LEARNER OUTCOMES

- Discuss the interaction between intracranial pathophysiology, cerebral perfusion and general anesthesia.
- Summarize the fast-track technique for neuroanesthesia

CEREBRAL ISCHEMIA

- Result of diminished blood and/or oxygen supply to the brain
- Divided into three categories
  - Reversible or irreversible
  - Complete or incomplete
  - Global vs. focal
- Certain areas more susceptible than others to injury

CEREBRAL PHYSIOLOGY

- CMRO₂ – Cerebral Metabolic Rate of Oxygen
- CBF – Cerebral Blood Flow
- CPP – Cerebral Perfusion Pressure
- ICP – Intracranial Pressure

CEREBRAL PHYSIOLOGY

- Cerebral O₂ Consumption (CMRO₂)
  - Comprises 20% of total body O₂ consumption (250 ml O₂/min)
  - CMRO₂ greatest in grey matter
  - CMRO₂ = 3.0-3.8 ml/100g/min (50 ml/min)
  - Physiologic effects
    - Mentally alert: 3.5 ml/100g/min
    - Mentally confused: 2.8 ml/100g/min
    - Comatose: 2.0 ml/100g/min
CEREBRAL PHYSIOLOGY

• Cerebral Blood Flow (CBF)
  • Parallels Metabolic Activity
    - $1 \text{CMR} = 1 \text{CMRO}_2 = 1 \text{CBF}$
  • Normal CBF: 50-55 ml/100g Of Brain Tissue/Minute
  • 15% Of Cardiac Output
  • Regional CBF Can Vary Between 20-80 ml/100g Of Brain Tissue/Minute

REGULATION OF CBF

• Arterial CO₂ Tension (PaCO₂)
  • CBF Is Directly Proportional To PaCO₂ Between Tensions Of 20-80 mmHg
  • Blood Flow Changes Approximate 1-2 ml/100g/min Per 1 mmHg Change In PaCO₂
  - Hypocapnia Results In Vasoconstriction And Decreased CBF, CBV And ICP
  - Hypercapnia Increases CBF By 2 ml/100 g Of Brain Tissue For Each Single Torr Increase In PaCO₂

• Arterial O₂ Tension
  • Resistant To Most Changes In PaO₂ Until It Falls Below 50 mmHg
  • Hypoxemia Leads To A Profound Increase In CBF
  • Hyperoxia Is Associated With A Less Than 10% Decrease In CBF

• Mean Arterial Pressure
  • Autoregulation
  • Cerebral Perfusion Pressure (CPP)
**REGULATION OF CBF**

- **Mean Arterial Pressure**
  - Severe Hypotension Leads To Cerebral Ischemia
    - 20-25 ml/100g/min - cerebral impairment
    - 15-20 ml/100g/min – produce iso-electric EEG
    - Below 10 ml/100g/min - associated with irreversible brain damage

- **Cerebral Perfusion Pressure**
  - CPP=MAP-ICP if ICP > CVP
  - CPP=MAP-CVP if CVP > ICP
  - Normal CPP 80-100 mmHg
    - Decrease in CPP - cerebral vasodilation
    - Increase in CPP - cerebral vasoconstriction
  - Effects of CPP on EEG
    - Lower limit of CPP is 50 mmHg
    - Less than 50 mmHg - slowing EEG
    - Between 25-40 mmHg - flat EEG
    - Less than 25 mmHg - irreversible brain damage

- **INTRACRANIAL PRESSURE**
  - Determined By Contents Of Intracranial Compartment
    - Consists of brain and water-80%
    - Blood-12%
    - CSF-8%
  - Normal ICP In Supine Position 5-15 mmHg
  - Compensatory Mechanisms
    - Displacement of CSF from cranial to spinal compartment
    - Increase in CSF absorption
    - Decrease in CSF production
    - Decreased in CBV

- **INTRACRANIAL COMPLIANCE**
  - Measures The Change In ICP In Response To Changes In Intracranial Volume

- **INTRACRANIAL PRESSURE**
  - Increased ICP
    - Normal Elastance Of Intracranial Contents
      - Without Intracranial Pathology
      - Abnormal Elastance
    - Causes Include
      - Mass Lesions
      - Bleeding
      - CSF Volume
      - Air
      - Foreign Body
INTRACRANIAL COMPLIANCE
• Measures the change in ICP in response to changes in intracranial volume.

