NEUROANESTHESIA: THE FAST-TRACK APPROACH

Bruce Weiner, CRNA, MS
Moffitt Cancer Center
Tampa, FL

LEARNER OUTCOMES

- Discuss the interaction between intra-cranial 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
    - ↑CMR = ↑$CMRO_2$ = ↑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 O2 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

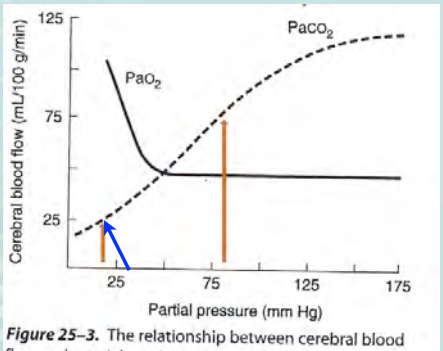


Figure 25–3. The relationship between cerebral blood flow and arterial respiratory gas tensions.

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

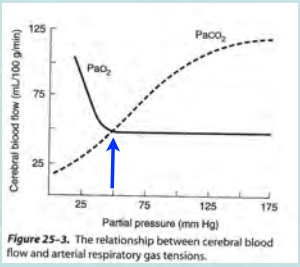


Figure 25–3. The relationship between cerebral blood flow and arterial respiratory gas tensions.

REGULATION OF CBF

- Mean Arterial Pressure

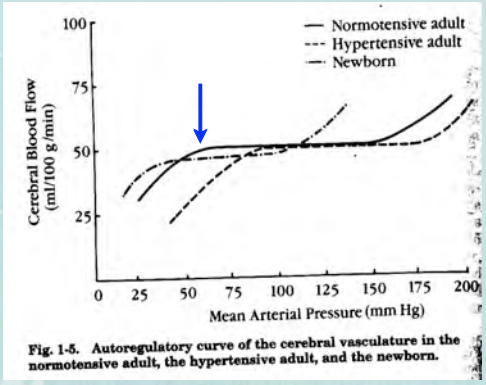


Fig. 1-5. Autoregulatory curve of the cerebral vasculature in the normotensive adult, the hypertensive adult, and the newborn.

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

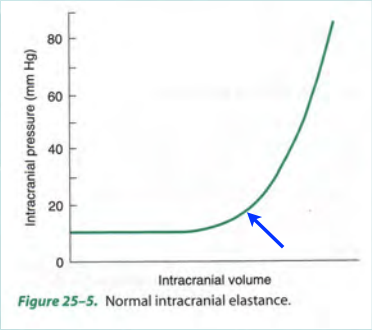


Figure 25–5. Normal intracranial elastance.

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

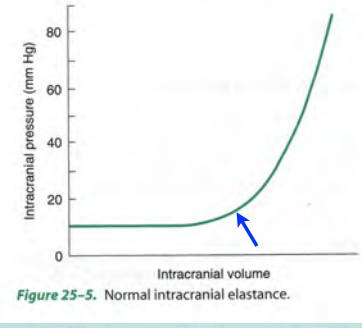


Figure 25–5. Normal intracranial elastance.

INTRACRANIAL PRESSURE

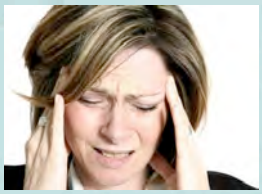
- Increased ICP
  - Normal Elastance Of Intracranial Contents
    - Without Intracranial Pathology
  - Abnormal Elastance
    - Causes Include
      - Mass Lesions
      - Bleeding
      - CSF Volume
      - Air
      - Foreign Body

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

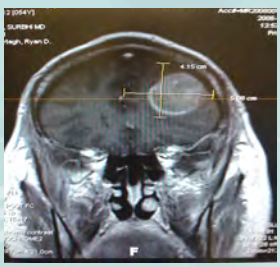
- Headache
- Nausea
- Vomiting
- Papilledema
- Focal neurologic deficits
- Cushing's Triad
- Altered consciousness



INTRACRANIAL HYPERTENSION

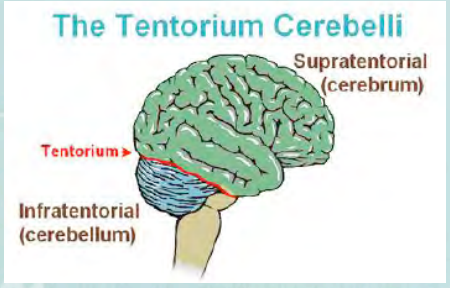
- Methods Of Control
  - Decrease the volume of the brain
    - Diuretics
    - Corticosteroids
  - Decrease the volume of blood
    - Hyperventilation
    - Optimized Hemodynamics (MAP,CVP,PCWP, HR)
    - Positioning
    - Fluid restriction
    - Temperature control (CBF changes 5-7%/C)
  - Decrease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

