.
3. You see classic signs: severe headache (worse lying flat or in the morning), projectile vomiting (from pressure on the brainstem's vomiting center, the area postrema), swelling of the optic nerve (papilledema) (swollen optic disc from blocked venous drainage), and progressive drowsiness (from starved blood flow (ischemia) in the reticular activating system, the brainstem network that keeps you awake). — High ICP stretches pain-sensitive structures (dura, blood vessels), so the headache is deep and throbbing. Lying flat or bending over raises venous pressure, making it worse. Vomiting happens because pressure irritates the medulla. Swelling of the optic nerve (Papilledema) develops over hours to days as CSF pressure transmits along the optic nerve sheath, stalling venous return and swelling the disc. Drowsiness progresses from confusion to stupor to coma as blood flow (perfusion) falls and the reticular activating system shuts down.
4. Rising pressure pushes the brain downward. In uncal herniation the medial temporal lobe (uncus) squeezes through the tentorial notch, compressing cranial nerve III (oculomotor nerve) and the midbrain. You see a fixed, dilated pupil on the same side as the mass (the nerve's parasympathetic fibers stop working, so the pupil cannot constrict) and then weakness on the opposite side of the body (the cerebral peduncle carrying motor signals gets crushed). — The uncus herniates because it sits right at the edge of the tentorium, the dura fold separating brain and cerebellum. Nerve III runs alongside, so it gets pinched first—parasympathetic fibers on the outside of the nerve are most vulnerable, causing pupil dilation (mydriasis). Continued herniation crushes the midbrain's motor tracts (corticospinal tract in the cerebral peduncle), causing contralateral weakness on one side (hemiparesis) or posturing.

5. The brainstem tries to save itself by triggering Cushing's reflex: blood pressure shoots up (hypertension) to force blood through the squeezed vessels, and the heart rate slows (bradycardia) because the vagus nerve (cranial nerve X in the medulla) fires in response to high pressure. Breathing becomes slow and irregular (Cheyne-Stokes or uncoordinated (ataxic) pattern) as the medulla's respiratory centers fail. — The Cushing reflex is a last-ditch effort by the medulla to maintain cerebral blood flow (perfusion). The medulla detects starved blood flow (ischemia) and sends a massive sympathetic surge, raising systemic blood pressure. The high pressure stretches baroreceptors in the carotid sinus and aortic arch, triggering a vagal reflex that slows the heart. This triad—high blood pressure (hypertension), a slow heart rate (bradycardia), irregular respirations—is a late and ominous sign that herniation is imminent or already happening.
6. In central transtentorial herniation both cerebral hemispheres push down, compressing the diencephalon (thalamus and hypothalamus) and then the midbrain. Pupils become small and reactive at first, then mid-position and fixed. The patient develops decorticate posturing (arms flexed, legs extended—damage above the midbrain) and then decerebrate posturing (arms and legs extended—damage at or below the midbrain). — Central herniation happens when pressure rises evenly across both sides—often from diffuse swelling (edema). As the diencephalon gets squeezed, you lose higher control: small reactive pupils (intact midbrain), then Cheyne-Stokes breathing (damage to cortex and diencephalon). When the midbrain herniates, pupils fix in mid-position (parasympathetic and sympathetic pathways both fail), and posturing worsens from decorticate (red nucleus intact) to decerebrate (red nucleus lost, only vestibular reflexes remain).
7. In tonsillar herniation the cerebellar tonsils push down through the foramen magnum, crushing the medulla. Breathing stops suddenly (apnea) because the medulla's respiratory center shuts off. Blood pressure crashes, and the heart stops soon after. — The foramen magnum is the only exit at the skull base, where the brainstem becomes the spinal cord. The medulla sits here and controls automatic breathing, heart rate, and blood pressure. When the tonsils herniate and compress it, you lose respiratory drive—the patient stops breathing and becomes bradycardic, progressing to cardiac arrest within minutes. This is the final common pathway of death from increased ICP.

