

Review Article

Emergency and Intensive Care Management of a Comatose Patient with Intracranial Hypertension: Current Concepts

Suchitra Ranjit

Altered mental status is a common occurrence in children with acute critical illness. The causes of non-traumatic coma are diverse ranging from neurological to systemic causes. Early appropriate supportive care is essential to avoid preventable secondary insults and optimize the neurological outcome. Evaluation and stabilization of the patient's airway, breathing and circulation (ABCs) must proceed simultaneously with assessments of the depth of coma and the presence of raised intracranial pressure (ICP). Any rapidly correctable cause of coma must be immediately corrected. Most patients with non-traumatic encephalopathies have raised ICP, although papilledema may be absent and the CT scan may be normal if ICP elevation occurs acutely. The most important early treatment for raised ICP is controlled intubation and ventilation followed by osmotherapy. Early control of seizures, including non-convulsive seizures is important. Urgent imaging is indicated in most cases particularly in the presence of afebrile coma, focal signs or papilledema. Following stabilization, isotonic fluids are administered, aiming for euvoemia and euglycaemia. Ventilation should aim for the lower end of eucapnia to avoid causing cerebral ischemia. Surgical options should be explored and, in refractory intracranial hypertension, barbiturates and mild hypothermia may have a role.

Key words: Coma, Cerebral perfusion pressure, Cerebral blood flow.

This article attempts to guide the

Correspondence to: Dr S. Ranjit, Consultant Pediatric Intensivist, Apollo Hospitals, Chennai, India.
E-mail: chitrasona@rediffmail.com

pediatrician through a problem oriented, prioritized approach to a child presenting with coma in the Emergency Room and Intensive Care, stressing the importance of early stabilization of the vitals, including early controlled ventilation. The dangers of overzealous hyperventilation, early lumbar puncture as well as the basis for the current recommendations for fluid therapy in modern neuro-critical care are discussed. Many algorithms in standard western literature are based on continuous intracranial pressure (ICP) measurement, a monitoring modality that is not widely available in India. The following guidelines outline ten steps of empiric ICP management, an approach that may have limitations of significant over- and under treatment with attendant complications. Guidelines for differentiating causes of coma are shown in Table I(1-9)

Management goals

The main goals of care include optimizing cerebral blood flow (CBF)/ cerebral perfusion pressure (CPP) and minimizing factors that can aggravate neuronal injury or trigger intracranial pressure (ICP) elevation(9-12).

1. Assess the Airway, Breathing and Circulation (ABCs)

The airway should be stabilized and an assessment made for the need for intubation. Even if spontaneously breathing with normal gas exchange, many comatose children will benefit from intubation, especially if they have intracranial hypertension(9,11). Early intubation, ventilation and deep sedation are often overlooked as key interventions for ICP control(10).

A GCS below 8 has been the standard

TABLE I– Causes of Coma (TIPS from VOWELS)(1,9)

T	Trauma, head injury	Shaken baby syndrome: non-specific history, retinal hemorrhages.
I	Intussusception Insulin, Hypoglycemia Inborn errors of metabolism	Mental status changes may precede abdominal finding
P	Psychogenic	Common in adolescents
S	Seizures	Post-ictal states, non-convulsive status may masquerade as undifferentiated coma.
	Shock, stroke	Coma secondary to poor brain perfusion, arterial and venous infarcts
	Shunt	Blocked or infected ventriculo-peritoneal shunts
A	Alcohol ingestion, abuse	
E	Electrolytes Encephalopathy	Disturbances of sodium, calcium, magnesium Hypertensive, Reye syndrome, hepatic failure, urea cycle defects, lead encephalopathy
I	Infections	Encephalitis, meningitis, malaria
O	Overdose, ingestion	Consider with unexplained loss of consciousness
U	Uremic encephalopathy	

Important causes of coma in Indian children include bacterial, tuberculous and viral meningoencephalitis, malaria; non-infectious causes including stroke, ingestions and Reye syndrome(2-8).

indication for intubation. Recent literature however states that intubation should be considered in patients with a GCS below 12(11). Other indications for intubation include deterioration in the level of consciousness, evidence of herniation and irregularities in respiration (*Table II*)(9-11).

