

Increased ICP

An increase in intracranial pressure which can be due to many underlying etiologies which must be considered separately, including hemorrhage, hematoma, tumor, edema, TBI, hydrocephalus, AVMs or aneurysm

ANESTHETIC CONSIDERATIONS:

- Conflict with potential difficult airway management
- Avoid factors which ↑ ICP
 - Shivering
 - Seizures
 - Hypertension
 - Coughing/bucking/straining
 - Succinylcholine?
 - Volatile anesthetic agents/N2O/Ketamine
- Maintain CPP
- Prevent secondary neurologic injury
 - Hypotension, hypoxia, hyper/hypoglycemia
- Cardiorespiratory instability (irregular breathing, dysrhythmias, HTN, hypotension, inferior wall MI)
- Neurologic Dysfunction (↓ LOC, herniation, ischemia)

ANESTHETIC GOALS:

1. Maintenance of CPP
2. Treat or prevent increased ICP
3. Maintain stable hemodynamics

HISTORY

- Standard anesthetic history
- ICU history and history of increased ICP

PHYSICAL

- **HEENT** - Airway - assess patency, difficulty to intubate, ?ability to protect
- **RESP** - Irregular breathing (respiratory rate and pattern)
- **CVS** - Dysrhythmias (tachycardia, bradycardia, ↑ QT), unstable BP(↑ / ↓)
- **CNS** - GCS, headache, vomiting, stiff neck, focal neurological deficits, papilledema
- **GU** - SIADH (oliguria) or DI (polyuria)

INVESTIGATIONS

- **Labs**
 - Serum and Urine Lytes and Osmolarity
- **Imaging**
 - ECG, ECHO
 - CT Head, MRI Head, Cerebral Angiographs

OPTIMIZATION

- HOB at 30°
- Neutral head position (encourage venous drainage)
- Moderate hyperventilation with PaCO₂ 25-30mmHg (AVOID ↑ CO₂, ↓ O₂)
- Osmotic therapy (mannitol) and diuresis (lasix)
- Corticosteroids (neoplasm or abscess)
- CSF drainage (VP Shunt)
- Stable hemodynamics
- Treatment of primary cause (removal of tumor, hematoma, abscess)
- Sedation, paralysis and controlled ventilation
- Consider other issues (STP, avoid glucose containing solutions, isotonic solutions and colloids)

ANESTHETIC OPTIONS

- GA

ANESTHETIC SETUP

- **Drugs**
 - Emergency drugs
- **Equipment**
 - Routine (including temp)
 - Art Line
 - CVP
 - Foley
 - ICP monitor
 - Esophageal stethoscope, precordial Doppler

MANAGEMENT OF ANESTHESIA

- **Induction**
 - Airway
 - Emergency / Not Difficult Airway

- Modified RSI (pre O₂, cricoid pressure)
 - Fentanyl, STP, Roc (0.9mg/kg)
 - Emergency Difficult Airway
 - Awake F/O intubation with good topicalization
 - Consider the use of SCh in emergency
 - Elective (fasted) / Not Difficult
 - Voluntary hyperventilation
 - Fentanyl, STP, Roc
 - Elective (fasted) / difficult
 - Awake F/O intubation
- **Maintenance**
 - 100% O₂, or O₂ / Air (50:50)
 - Moderate hyperventilation
 - Fentanyl + isoflurane (0.25%-1.2%); hyperventilation attenuates or abolishes effects of cerebral vasodilation, ↑ CBF and ↑ ICP
 - Maintain CPP > 60 mmHg
 - Avoid PEEP
 - Avoid N₂O
 - Consider no volatiles in patients with severe head injuries and run fentanyl and STP infusions and expect to keep intubated following procedure
- **Emergence**
 - Extubate promptly for early neurologic evaluation
 - Keep intubated if concerned about postoperative respiratory neurologic function