8. If you trace every finding backward—headache, vomiting, swelling of the optic nerve (papilledema), dilated pupil, slow heart, high blood pressure, abnormal posturing, irregular breathing—they all point upstream to one broken thing: rising intracranial pressure from added volume in a closed space. The fix is not to chase each symptom but to lower ICP fast (elevate head, give hyperosmolar therapy, hyperventilate briefly, drain CSF, or remove the mass surgically) and restore blood flow (perfusion) before herniation becomes irreversible. — Every sign you see is the body's attempt to cope with too much pressure—pushing fluid out, raising blood pressure, shutting down consciousness to lower metabolic demand. But compensation eventually fails. The only way to save the patient is to remove the cause: shrink the brain (mannitol or hypertonic saline pulls water out), drain CSF (ventriculostomy), remove the mass (craniotomy for a pooled collection of blood (hematoma) or tumor), or treat the underlying problem (antibiotics for abscess, antiedema measures for stroke). Once herniation is complete and the medulla is crushed, brain death follows, so early recognition and aggressive ICP management are life-saving.

Symptoms · what the patient feels, and why

- Headache that gets worse and worse: The rising pressure inside the skull pushes on pain-sensitive tissue around the brain (like the dura, which is the tough outer cover). The brain itself has no pain nerves, but the structures around it do, so they signal pain as they stretch.
- Throwing up without feeling sick to the stomach first: High pressure presses on the area postrema (the vomit-trigger zone in the brainstem at the base of the brain). This center fires off a vomit reflex even though there is no stomach problem — the signal comes from inside the skull.
- One pupil gets bigger than the other, or both pupils stop reacting to light: When part of the brain (often the temporal lobe) herniates (gets squeezed downward), it traps the oculomotor nerve (cranial nerve III, which controls pupil size). The nerve stops working, so the pupil stays wide open and will not shrink when you shine a light in the eye.
- Vision gets blurry or dims, sometimes seeing double: Pressure inside the skull squeezes the optic nerves (the cables that carry vision from the eye to the brain) and can also press on the abducens nerve (cranial nerve VI, which moves the eye outward). Squeezing the optic nerve clouds vision; pinching nerve VI causes double vision because the eyes do not line up.
- Confusion, trouble staying awake, or falling into a coma: Rising pressure squeezes the reticular activating system (a network in the brainstem that keeps you awake and alert). When it gets compressed, the brain's wake-up signal fades and the person becomes drowsy, confused, and eventually unconscious.

- Body suddenly gets stiff with arms bent inward or stretched out straight (posturing): Herniation cuts off signals from the cerebral cortex (the outer thinking layer) or damages the brainstem (the control tower for movement and posture). Without the cortex keeping the brainstem in check, primitive reflex circuits fire and lock the muscles into abnormal postures — decorticate (arms bent in) or decerebrate (arms straight out).
- Breathing becomes slow, irregular, or stops and starts in strange patterns: The medulla oblongata (the lowest part of the brainstem that runs the automatic rhythm of breathing) gets squeezed by herniation. Damage here disrupts the breathing center, producing patterns like Cheyne-Stokes (fast then slow breaths with pauses) or uncoordinated (ataxic) breathing (totally chaotic breaths).
- Blood pressure shoots up while heart rate drops (Cushing's triad with abnormal breathing): The brainstem senses dangerously high pressure and tries to force more blood up to the brain by cranking blood pressure way up (through the vasomotor center). At the same time, the vagus nerve (cranial nerve X) slows the heart in response to the high pressure. Together with abnormal breathing, these three signs — high BP, slow pulse, weird breathing — are the Cushing reflex, a last-ditch warning that herniation is happening.
- Seizures: Pressure irritates or damages the cerebral cortex (the outer layer where thinking and movement start). Injured or compressed cortex cells fire in wild, uncontrolled bursts, causing a seizure.

Focused exam

- Severe headache that gets worse when lying flat, coughing, or bending over: When pressure inside the skull (intracranial pressure, or ICP) rises, it stretches the dura (the tough covering around the brain) and the blood vessels, which have pain sensors. This is often the first warning that something is taking up too much space inside the skull.
- One pupil bigger than the other (anisocoria), especially if it does not react to light: When the brain gets pushed sideways or downward (herniation), it squeezes the oculomotor nerve (cranial nerve III, the nerve that controls the pupil). A blown pupil—one that is large and fixed—means that nerve is being crushed right now. This is a sign that the brain is herniating through the tentorium (the shelf of tissue between the top and bottom of the brain).
- Slow heart rate with high blood pressure and irregular breathing (Cushing's triad): When the brainstem (the part of the brain that runs the heart, lungs, and blood pressure) gets squeezed from rising ICP, it triggers a reflex: the body slows the heart, jacks up blood pressure, and changes breathing rhythm to try to force more blood into the compressed brain. This is the body's last-ditch effort to save itself.