The blood pressure should be kept at the higher range of normal (for age). This requires ensuring appropriate fluid and inotrope management(10,11).

2. *Assess and Treat for Immediately Correctable Cause of Coma*

Perform bedside capillary glucose test and correct if low, send samples to lab for routine hematological and biochemical testing.

3. *Assessment of the Depth of Coma*

The standard assessment tool is the Glasgow Coma Score (GCS) in older children

and modified GCS in children <5 years old(1,2,13). The AVPU score A (Awake), V (Response to verbal commands), P (Response only to pain), U (unresponsive) is an alternate coma score(1).

4. *Assessment and Treatment of Raised ICP*

The focus of contemporary ICP management has changed in recent years in two important aspects: firstly, increasing emphasis on CPP (cerebral perfusion pressure) management in addition to ICP control and secondly, the increasing recognition of the potential for overzealous hyperventilation to aggravate cerebral ischemia by reducing CBF(9-12).

CPP = Mean arterial pressure (MAP) – Intracranial pressure (ICP)

Cerebral ischemia may result when CPP is lowered, either from raised ICP or lowered MAP (hypotension). When the ICP is critically raised, herniation syndromes (uncal, central or

medullary herniation) can occur, which, along with hypoxic-ischemic damage from reduced CPP, are the most important causes of death(10,11). *Table III* describes the signs of herniation(9,11).

If raised ICP is clinically suspected, therapeutic measures should be immediately instituted as papilledema may not be seen in acutely elevated ICP and fatal herniation can occur even after a “normal” CT scan(11,14).

Role of Mannitol

Mannitol is indicated acutely for patients in whom there is a strong clinical suspicion of raised ICP or imminent herniation(9-11). Mannitol has two distinct effects(9,10,15). The immediate effect is related to its rheologic properties (decreased blood viscosity) resulting in a transient increased CBF followed by a more sustained fall in CBF. The delayed osmotic effects occur after 15-30 minutes and last for 4-6 hours. Urinary fluid losses should be replaced with normal saline to avoid volume depletion(10).

Emerging Role of Hypertonic Saline (HTS) (16-21)

HTS acts like mannitol by establishing a constant osmolar gradient in order to draw

fluid from the brain parenchyma but without the risks of dehydration and tubular damage as in the case of mannitol. In the hypotensive/hypoperfused patient, HTS may be the osmotherapy of choice for reducing ICP while maintaining MAP/ CPP, although most literature in this context is in reference to adults(16,17).

However, beneficial effects of HTS with a low frequency of side-effects have been described in the setting of pediatric traumatic brain injury(18,19) and cerebral edema occurring during DKA treatment in children(20-21).

5. Anti-seizure Medications in Coma

Convulsions can cause massive increases in CBF, consequent increase in ICP, can lead to secondary brain damage and may precipitate or be precipitated by cerebral herniation(9-12). Apart from generalized tonic clonic seizures (GTCS), some comatose children may have non-convulsive seizures (NCS) manifesting with subtle signs such as eyelid twitching, eye deviation or nystagmus(11). A bedside EEG may be informative(22). If in doubt, empiric treatment of seizures may be justified and can result in improvement of consciousness(11).

6. Neuro-imaging

Urgent imaging is indicated in afebrile coma and the presence of focal signs or papilledema, as the diagnosis includes stroke, intra-cranial bleed, tumor or hydrocephalus(11,22). However, any child who does not have a very obvious metabolic/ toxic cause for the coma generally requires to be imaged. A CT scan may provide information about the cause of altered mental status and the presence of intracranial hypertension(22), however a normal CT scan does not rule out raised ICP(11).

