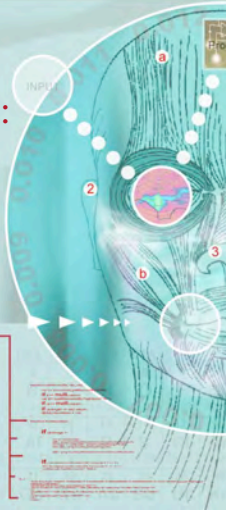


NEUROANESTHESIA: THE FAST-TRACK APPROACH

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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

- $CMRO_2$ – Cerebral Metabolic Rate of Oxygen
- CBF-Cerebral Blood Flow
- CPP-Cerebral Perfusion Pressure
- ICP-Intracranial Pressure

CEREBRAL PHYSIOLOGY

- Cerebral O_2 Consumption ($CMRO_2$)
 - Comprises 20% Of Total Body O_2 Consumption (250 ml O_2 /min)
 - $CMRO_2$ Greatest In Grey Matter
 - $CMRO_2 = 3.0-3.8$ 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
 - $\uparrow\text{CMR} = \uparrow\text{CMRO}_2 = \uparrow\text{CBF}$
 - 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

CEREBRAL PHYSIOLOGY

- Regulation of Cerebral Blood Flow
 - Arterial CO_2 Tension (PaCO_2)
 - Arterial O_2 Tension (PaO_2)
 - Mean Arterial Pressure (MAP)
 - Autoregulation
 - Cerebral Perfusion Pressure (CPP)

REGULATION OF CBF

- Arterial CO_2 Tension (PaCO_2)
 - CBF Is Directly Proportional To PaCO_2 Between Tensions Of 20-80 mmHg
 - Blood Flow Changes Approximate 1-2 ml/100g/min Per 1 mmHg Change In PaCO_2
 - -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 PaCO_2

RELATIONSHIP BETWEEN PaCO_2 AND CBF

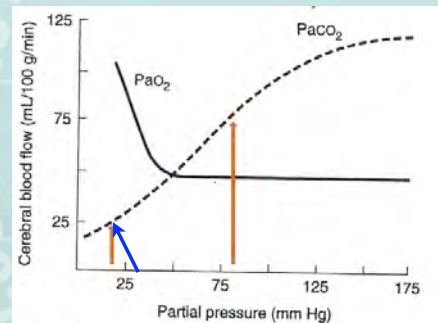


Figure 25-3. The relationship between cerebral blood flow and arterial respiratory gas tensions.

REGULATION OF CBF

- Arterial O_2 Tension
 - Resistant To Most Changes In PaO_2
 - Hypoxemia Leads To A Profound Increase In CBF
 - Hyperoxia Is Associated With A Less Than 10% Decrease In CBF

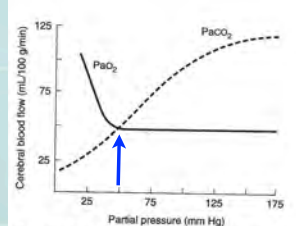


Figure 25-3. The relationship between cerebral blood flow and arterial respiratory gas tensions.

REGULATION OF CBF

- Mean Arterial Pressure

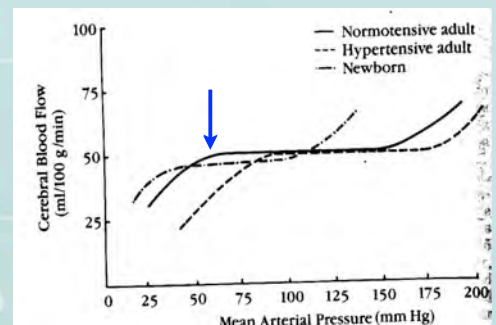


Fig. 1-5. Autoregulatory curve of the cerebral vasculature in the normotensive adult, the hypertensive adult, and the newborn.