- Projectile vomiting, often without nausea beforehand: High ICP presses on the area postrema and the vomiting center (both in the brainstem, the region that controls automatic body functions). When vomiting comes on suddenly and forcefully in someone with ICP signs, it means the pressure is already dangerously high.
- Swelling of the optic nerve (Papilledema) (swollen optic disc) seen with an ophthalmoscope: Cerebrospinal fluid (CSF, the clear liquid that cushions the brain) surrounds the optic nerve all the way to the back of the eye. When ICP climbs, that fluid gets pushed into the optic nerve and makes the disc swell. You can see this bulge with a light. It takes hours to days to develop, so it tells you pressure has been high for a while.
- Decreased level of consciousness—sleepy, hard to wake, or dropping Glasgow Coma Scale score: The reticular activating system (the network in the brainstem that keeps you awake) is very sensitive to pressure. When ICP rises and the brain starts to herniate, this system shuts down first. A drop in alertness means the brain is running out of room and oxygen.
- Abnormal posturing—decorticate (arms bent in, legs straight) or decerebrate (arms and legs straight, stiff): When herniation squeezes the brainstem and the motor tracts (the highways that carry movement signals), the brain loses fine control and reflexes take over, locking the body into rigid positions. Decerebrate posturing (all limbs extended) is worse than decorticate and means the damage has reached deeper into the brainstem.

Diagnostics · every test answers a question

- Non-contrast head CT (computed tomography) → Is there a mass (tumor, blood clot, abscess), midline shift (brain pushed sideways), or signs of herniation (flattened ventricles, missing cisterns, or brain tissue shoved into an opening)?
- Brain MRI with and without gadolinium contrast → What is the exact cause of the mass or swelling—tumor, infection, demyelination (damage to nerve insulation), or starved blood flow (ischemia) (stroke)? How far does it extend?
- Serum sodium (Na^+) → Is the sodium low (hyponatremia), which can cause or worsen brain swelling?
- Serum osmolality → What is the blood's overall concentration of dissolved particles (salts, sugar, urea)? This tells us how much water is being pulled into or out of the brain.
- Arterial blood gas (ABG) with PaCO_2 → What is the carbon dioxide level in the blood? CO_2 controls how wide or narrow the brain's blood vessels are.
- Intracranial pressure (ICP) monitor—intraventricular catheter or intraparenchymal bolt → What is the exact pressure inside the skull right now, in real time?
- Complete blood count (CBC) and coagulation panel (PT, INR, aPTT, platelets) → Is there an infection (high white blood cell count) or a bleeding problem (low platelets, high INR) that could cause or worsen intracranial bleeding (hemorrhage)?

- Lumbar puncture (LP) with opening pressure (only if no mass or herniation risk on imaging)
→ What is the CSF pressure, and is there infection (meningitis) or blood (subarachnoid bleeding (hemorrhage))?

Treatment logic

- Elevate the head of the bed to 30 degrees and keep the neck midline (straight, not turned)
→ Gravity helps venous blood and CSF drain out of the skull through the jugular veins (the big veins in the neck), lowering the volume inside and dropping ICP by several mmHg.
- Hypertonic saline IV—3% continuous infusion or 23.4% bolus (30 mL over 10–20 minutes) → The high salt concentration in the blood pulls water out of swollen brain tissue (osmosis) and into the bloodstream, shrinking the brain and dropping ICP within minutes. Target serum sodium is 145–155 mEq/L. Effect lasts 4–6 hours.
- Mannitol IV—0.25–1 g/kg bolus over 15 minutes → Mannitol (an osmotic diuretic, a drug that pulls water into the blood and makes you pee) pulls water out of the brain into the blood, then the kidneys remove it. ICP drops in 10–30 minutes. Effect lasts 2–6 hours.
- Controlled hyperventilation—target PaCO₂ 30–35 mmHg → Lowering CO₂ makes brain arteries constrict (squeeze tight), which shrinks the volume of blood inside the skull and drops ICP within minutes. This is the fastest emergency measure.
- External ventricular drain (EVD)—catheter placed into the lateral ventricle to drain CSF → Removes CSF directly from the brain's fluid chambers, instantly creating space and dropping ICP. Also allows real-time ICP monitoring. Can drain 5–20 mL per hour depending on pressure.
- Surgical decompression—craniotomy (opening the skull) to remove mass (hematoma, tumor, bone fragment) or decompressive craniectomy (removing part of the skull to give the brain room to swell) → Removes the source of pressure—blood clot, tumor, or abscess. If the skull bone is removed (craniectomy), the swollen brain can expand outward instead of crushing the brainstem. ICP drops immediately.
- Sedation and analgesia—propofol infusion (25–75 mcg/kg/min) or midazolam, plus fentanyl for pain → Sedation lowers the brain's metabolic demand for oxygen and glucose, reduces agitation (which raises ICP), and makes mechanical ventilation comfortable. Propofol (a sedative drug) also directly lowers ICP. Keeps the patient calm so the other treatments can work.

