Cerebral Edema (Brain Swelling) — Causes and Treatment Guidelines

Definition

Cerebral edema is defined as the excess accumulation of water in the intracellular and extracellular spaces of the brain.

Epidemiology

The disease is common but rarely reported due to the complexities associated with its diagnosis. It is more common especially since it occurs as a secondary occurrence following other primary brain conditions.

Pathophysiology of Cerebral Edema

Cerebral edema can occur if the brain cells become damaged, i.e. cytotoxic edema, or if the blood vessels get injured, vasogenic edema. Cellular and blood vessel damage results in the release of glutamate into the extracellular space, i.e. excitotoxicity, and entry of calcium and sodium into the cells. The sodium-potassium ATP pump pushes out some calcium thus sodium builds up within the cell creating an osmotic gradient that pulls water into the cell and results in intra-cellular edema and cell swelling.

Calcium accumulation within the cells in the brain results in the activation of intracellular cytotoxic processes which can result in apoptosis. Moreover, the formation of
inflammatory mediators such as c-foc, c-jun, and cytokines get activated.

Injury and ischemia of the central nervous system can also release glutamate from the intracellular space to the extracellular space. This is the cause of cerebral edema in ischemic brain injury. Direct cell injury is responsible for brain edema in traumatic brain injury.

The effects of cerebral edema are as a direct result of the Monroe-Kellie doctrine that states that the cranial cavity is fixed in volume and contains the following components in fixed proportions such that increase in one must be followed by compensatory loss of another component in equal proportions. **The contents of the cranial cavity are:**

- Brain matter making up 1400 ml
- Blood making up 150 ml
- Cerebrospinal fluid at 150 ml

Cerebral edema alters the level of brain cavity and thus increase in the amount of brain volume leads to increased intracranial pressure where the body responds by reducing the amount of blood flow to the brain which may cause further damage to the brain.

### Types of Cerebral Edema

Broadly, cerebral edema can be either of vasogenic origin or cytotoxic/cellular edema. However, many are the times when smaller categories of four types of cerebral edema are used in practice. They include:

#### Vasogenic

Vasogenic cerebral edema is caused by the disruption of the blood-brain-barrier. Disruption of this barrier results in the influx of fluid and solutes into the brain. This is the most common type of brain edema. Vasogenic cerebral edema mainly affects the white matter.

#### Cellular edema

Cellular, previously known as cytotoxic, cerebral edema is characterized by cellular swelling. Cellular edema is seen in patients with traumatic brain injury and ischemic cerebral injury. Cellular cerebral edema affects the glial, neuron, and endothelial cells. Cellular cerebral edema typically occurs within minutes after injury, whereas, vasogenic edema occurs over a period of days. Cellular edema affects the gray matter.

#### Interstitial cerebral edema

Interstitial cerebral edema is caused by the outflow of cerebrospinal fluid from the intraventricular space to the extracellular interstitial space of the brain. This type of cerebral edema is seen in patients with increased intraventricular pressure, i.e. hydrocephalus. Interstitial cerebral edema might be also seen in patients with meningitis.

#### Osmotic cerebral edema

This results from abnormal levels of osmolarity in plasma and fluids within the brain. Plasma may have lower osmotic levels following dilution say from SIADH secretion or
increased volume intake. The high osmotic brain matter pulls water from the plasma causing cerebral edema.

Etiologies of Cerebral Edema

We can summarize the causes of cerebral edema according to the following classification:

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<th>Neurological causes</th>
<th>Non-neurological causes</th>
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<td>• Ischemic and hemorrhagic stroke</td>
<td>• Diabetic ketoacidosis</td>
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<td>• Brain tumors</td>
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<td>• Encephalitis</td>
<td>• Hypertensive encephalopathy</td>
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<td>• Tuberculosis and toxoplasmosis.</td>
<td>• Fulminant hepatitis</td>
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<td>• Reye’s syndrome</td>
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<td>• Systemic poisoning with carbon monoxide or lead</td>
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<td></td>
<td>• Hyponatremia, and high altitude cerebral edema.</td>
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Clinical Presentation of Cerebral Edema

Cerebral edema per se is asymptomatic. Symptoms start to arise once the intracranial pressure reaches a level that is sufficient to cause local ischemia.