ANESTHETIC MANAGEMENT



INTRACRANIAL MASSES

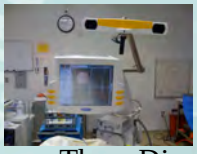
- Location
  - Supratentorial vs. Intratentorial
    - Tentorium-"tent of the cerebellum"



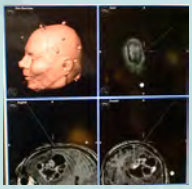
INTRACRANIAL MASSES

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

STEREOTACTIC NAVIGATION

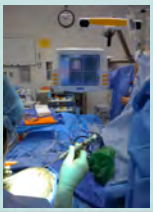


- Three Dimensional Imaging
  - Localizes intracranial point in relation to the computed image, using CT, MRI or angiographic studies

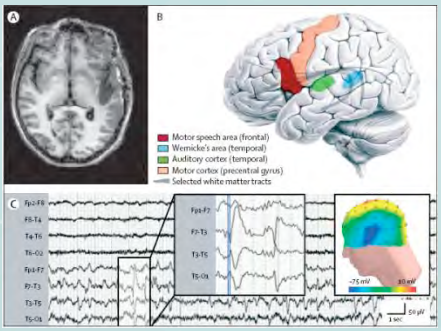


STEREOTACTIC NAVIGATION

- 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 – $CMRO_2$ 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
  - N_2O-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 $CMRO_2$
  - Maintains Responsiveness To CO_2 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 $CMRO_2$
  - Autoregulation And Responsiveness To CO_2 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 Alpha$_2$-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

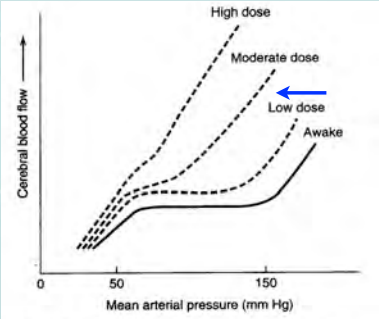
- Remifentanil
  - Acid Methyl Structure Susceptible To Esterase Metabolism In Blood And Tissues
  - Rapid Emergence
    - Increased incidence of hypertension
    - Consider transitional narcotics post-op
    - Permits Immediate Postoperative Neurologic Evaluation
  - No Effect On ICP

INHALATIONAL ANESTHETICS

- Produce A Dose-dependent Decrease In Cerebral Metabolic Rate ($CMRO_2$)
  - 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
- N_2O Increases CBF And Increases $CMRO_2$

INHALATIONAL ANESTHETICS

- Sevoflurane
  - CBF And $CMRO_2$ Reduced 50% Below 1 MAC
  - Autoregulation And Responsiveness Of CBF To $PaCO_2$ 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.

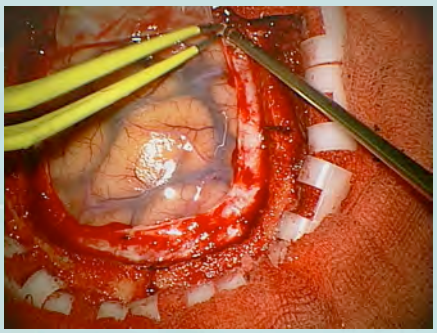
Agent	CMR	CBF	CSF Production	CSF Absorption	CBV	ICP
Halothane	↓↓	↑↑↑	↓	↓	↑↑	↑↑
Enflurane	↓↓	↑↑	↑	↓	↑↑	↑↑
Isoflurane	↓↓↓	↑	±	↑	↑↑	↑
Desflurane	↓↓↓	↑	↑	↓	?	↑↑
Sevoflurane	↓↓↓	↑	?	?	?	↑↑
Nitrous oxide	↓	↑	±	±	±	↑
Barbiturates	↓↓↓↓	↓↓↓	±	↑	↓↓	↓↓↓
Etomidate	↓↓↓	↓↓	±	↑	↓↓	↓↓
Proprofol	↓↓↓	↓↓↓↓	?	?	↓↓	↓↓
Benzodiazepines	↓↓	?	±	↑	↓	↓
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 $CMRO_2$
- 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

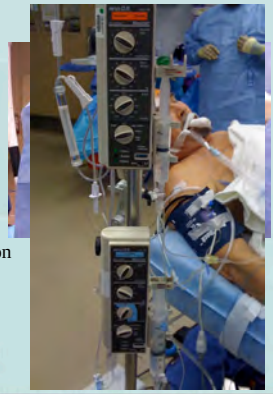
- Allow Rapid Onset And Rapid Emergence
- Maintain Hemodynamic Stability
- Not Increase Cerebral Blood Flow (CBF)
- Decrease Cerebral Blood Volume (CBV)
- Decrease Intracranial Pressure
- Maintain CO2 Reactivity
- Maintain Cerebral Autoregulation
- Allow For Neurophysiologic Monitoring Of EP And EEG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

INDUCTION

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

MAINTENANCE

- Remifentanil 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

- 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