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

REGULATION OF CBF

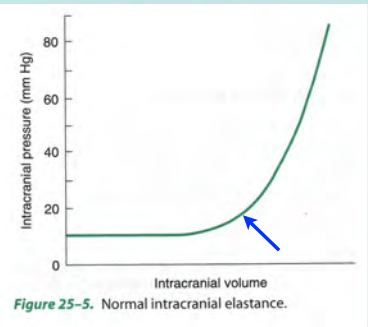
- Cerebral Perfusion Pressure
 - $CPP = MAP - ICP$ if $ICP > CVP$
 - $CPP = MAP - CVP$ if $CVP > ICP$
 - Usually $ICP < 10$ mmHg, therefore CPP dependent on MAP
 - Normal CPP-80-100 mmHg
 - Decrease in CPP - cerebral vasodilation
 - Increase in CPP - cerebral vasoconstriction
 - Effects of CPP on EEG
 - 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

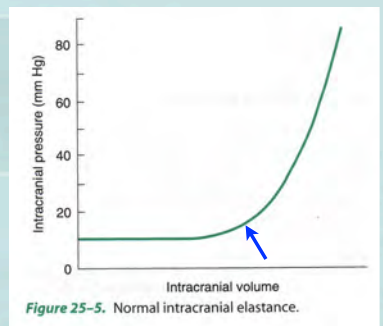


INTRACRANIAL PRESSURE

- 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

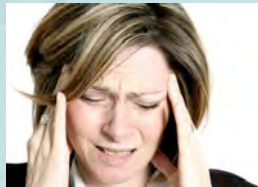
- Increased ICP
 - Normal Elastance Of Intracranial Contents
 - Without Intracranial Pathology
 - Abnormal Elastance
 - Causes Include
 - Mass Lesions
 - Bleeding
 - CSF Volume
 - Air
 - Foreign Body

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

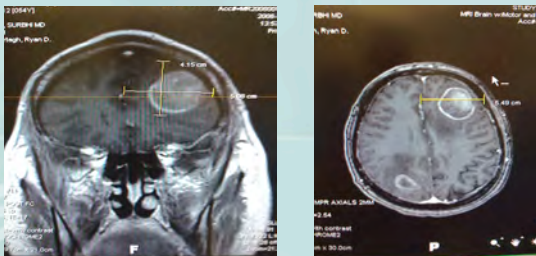
- Headache
- Nausea
- Vomiting
- Papilledema
- Focal neurologic deficits
- Cushing's Triad
- Altered consciousness



INTRACRANIAL HYPERTENSION

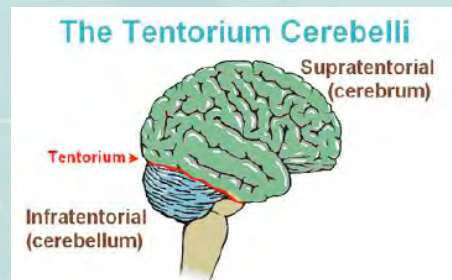
- Methods Of Control
 - Decrease the volume of the brain
 - Diuretics
 - Corticosteroids
 - Decrease the volume of blood
 - Hyperventilation
 - Optimized Hemodynamics (MAP, CVP, PCWP, HR)
 - Positioning
 - Fluid restriction
 - Temperature control (CBF changes 5-7%/C)
 - Decrease the volume of CSF
 -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

ANESTHETIC MANAGEMENT



INTRACRANIAL MASSES

- Location
 - Supratentorial vs. Intra-tentorial
 - Tentorium- "tent of the cerebellum"



INTRACRANIAL MASSES

- Adult Tumors Are Supratentorial
 - Meningiomas
 - Glioblastomas
 - Neuroblastomas
- Childhood Tumors Are Infratentorial
 - Medulloblastomas
 - Cerebellar Astrocytomas
 - Intratentorial Ependymomas
 - Brain Stem Gliomas
- Primary vs. Metastatic

STEREOTACTIC NAVIGATION

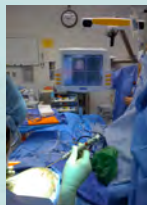


- Three Dimensional Imaging
 - Localizes intracranial point in relation to the computed image, using CT, MRI or angiographic studies

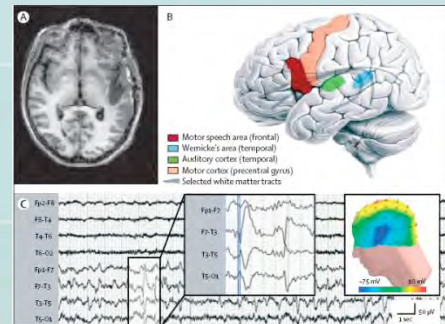


STEREOTACTIC NAVIGATION

- Fiducial Markers Indicate Imaging Coordinates
- Coordinates Of Brain Are Automatically Calibrated To Coordinates Of System.