Medications

Hypertonic saline 3% (IV infusion) or 23.4% (bolus) · Osmotic agent

Hypertonic saline is much saltier than normal blood. When you drip it into the bloodstream, it pulls water OUT of the swollen brain tissue and into the blood vessels. The brain shrinks just enough to lower the pressure inside the skull. Think of sprinkling salt on a wet sponge — the salt draws the water out.

1. The very salty fluid enters the bloodstream through an IV.
2. Blood vessels in the brain now carry blood that is saltier than the fluid sitting around brain cells.
3. Water moves from the swollen brain tissue into the bloodstream to even out the salt levels.
4. The brain tissue shrinks slightly, creating more room inside the rigid skull.
5. Intracranial pressure (the squeeze inside the skull) drops within minutes to hours.

SAFETY WATCH

Can push sodium levels in the blood too high (hypernatremia), which can trigger seizures or confusion if it climbs too fast. · The super-concentrated 23.4% form must go through a central IV line (a tube placed in a large vein near the heart) to avoid burning smaller veins. · Check sodium and other salt levels in the blood every few hours. · Use carefully in patients with heart failure or kidney failure because the extra salt and fluid can overload the heart or kidneys.

Mannitol 20% (IV bolus) · Osmotic diuretic

Mannitol is a sugar alcohol that the body cannot soak into cells. When you give it into the bloodstream, it pulls water out of swollen brain tissue and into the blood. Then the kidneys flush that extra water out as urine. It shrinks the brain quickly and lowers skull pressure fast.

1. Mannitol enters the bloodstream and stays in the blood vessels. It does not cross into brain cells.
2. Blood inside brain vessels becomes more concentrated, so water is pulled out of the swollen brain tissue into the blood.
3. The brain shrinks, creating more space inside the skull and lowering intracranial pressure.
4. Mannitol travels to the kidneys and pulls water into the urine, flushing the extra fluid out of the body.
5. Intracranial pressure drops within 15 to 30 minutes and the effect lasts 2 to 6 hours.

SAFETY WATCH

Can cause severe dehydration and low blood pressure if too much fluid is pulled out. · May trigger acute kidney injury, especially if given many times or if the patient is already dehydrated. · Can leak into damaged brain tissue if the blood-brain barrier is broken, which can backfire and worsen swelling (rebound effect). · Check kidney function, blood pressure, and urine output closely. · Avoid in patients with severe kidney failure or heart failure unless life-threatening herniation is happening right now.

Propofol (IV infusion) · Sedative-hypnotic and anesthetic agent

Propofol calms the entire brain by boosting GABA (the brain's main shut-off chemical), which slows brain cell activity. When the brain is less active, it uses less oxygen and energy. Blood vessels in the brain tighten slightly, and blood volume inside the skull drops. All of this lowers intracranial pressure. It also keeps the patient deeply asleep so they do not move, cough, or fight the breathing tube, which would spike pressure.

1. Propofol binds to GABA-A receptors all over the brain and makes them fire more strongly.
2. Brain cells slow their electrical activity and use less energy.
3. The brain's demand for oxygen and glucose drops.
4. Blood vessels in the brain tighten slightly, reducing blood volume inside the skull.
5. The combination of lower brain activity and less blood volume lowers intracranial pressure.
6. The patient stays deeply asleep, so they do not buck the ventilator or raise pressure with movement.

SAFETY WATCH

Can drop blood pressure dangerously, which cuts blood flow to the injured brain. Must watch blood pressure continuously and support it with IV fluids or medications that raise blood pressure (vasopressors). · Long-term or high-dose use in children or very sick adults can trigger propofol infusion syndrome (PRIS), a life-threatening condition with severe acid buildup, muscle breakdown, heart failure, and kidney failure. Watch for rising lactate (an acid marker), abnormal heart rhythms, and green urine. · Requires a breathing tube and mechanical ventilator because it shuts off the drive to breathe. · Can raise triglyceride levels (a type of fat) in the blood because the drug is dissolved in a fat mixture. · Check blood pressure, heart rhythm, triglycerides, and metabolic markers every day.