**Symptoms of increased intracranial pressure include:**

- Altered level of consciousness
- Bradycardia
- Rise in blood pressure
- Abnormal breathing patterns
- Anisocoria
- Extensor plantar response on the side of the lesion

Cerebral edema is the most common cause of death in patients with acute ischemic stroke. Patients with acute ischemic stroke typically have cytotoxic cerebral edema in the earlier stages but they later develop vasogenic edema due to blood-brain-barrier disruption.

Diagnostic Workup for Cerebral Edema

A brain computed tomography scan is an excellent imaging modality for the evaluation and exclusion of acute brain pathologies including cerebral edema. Brain edema appears as an area of low density on unenhanced computed tomography scans of the brain.

When evaluating a brain computed tomography scan of a patient suspected to have cerebral edema, one should focus on the appearance of the white matter. Brain computed tomography scans should be also ordered during the follow-up period to monitor the resolution of brain edema once treatment is initiated. Other features that suggests increased intracranial pressure include flattened gyri and narrowed sulci as well as compression of the ventricles.

Patients with epidural and intracerebral hematomas due to traumatic brain injury typically have white matter confined cerebral edema without apparent involvement of the cortex.
Magnetic resonance imaging is superior to computed tomography scans of the brain in detecting brain abscess which can be the cause of cerebral edema in a septic patient with focal neurological deficits.

![Image](https://via.placeholder.com/150)

Image: "Edema (darker areas) surrounding a secondary brain tumor" by Bobigalindo. License: CC BY-SA 4.0

Intracranial pressure monitoring is indicated when cerebral edema is seen in the previous imaging studies. Despite this, the routine use of intracranial pressure monitoring remains controversial. Nowadays, intracranial pressure monitoring should be initiated only if the management plan is going to be affected by the results of the monitoring.

The electroencephalogram is not useful in the evaluation of cerebral edema; however, it might be helpful in a subgroup of patients with an epilepsy disorder as the cause of cerebral edema, i.e. status epilepticus.

**Medical Treatment of Cerebral Edema**

While our understanding of cerebral edema and its pathogenesis has expanded dramatically in the last decade, treatment options are still limited.

**Osmotherapy for Cerebral Edema**

Osmotic therapy is the mainstay of treatment of cerebral edema. Osmotic therapy aims to decrease brain bulk and water content via osmodiuresis.

**Osmotic therapy helps to:**

- draw water out of the brain
- decrease intracranial pressure
- increase cerebral blood flow

**Mannitol** is the most common osmotic agent. Mannitol decreases the intracranial pressure dramatically by decreasing the overall water content of the brain, reducing blood volume by vasoconstriction, and reducing cerebrospinal fluid volume. Mannitol also decreases blood viscosity, improves cerebral perfusion, and might have a cyto-protective effect. The most commonly used dose of mannitol for cerebral edema is a **bolus dose of 1 gram**
per kg followed by 50 grams every 2 to 3 hours.

Glycerol can be administered in oral doses of 30 ml every 4 to 6 hours for its osmotic effects as an alternative to mannitol.

Diuretic Therapy for Cerebral Edema

**Loop diuretics** such as furosemide can be administered after the administration of mannitol as they were found to prolong the osmotic effects of mannitol. The typical dose of furosemide is 0.7 mg/kg.

Corticosteroids for Cerebral Edema

Corticosteroids are beneficial in patients with vasogenic cerebral edema. Corticosteroids are not useful in the treatment of cytotoxic cerebral edema. Therefore, corticosteroids should not be routinely administered to patients with cerebral edema due to ischemic stroke, hemorrhagic stroke, or traumatic brain injuries. Corticosteroids have been found to increase the rate of complications in patients with cytotoxic cerebral edema.

Corticosteroids decrease tumor-associated vasogenic edema by decreasing capillary permeability of the disrupted blood-brain-barrier.

Hyperventilation for Cerebral Edema

Controlled hyperventilation is helpful in reducing raised intracranial pressure, especially in patients with cerebral edema after traumatic brain injury. If hyperventilation is used, care must be taken to not reduce the pCO2 level below 25 mm Hg.

Surgical Treatment of Cerebral Edema

Nowadays, **barbiturates and procaine derivatives are no longer recommended** in the management of acute cerebral edema. Therefore, patients who fail to respond to the previous medical treatments of cerebral edema might need some sort of surgical intervention to decompress the swollen brain.

Patients with life-threatening brain-shifts might need a temporary ventriculostomy or a decompressive craniectomy. These procedures might be life-saving. Patients with large cerebral and cerebellar infarcts with cerebral edema should undergo surgical decompression as it can be lifesaving.

References


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