Traumatic Brain Injury—The Anesthesiologist Saves the Day

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Lecture Outline

- Epidemiology
- Management Principles
- Care in the ER/OR/ICU
  - Anesthetic
  - Fluid
  - Physiologic abnormalities

Epidemiology

- Severity of the Problem
  - 470,000 traumatic brain injuries
    - 49% MVA, 28% falls, 22% guns-weapons
  - 70,500 die
  - 47,000 remain vegetative
- Who
  - Young adult 15-44 years
  - Men 2:1
- Types of Injury
  - Closed (includes skull fractures)
  - Penetrating (primarily gunshot wounds)

Glasgow Coma Scale (GCS)

- Parameters: Best 15, Worst 3
  - Eye Opening : Spontaneous 4, None 1
  - Best Motor Response: Obeys 6, Flexion 3, Extension 2, None 1
  - Verbal Response: Oriented 5, None 1
- Addition of Pupil Response
  - Dilated: Unilateral, Bilateral
- Grouped GCS for Outcome
  - Mild 13-15, Moderate 9-12, Severe 8 or less

Predictors of Outcome

- Initial GCS
- Age
  - < 40 years predicts poor outcome
- Gender
  - No impact
- Initial CAT or MRI Scan
- *Management Principles to prevent 2^0 injury*
  - *At scene resuscitation*
  - *Number of episodes of hypotension, hypoxia, hypercarbia, ?temperature?*

Outcome Prediction Based on *Initial* Glasgow Coma Score (1^0 injury)

Initial Glasgow Coma Score	***Outcome***		
	Good*	Moderate^	Poor#
Score 13-15	97%	2%	1%
Score 9-12	47%	50%	3%
Score 3-8	27%	32%	41%

*Return to normal life; ^ Can give self care with assistance;
#Vegetative or death

Jaggi JL et.al. J Neurosurg 72:176-182, 1990.

Glasgow Outcome Scale (GOS)

- Good outcome
  - Means can function at some level in society NOT at same level.
  - Does not measure
    - Short term memory
    - Information process (problem solving)
    - Ability to learn new information
- Many are significantly impaired when compared to previous abilities.

Hlatkey R et.al. Neurosurg Focus 14:1-6, 2003

Physiologic Principles

Maintaining CNS perfusion and oxygenation are the Critical to effective therapy!!

Maintain:

- Systolic BP ≥90 mm Hg)
- Cerebral Perfusion Pressure

  ≥60-70 mm Hg

  Where CPP =mBP-ICP
- Normoxia

  SpO_2 ≥ 95%
- Adequate O2 Carrying Capacity

  Hct ≥30%??

Effect of Hypoperfusion

Causes

- High ICP
- Hypocapnia
- Hypotension
- Hypoxia
- Anemia/ vasospasm

Outcome	Desat. Episodes None	≥2
GD/MD	77 %	23 %
SD/V	70 %	30 %
Death	31 %	69%

GD/MD: good outcome-moderate disability SD/V: Severe disability-vegetative

Outcome in TBI: Effect of Hypotension

Hypotension (n)	Outcome (%)	
	Good /Moderate disability	Severe disability/ PVS/Death
None (307)	64	36
Early (30)	40	60
Late (117)	20	80
Early and Late (39)	15	85

Modified from Chesnut RM. J Trauma 42 S4-S9, 1997.

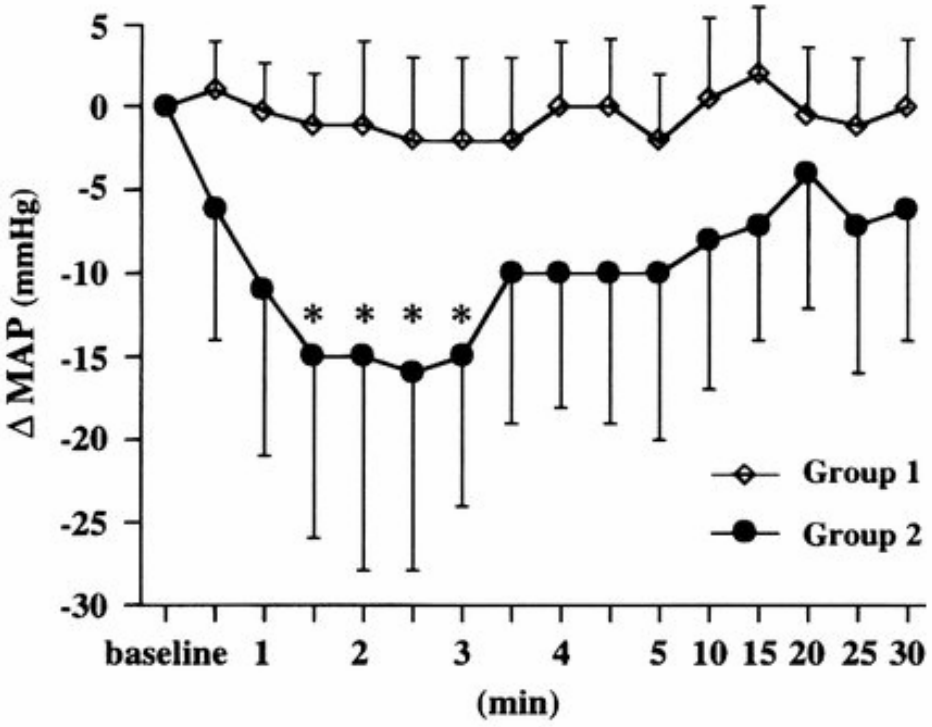
Hypotension Predicts Outcome in Head Injury (TBI)