NEUROLOGIC MONITORING



NEUROLOGIC MONITORING

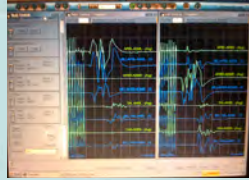
- EEG monitoring
 - Used to monitor balance between oxygen supply and demand in cerebral cortex
 - EEG changes seen when CBF decreases from norm to 20 ml/100g/min
- Burst suppression
 - EEG pattern of periods of electrical silence interspersed with brief periods of activity

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

NEUROLOGIC MONITORING

- 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



NEUROLOGIC MONITORING

- 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
 - Reduction in ICU care
 - Shorter hospital stay
 - General Anesthetic
 - Short acting anesthetics provide similar advantages to awake technique
 - Outcome data is not significant

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

INDUCTION AGENTS

- 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

INDUCTION AGENTS

- 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

INDUCTION AGENTS

- Ketamine
 - Dilates Cerebral Vasculature
 - Causes Marked Increases In CBF And $CMRO_2$
 - Impedes CSF Absorption

INDUCTION AGENTS

- 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

OPIOIDS

- Remifentanyl
 - 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

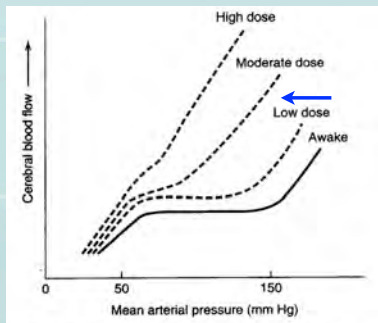
INHALATIONAL ANESTHETICS

- Produce A Dose-dependent Decrease In Cerebral Metabolic Rate ($CMRO_2$)
 - 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

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

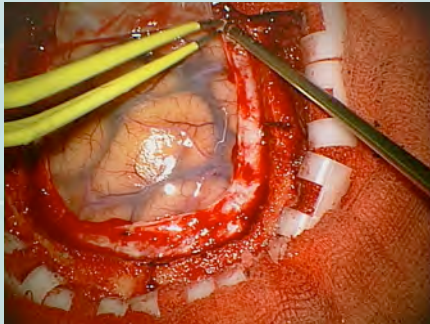
Agent	CMR	CBF	CSF Production	CSF Absorption	CBV	ICP
Halothane	↓↓	↑↑↑	↓	↓	↑↑	↑↑
Enflurane	↓↓	↑↑	↑	↓	↑↑	↑↑
Isoflurane	↓↓↓	↑	±	↑	↑↑	↑
Desflurane	↓↓↓	↑	↑	↓	?	↑↑
Sevoflurane	↓↓↓	↑	?	?	?	↑↑
Nitrous oxide	↓	↑	±	±	±	↑
Barbiturates	↓↓↓	↓↓↓	±	↑	↓↓	↓↓↓
Etomidate	↓↓↓	↓↓	±	↑	↓↓	↓↓
Propofol	↓↓↓	↓↓↓↓	?	?	↓↓	↓↓
Benzodiazepines	↓↓	?	±	↑	↓	↓
Ketamine	±	↑↑	±	↓	↑↑	↑↑
Opioids	±	±	±	↑	±	±
Lidocaine	↓↓	↓↓	?	?	↓↓	↓↓

↑ = increase; ↓ = decrease; ± = little or no change; ? = unknown; CMR = cerebral metabolic rate; CBF = cerebral blood flow; CSF = cerebrospinal fluid; CBV = cerebral blood volume; ICP = intracranial pressure.

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

- Pre-operative Meds
 - 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 phenytoin 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 pro-drug 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

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



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 Neurophysiologic Monitoring Of EP And EEG
- Does Not Increase Cerebral Metabolic Rate (CMR)
- Has Anti-convulsant Properties
- Decreases Cerebral Edema
- Protects The Brain From Ischemia

INDUCTION

- Remifentanyl-0.25ug/kg
- Propofol 1-2 mg/kg
- Rocuronium 0.6 mg/kg
- Tracheal Intubation With Reinforced Tube

MAINTENANCE

- Remifentanyl Infusion -0.125 ug/kg/min
- Additional Boluses As Necessary
- 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



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

- Remifentanyl 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 Remifentanyl

EMERGENCY

- Ondansatrom-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