DISPOSITION & MONITORING

- HDU

COMPLICATIONS

- ↓ CPP (MAP-ICP) → brain ischemia / infarction
- Herniation

PATHOPHYSIOLOGY

- General Facts
 - ICP > 20 mmHg
 - Factors which ↑ ICP by ↑ CBF and CBV
 - HTN
 - ↑ CO₂
 - ↓ O₂
 - coughing, straining, vomiting
 - ketamine, SCh
- Mechanism
 - ↑ CSF
 - ↑ Brain (edema or tumor)
 - ↑ Blood (hemorrhage, hematoma, aneurysm)
- Etiology
 - Trauma (hemorrhage, hematoma, edema)
 - Tumors (primary, metastatic)
 - Vascular (AVMs and aneurysms)
 - Infections (Abscess, meningitis, encephalitis)
 - Hydrocephalus (obstructive)
 - Status Epilepticus
- **Monitoring:**
 - Clinical monitoring: for mild injuries with no evidence of CT pathology, frequent (q1-2h) neurological vital signs are warranted
 - Early signs of elevated ICP in the awake patient include:
 - Headache, N/V, altered LOC, papilledema
 - Late signs of elevated ICP in awake or sedated patients include:
 - Cushing's response (HTN, bradycardia), focal neurological signs, deterioration of GCS
 - Any unexplained deterioration or focal signs is an indication to repeat a CT scan
 - This may lead to surgical evacuation of mass lesion or placement of an ICP monitor
 - CT scan changes indicative of elevated ICP:
 - Midline shift
 - Distortion of ventricles or cisterns
 - Effacement of sulci
 - Any hematoma presence
 - ICP monitoring:
 - Indications for placement of ICP monitors in the setting of traumatic brain injury
 - Unevaluated head injury in the setting of non-neurosurgical emergency surgery
 - Head injury which required surgical intervention
 - History suggestive of head injury, but unable to evaluate the patient clinically
 - Types of ICP monitors: Ventriculostomy (EVD) – standard of care

TECHNIQUES OF DIRECT INTRACRANIAL PRESSURE MONITORING

ICP Monitor	Advantage	Disadvantage
Ventriculostomy	Very accurate	Must pass through brain tissue
	Access to cerebrospinal fluid for pressure control and culture	Infection
Subarachnoid bolt	Easily performed	Infection
	Bedside procedure	Less accurate
Epidural transducer	Easy to place	Questionable accuracy and reliability
	Little risk of infection	

- **Jugular Bulb Venous Saturation:**

- Physiology:
 - $CMRO_2 = \text{arterial } O_2 \text{ content} - \text{venous } O_2 \text{ content}$
 - $O_2 \text{ content} = (\text{Hb} \times \text{SpO}_2 \times 1.34) + (\text{PO}_2 \times 0.003)$
 - In practice, these values are not actually calculated, but surrogates are used (see below)
- Indications (in traumatic brain injury):
 - Some centers use it routinely, early after brain injury (< 12h)
 - Unstable or refractory ICP requiring intervention (no distinct guidelines exist for their use, however)
- Technique:
 - Retrograde insertion (same insertion point as for CVC cannulation)
 - Use of sonosite is advocated by some authors
 - Place tip of catheter (usual specialized fiberoptic catheter) just inferior to base of skull, superior to C₁ / C₂ disc on lateral X-ray
- Interpretation:
 - Raw jugular bulb saturation (SjvO₂) – used more commonly
 - 55-70% is normal
 - < 50% is critical
 - Demand > Supply
 - Increased demand (fever, seizures)
 - Decreased supply (anemia, hypoxia, decreased flow)
 - > 75% may indicate hyperemia
 - Supply > Demand
 - Increased supply (vasodilation, increased MAP)
 - Decreased demand (brain death)
 - Cerebral extraction of oxygen (CEO₂) – useful if SaO₂ is not normal
 - $CEO_2 = \text{SaO}_2 - \text{SjvO}_2$
 - 24-42% is normal
 - < 24% corresponds to high SjvO₂
 - > 42% corresponds to low SjvO₂ (see above)

- **Somatosensory evoked potentials:**

- Sensitive monitor for deep brain structure dysfunction
- May have prognostic value, but is not routinely used

- **Trans-cranial Doppler:**

- Detects regional CBF, and changes in flow
- Not used routinely

- **EEG:**

- Useful intermittently when indicated
 - To rule-out seizure activity
 - Monitor burst-suppression in barbiturate coma
 - Prognostic for possible brain death

- **Treatment of Elevated ICP:**

- Indicated if ICP > 15-20, or lower if clinical signs of deterioration exist
- These guidelines pertain to traumatic brain injury, but can be extended (in some ways) to other pathology
- **First-line treatment:**
 - Avoid hypoxia, hypercarbia, acidosis, anemia, hyperthermia, coughing, agitation, hyperglycemia
 - Aim for normovolemia (with aid of invasive monitors)
 - Determine cause, and need for possible repeat CT scan
 - Transport to OR immediately if surgical lesion present
 - Position head in neutral, and elevated at 30° to facilitate venous drainage
 - Hyperventilation to PCO₂ of 25-30 in acute ICP increases (chronic hyperventilation is associated with worse outcomes)
 - Mannitol 0.25 – 0.5 g/kg IV over 10-20 min (rapid infusion may lead to HTN)
 - Leads to decreased blood viscosity and increased O₂ delivery within 10 min
 - Provides hyperosmotic fluid shift out of brain tissue and osmotic diuresis within 15-30 min, lasts 6h
 - Do not exceed 2 g/kg per 6 hours (or serum osmolarity of 320 mMol/L)
 - Consider furosemide 0.5 mg/kg if not hypovolemic as it enhances mannitol's diuresis