An MRI may be more specific for early

TABLE II—*Signs of cerebral herniation(9-11)*

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|--|
| 1. Glasgow coma score <8 |
| 2. Abnormal pupil size and reaction (unilateral or bilateral) |
| 3. Absent doll's eye movements |
| 4. Abnormal tone (decerebrate / decorticate posturing, flaccidity) |
| 5. Hypertension* with bradycardia* |
| 6. Respiratory abnormalities (hyperventilation, Cheyne-Stokes breathing, apnea*, respiratory arrest) |
| 7. Papilledema (rare, especially in infants) |

* (Cushings Triad) - Late findings

TABLE III - Mannitol: Concerns and contra-indications(10,11,17)

Concerns	Effects	How/ when to avoid
Excess diuresis	Hypovolemia, fall in CPP	Lower doses 0.25-0.5 g/kg (1.2-2.5 ml/kg of a 20% solution) repeated 4-6th hourly*
Use in focal pathology with midline shift: (<i>e.g.</i> , necrotizing encephalitis, edema surrounding intracranial hemorrhage, tumor, infarct)	Mannitol may cause “selective debulking” of normal brain parenchyma with increase in midline shift	Mannitol should be reserved for features of severely increased ICP or impending herniation
Rebound effect	Worsening edema after discontinuation	Limit use to less than 48-72 hours Use smaller doses Avoid concurrent hypotonic IV fluid or dilute enteral feeds
Contra-indications		Hypotension Renal failure Serum osmolality > 320mOsm/kg

* Emergency therapy for herniation syndromes: 1.0-1.5 g/kg of 20% mannitol, Subsequent doses: 0.2.5-0.5 g/kg Q4-6H, measure serum osmolality

changes of herpes simplex encephalitis (where CT may be normal), posterior fossa and white matter pathology(9,11) . A cranial ultra-sound may miss subdural collections or even extensive infarcts and a CT or MRI is an essential investigation in a deeply comatose infant even when the anterior fontanelle is open(11).

7. Lumbar Puncture (LP) in a Comatose Child

The potential benefits of early LP include making an early diagnosis of CNS infection and identification of the pathogen and drug sensitivities(9,23). Contra-indications for LP include signs of cerebral herniation, low GCS, focal neurological signs, or cardiorespiratory compromise(9,11,23). In an unconscious child with potential raised ICP , the decision is controversial with some authors stating that the risk of herniation far outweighs the benefit of knowing the pathogen from an early LP(24).

8. Choice of Empiric Antimicrobials

If a CNS infection is suspected in a febrile child presenting in acute coma and seizures, empiric anti-microbial should include acyclovir in addition to a third generation cephalosporin until further confirmatory tests are available(11). The need for empiric antimicrobials should be carefully assessed(6,11).

9. Fluid Therapy

There is accumulating data that hypovolemia worsens outcome in children with meningitis(25-27), malaria(28) and severe head injury(18,19). Hypovolemia (fluid restriction, diuretics) can lower the CPP and lead to worse ICP due to auto-regulatory vasodilation(10) .What must be restricted are hypotonic fluids such as 1/5th normal saline in 5% dextrose (Isolyte P). The dextrose will be metabolized with a resultant hypotonic fluid that can exacerbate cerebral edema and ICP(10-12). Adult and pediatric literature stress the importance of avoiding both

hyperglycemia as well as hypoglycemia since the former can also worsen neurological outcome(10,18,19,29).

Enteral feeds should be started at the earliest(11,18).

10. Management of persistent raised ICP in the ICU

If despite the above treatment, the patient continues to show evidence of raised ICP, further measures to tackle refractory raised ICP must be instituted. Specific surgically correctible lesions should be attended to.

While steroids should not be used for ICP related to infarcts, hemorrhage or trauma, the use of dexamethasone for vasogenic edema related to tumors, granulomas and abscesses can lead to dramatic reduction in lesion volume(10).

Head end elevation by 30° (provided patient not hypotensive)(30) and avoidance of neck kinking are important. Fever, agitation and seizures must be assiduously controlled as they can cause massive increases in CBF and CPP(9-12). If ventilated, the PaCO₂ should be maintained in the low 30s in order to prevent cerebral ischemia(9-12,31). More extreme hypocapnia can be employed as a short-term temporizing measure for acute deterioration(10,11).

Barbiturate coma(9,18,19) and/or mild hypothermia(19,32) are used in some centers in order to reduce the cerebral metabolic rate for oxygen (CMRO₂) and thus the cerebral blood flow, although most references pertain to adults(32). Hypotension during barbiturate use may require vasopressors to optimize the MAP/ CPP(10,12).

In ICP refractory to medical measures, surgical decompression has been shown to improve survival and functional outcome(33).

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REVIEW ARTICLE

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