Controlled hyperventilation (mechanical ventilation with target PaCO₂ 30-35 mm Hg) · Ventilator strategy (not a drug, but a critical medical treatment)

Breathing faster than normal lowers the level of carbon dioxide (CO₂) in the blood. When CO₂ drops, blood vessels in the brain tighten and narrow. This cuts the volume of blood inside the

skull and lowers intracranial pressure. This works very fast but only for a short time and must be used carefully.

1. The ventilator cranks up the breathing rate to blow off more CO₂ with each breath.
2. Blood CO₂ level (PaCO₂) drops to 30–35 mm Hg. Normal is 35–45.
3. Lower CO₂ makes the smooth muscle in brain blood vessels squeeze and narrow (vasoconstriction).
4. Less blood fills the brain at any moment, so intracranial pressure drops within minutes.
5. Pressure falls quickly, buying time for surgery or other definitive treatment.

SAFETY WATCH

If CO₂ drops too low or stays low too long, brain blood vessels can tighten so much that parts of the brain do not get enough oxygen. This worsens injury (cerebral starved blood flow (ischemia), meaning not enough blood reaching the tissue to feed it). · Use ONLY for sudden herniation or wild intracranial pressure spikes, and ONLY until other treatments like surgery or osmotic agents take over. · Target PaCO₂ 30–35 mm Hg. Do NOT go lower except in dire emergencies. · Watch with continuous end-tidal CO₂ monitoring (a sensor on the breathing tube) and check arterial blood gases often. · Stop hyperventilation as soon as intracranial pressure is controlled or the cause is treated.

Red flags

- One pupil suddenly much bigger than the other or not reacting to light
- Stiff posturing (arms bent in tight or stretched out straight)
- Glasgow Coma Scale dropping (person less awake, less responsive)
- Cushing's triad: high blood pressure, slow heart rate, and abnormal breathing
- Sudden severe headache with projectile vomiting

Nursing priorities

1. Keep the head of the bed at 30 degrees and the neck straight in midline position without flexion or rotation — This position lets blood drain out of the brain through the jugular veins (neck veins) and keeps cerebrospinal fluid flowing; a bent or twisted neck blocks these veins and traps blood and fluid inside the skull
2. Check pupils and Glasgow Coma Scale score every 15 to 60 minutes and report any change immediately — A dilating pupil or dropping Glasgow Coma Scale means the brain is herniating (pushing down through the skull opening onto the brainstem) and the patient may die within minutes without emergency treatment

3. Give 3% hypertonic saline continuous IV infusion or 23.4% saline bolus as ordered and monitor serum sodium every 4 to 6 hours — Hypertonic saline (extra-salty IV fluid) pulls water out of swollen brain tissue into the blood vessels through osmosis (water moving toward salt); this shrinks the brain and lowers pressure
4. Maintain PaCO₂ between 30 and 35 mmHg by adjusting ventilator rate if the patient is intubated — Low carbon dioxide makes brain blood vessels constrict (get smaller) which reduces blood volume inside the skull and lowers pressure; below 30 mmHg causes too little brain blood flow and damage
5. Keep the patient sedated with propofol or other IV sedatives and give IV pain medicine like fentanyl to keep them calm — Pain, agitation, and coughing raise intrathoracic pressure (pressure in the chest) which blocks blood from leaving the brain and spikes intracranial pressure; sedation lowers brain metabolism and oxygen demand
6. Monitor the external ventricular drain if present and drain cerebrospinal fluid to keep intracranial pressure below 20 mmHg — Cerebrospinal fluid takes up space inside the skull; draining it through the external ventricular drain is the fastest way to lower pressure and prevent herniation
7. Prevent fever and treat temperatures above 38°C with IV acetaminophen or cooling blankets — Fever increases brain metabolism and oxygen demand by 10% for every degree Celsius; higher metabolism means more blood flow to the brain which raises intracranial pressure
8. Avoid suctioning the endotracheal tube unless absolutely necessary and pre-oxygenate with 100% oxygen before suctioning — Suctioning triggers coughing and straining which spike intracranial pressure by 20 to 40 mmHg; low oxygen during suctioning dilates brain blood vessels and raises pressure even more

Sources

- Brain Trauma Foundation Guidelines for Management of Severe TBI
- Neurocritical Care Society
- American Association of Neurological Surgeons
- AHA/ASA Stroke Guidelines

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