INTRACRANIAL PRESSURE
• Increased ICP
  – Normal elastance of intracranial contents
    • Without intracranial pathology
  – Abnormal elastance
    • Causes include
      – Mass lesions
      – Bleeding
      – CSF volume
      – Air
      – Foreign body

INTRACRANIAL HYPERTENSION
• Sustained increase in ICP above 15 mmHg
• Causes
  – Increase in tissue or fluid mass
  – Interference with normal CSF absorption
  – Excessive cerebral blood flow
  – Increase in brain edema from systemic derangement of blood brain barrier
• ICP > 30 mmHg
  – Decrease in CBF
  – Vicious cycle
    • Brain ischemia → brain edema → ↑ ICP → more brain ischemia

SYMPTOMS OF ↑ ICP
• Headache
• Nausea
• Vomiting
• Papilledema
• Focal neurologic deficits
• Cushing’s triad
• Altered consciousness

INTRACRANIAL HYPERTENSION
• Methods of control
  – Decrease the volume of the brain
    • Diuretics
    • Corticosteroids
  – Decrease the volume of blood
    • Hyperventilation
    • Optimized hemodynamics (MAP, CVP, PCWP, HR)
    • Positioning
    • Fluid restriction
    • Temperature control (CBF changes 5-7%/C)
  – Decrease the volume of CSF
    • CSF drainage
    • Surgical decompression

ANESTHETIC MANAGEMENT


**INTRACRANIAL MASSES**

- **Location**
  - Supratentorial vs. Intratentorial
  - Tentorium—"tent of the cerebellum"

- **Adult Tumors Are Supratentorial**
  - Meningiomas
  - Glioblastomas
  - Neuroblastomas

- **Childhood Tumors Are Infratentorial**
  - Medulloblastomas
  - Cerebellar Astrocytomas
  - Intratentorial Ependymomas
  - Brain Stem Gliomas

- **Primary vs. Metastatic**

**STEREOTACTIC NAVIGATION**

- **Three Dimensional Imaging**
  - Localizes intracranial point in relation to the computed image, using CT, MRI or angiographic studies

- **Fiducial Markers Indicate Imaging Coordinates**

- **Z-touch laser register used as alternative site marker**

- **Coordinates Of Brain Are Automatically Calibrated To Coordinates Of System**

**NEUROLOGIC MONITORING**

- **EEG monitoring**
  - Used to monitor balance between oxygen supply and demand in cerebral cortex
  - EEG changes seen when CBF decreases from norm to 20 ml/100g/min

- **Burst suppression**
  - EEG pattern of periods of electrical silence interspersed with brief periods of activity
**NEUROLOGIC MONITORING**

- **EEG Is Sensitive To All Anesthetics**
- **Volatile Agents Have Dose-dependent Suppressive Effect**
  - < 0.5 MAC – CMRO₂ decreased
  - 1.0 MAC - ↓ frequency and max. voltage
  - Greater than 1 MAC - burst suppression and isoelectricity
  - 2.0 MAC - electrical silence
- **Opioids Have Minimal Effect On EEG And Evoked Potentials**

**Evoked Potentials**
- **SSEP - Somatosensory Evoked Potential**
  - Most common used nerves
    - Median (wrist)
    - Posterior tibial nerve (ankle)
    - Peroneal nerve (popliteal fossa or below the knee)
- **MEP - Motor Evoked Potential**
  - Assesses Descending Motor Pathways

**EP Measurement**
- Latency
- Amplitude

- **Effected By Certain Anesthetics**
  - NMR-avoid with use of MEPs
  - Volatile agents decrease amplitude and increase latency
  - N₂O-decreases amplitude
  - Changes in anesthetic depth misinterpreted as change attributed to tissue viability

**ANESTHETIC MANAGEMENT: CHOOSING THE RIGHT ANESTHETIC**

- **Awake vs. General**
  - Awake Craniotomy
    - Opportunity for brain mapping
    - Preservation of functional status
    - reduction in ICU care
    - shorter hospital stay
  - General Anesthetic
    - Short acting anesthetics provide similar advantages to awake technique

**INDUCTION AGENTS**

- **Barbiturates**
  - ↓ CBF And CMRO₂
  - Maintains Responsiveness To CO₂ Changes And Autoregulation
  - Provide Protection During Focal But Not Global Ischemia
  - Anticonvulsant Activity
  - Cause Robin Hood Or Reverse Steal Phenomenon
  - Facilitates CSF Absorption
  - Highly Effective In Lowering ICP

- **Propofol**
  - Dose-dependent Reduction In CBF
  - 40-60% Reduction In CMRO₂
  - Autoregulation And Responsiveness To CO₂ Changes Are Maintained
  - Anti-convulsant Effect
  - Reduces Or Has Minimal Effect On ICP
  - More Effective Than Thiopental In Attenuating Rises In MAP, CSF Pressure And CPP During Induction
INDUCTION AGENTS

- **Dexmedetomidine**
  - Selective Alpha₂-adrenoceptor Agonist
  - Slow Onset And Offset
  - Reduces MAC By 50%
  - No Change Or Minimal Decrease In ICP As Long As MAP Is Maintained
  - Does Not Alter Seizure Threshold

- **Etomidate**
  - Depresses CMR, CBF, And ICP
  - Decreases CMR In Cortex > Brainstem
  - Decrease CSF Production And Enhances CSF Absorption
  - Epileptogenic Properties
  - Increases EP Amplitude And Latency

- **Ketamine**
  - Dilates Cerebral Vasculature
  - Causes Marked Increases In CBF And CMRO₂
  - Impedes CSF Absorption

- **Benzodiazepines**
  - Midazolam
    - Drug Of Choice Due To Short Half-life
  - Lower CBF And CMR
  - Anticonvulsant Properties
  - Significant Decreases In CPP
  - Avoid In Elderly & Unstable Patients
  - Prolong Emergence (Renal Failure)

OPIOIDS

- **Minimal Effects On CBF, CMR, And ICP**
- **Sufentanil Can Increase ICP**
- **Morphine Not Considered Optimal In Due To Poor Lipid Solubility**
- **Meperidine Avoided In Renal Failure Patient**

- **Remifentanil**
  - Acid Methyl Structure Susceptible To Esterase Metabolism In Blood And Tissues
  - Rapid Emergence
    - Increased incidence of hypertension
    - Consider transitional narcotics post-op
    - Permits Immediate Postoperative Neurologic Evaluation
  - No Effect On ICP
INHALATIONAL ANESTHETICS

• Produce A Dose-dependent Decrease In Cerebral Metabolic Rate (CMRO₂)
  – Iso >> Des = Sevo
• Up To 50% Reduction In CMR With Isoflurane
• Produces EEG Burst Suppression In Higher Doses

INHALATIONAL ANESTHETICS

• Effect On Autoregulation

INHALATIONAL ANESTHETICS

• Increase In Cerebral Blood Flow (CBF)
  – Isoflurane > Desflurane > Sevoflurane
• Minimal or no effect at 0.5 MAC
• Hyperventilation can blunt the increase in CBF
• Increased ICP In Presence Of Space Occupying Lesions
• All Volatile Anesthetics Increase CBV
• Easy To Monitor End-tidal Concentrations
• N₂O Increases CBF And Increases CMRO₂

INHALATIONAL ANESTHETICS

• Sevoflurane
  • CBF And CMRO₂ Reduced 50% Below 1 MAC
  • Autoregulation And Responsiveness Of CBF To PaCO₂ Preserved
  • Dose Dependent Increase In ICP
  • Decrease In CVR
  • SSEP And EEG Are Suppressed In A Dose-dependent Fashion

INHALATIONAL ANESTHETICS

• Desflurane
  • Rapid Onset And Emergence
  • Decreases CMRO₂
  • At 0.5 MAC, Does Not Increase CBF Or CBV

EFFECTS OF ANESTHETICS ON CEREBRAL PHYSIOLOGY

Table 25-1: Comparative effects of anesthetic agents on cerebral physiology.

<table>
<thead>
<tr>
<th>Agent</th>
<th>CMR</th>
<th>CBF</th>
<th>CBF Production</th>
<th>CBF Consumption</th>
<th>CBV</th>
<th>ICP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halothane</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Isoflurane</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Sevoflurane</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ketamine</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Propofol</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Remifentanil</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Desflurane</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Sevoflurane</td>
<td>+</td>
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<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

T = increase, L = decrease, + = definite change, − = unknown; CBF = cerebral blood flow, CBV = cerebral blood volume, CMR = cerebral metabolic rate, CVR = cerebral vascular resistance, PaCO₂ = partial pressure of carbon dioxide.
MUSCLE RELAXANTS

- Succinylcholine Increases ICP
- Non-depolarizers Have No Clinically Significant Effects On CBF And CMRO₂
- Chronic Anticonvulsant Therapy - shortened Duration Of Action Of NDMR

THE FAST-TRACK APPROACH TO NEUROANESTHESIA

PRE-OPERATIVE ASSESSMENT

- Neurological Assessment Prior To OR
- Pre-operative Meds
  - Sedatives And Opioids Avoided
  - Steroids
    - Reduce cerebral edema
    - DO NOT improve outcome or lower ICP in face of head injury
    - Complications include hyperglycemia, infection, GI bleeding

PRE-OPERATIVE ASSESSMENT

- Anti-epileptic Drugs
  - Dilantin (Phenytoin)
  - Cerebyx (Fosphenytoin)
  - Keppra (Levetiracetam)

PRE-OPERATIVE ASSESSMENT

- Anti-epileptic Drugs
  - Dilantin (Phenytoin)
    - Infusion-related adverse reactions due to the sodium hydroxide, propylene glycol and alcohol content of the intravenous formulation
    - Extravasation reported when large doses of undiluted phenoxytin are given through a small-bore catheter in a peripheral vein
    - Hypotension and arrhythmias related to rapid administration (> 50 mg/minute) rates
  - Cerebyx (Fosphenytoin)
    - Water-soluble prodrug of phenytoin that is associated with fewer infusion-related events

PRE-OPERATIVE ASSESSMENT

- Anti-epileptic Drugs
  - Keppra (Levetiracetam)
    - Devoid of cardio-toxic effects
    - Acts by binding to synaptic plasma membrane in CNS
    - Inhibits burst firing without effecting normal neuronal excitability
    - Loading dose-1 gm/24 hours
Awake Craniotomy Technique

**Pre-operative Period**
- Dexmedetomidine - 200 mcg/50 cc
  - Front load 1 mcg/kg over 10 min
  - Infuse at 0.6 mcg/kg/hr
- Scalp nerve block - Ropivacaine 0.5% 30 ml
  - Supraorbital
  - Supratrochlear
  - Auriculotemporal
  - Lesser occipital and greater occipital nerves

**Intraoperative Period**
- Maintain Dexmedetomidine infusion
- Remifentanil 1 mg/40 cc
  - Infuse at 0.03 mcg/kg/min

**MONITORING**
- Standard Monitors Plus Arterial Line
  - Permits beat to beat monitoring, extrapolation of data to determine CPP
- Central Venous Line
  - Subclavian approach preferred
  - Indirect correlation of ICP in determination of CPP
  - Central route for vasoactive drugs

**POSITIONING**
- Positioned In Head Up Position, Either Supine, Lateral Or Prone
- HOB 30 degrees
  - Promotes gravitational drainage of blood and CSF
- Sitting Craniotomies Avoided Unless Access Is Not Possible

**INDUCTION**
- Remifentanil - 0.25 ug/kg
- Propofol 1.2 mg/kg
- Rocuronium 0.6 mg/kg
- Tracheal Intubation With Reinforced Tube

**MAINTENANCE**
- Remifentanil Infusion - 0.125 ug/kg/min
- Rocuronium Infusion - 6-8 ug/kg/min
  - Based on train of four response
  - Not utilized during MEP monitoring
- Desflurane - 0.5 MAC
- If MEP Monitoring Is Used
  - Consider not using volatile agents
  - Propofol infusion 100 ug/kg/min
  - No muscle relaxants after induction dose
- Hyperventilation
  - 25-30 mmHg
  - If ICP is elevated, 20-25 mmHg

**IDEAL CHARACTERISTICS OF ANESTHETIC DRUGS**
- Allow Rapid Onset And Rapid Emergence
- Maintain Hemodynamic Stability
- Not Increase Cerebral Blood Flow (CBF)
- Decrease Cerebral Blood Volume (CBV)
- Decrease Intracranial Pressure
- Maintain CO2 Reactivity
- Maintain Cerebral Autoregulation
- Allow For Neuropysilologic Monitoring Of EP And EEG
- Does Not Increase Cerebral Metabolic Rate (CMR)
- Has Anti-convulsant Properties
- Decreases Cerebral Edema
- Protects The Brain From Ischemia
PERIOPERATIVE HYPERTENSION

• Occurrence
  – Intubation
  – Injection of Epinephrine Containing Solutions
  – Stimulation
    • Pin Placement,
    • Incision and Opening of the Bone and Dura
  – Emergence

• Vasoactive Modulators
  – Epinephrine, norepinephrine, aldosterone, and cortisol,
  – Elevated in the absence of hypertension

MANAGEMENT OF PERIOPERATIVE HYPERTENSION

• Remifentanil 200ug With Pin Placement
• Hydralazine, 10 Mg - 20 Minutes Before the End Of The Procedure
• Supplemented With Labetalol 5-10 mg Following The Discontinuation Of Remifentanil

EMERGENCE

• Ondansatron – 4mg
• Rocuronium Infusion Discontinued Prior To Scalp Closure
• Propofol Infusion Discontinued Following Closure Of Scalp
  – Small Amount Of Accumulation
• Remifentanil And Desflurane (If Utilized) Discontinued Prior To Removal Of Pins
• Transported To CT Scan 20 Minutes After Awakening And Arrival In PACU