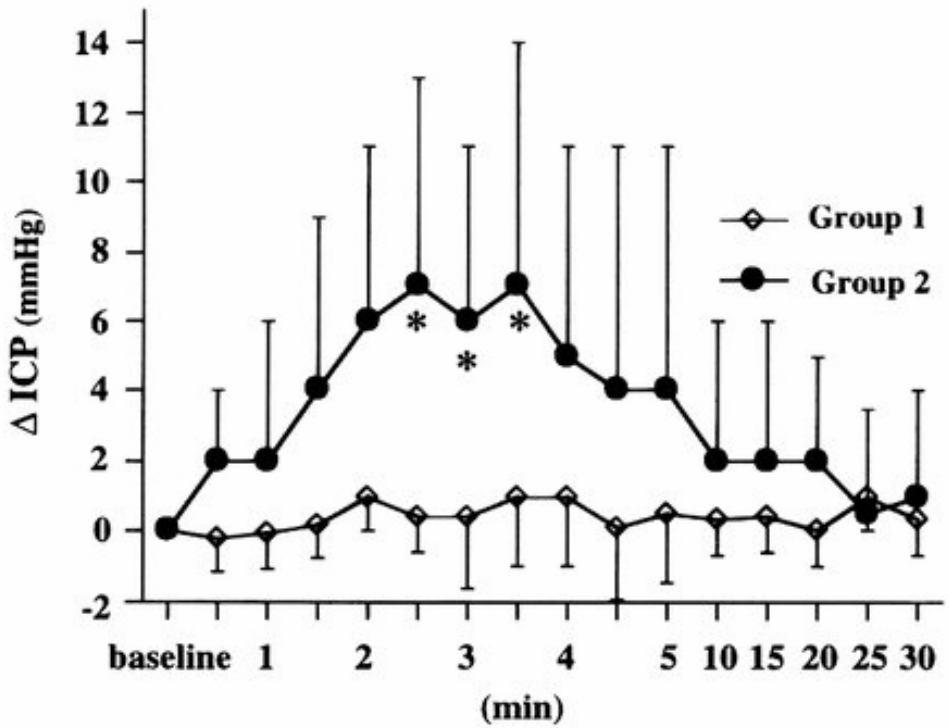
Predictor	Relative Risk	Significance (p)
Early hypotension	15-fold excess	< 0.001
Late hypotension	11-fold excess	< 0.001
Intracranial diagnosis	5.2-fold excess	< 0.001
Age	4% per year	< 0.001

- Effect of systolic BP below 90 either
  - Early--Prior to ICU admission
  - Late—After ICU admission
- Additional Risk Factors

J Trauma 44:45, 1999

Hypotension: Impact on ICP and CPP





Group 1: Control, Group 2: TBI

Werner et.al., Anesth 83:721, 1995

Maintaining Adequate CPP—At least70

CPP = mBP – ICP

- **Maintain BP above 90 systolic**
- **Keep ICP Low by reducing intracranial volume**
  - **Reduce CSF volume**
    Production—Lasix
    Absolute—venticulostomy
  - **Reduce Extra cellular Fluid –**
    Mannitol, hypertonic saline
  - **Reduce Blood Volume**
    Venous Volume with head elevation, head position
    Arterial Volume with adequate tissue oxygenation
  - Reduce oxygen demand ($CMRO_2$)
    Drugs, Temperature
  - Reduce CBF with hyperventilation (out of favor)

Hypertonic Saline (3%-10% Na)

- Primary effect reduction in extra cellular water content
- Outcome studies have not proven better outcome when compared to LR
  - All small trials in children and adults
- Risk
  - Central Pontine Myelinolysis (most likely theoretical
    - Demyelization of pons
    - SX lethargy, quadriplegia
  - SAH
  - Renal failure (4X increase)
  - Rebound intracranial hypertension

Hypothermia & Head Injury

- National Acute Brain Injury Study
  - Prospective, randomized, multi-centered
  - Temperature 33^0 C within 8 hours, 500 patients
- NO IMPROVEMENT IN OUTCOME BY ANY MEASURE
  - Mortality (28% both), Severe disability (57% both)
- INCREASED MORBIDITY

  ↑Hospital Days, Complications (Renal failure, pneumonia, critical hypotension, bradycardia etc.)

Latest Hypothermia View

- Meta-analysis which excluded multi-centered trial
- Temperature 32-33^{0}C, Time 24+ hours
- Findings

  Hypothermia 24 hours

  – 19% decrease in mortality (OR .63-.96)

  – 22% reduction in poor outcome (OR .63-.98)

  Hypothermia 48 hours, re-warm over 24 hours

  – Relative risk of death 0.7 (CI 0.56-0.87)

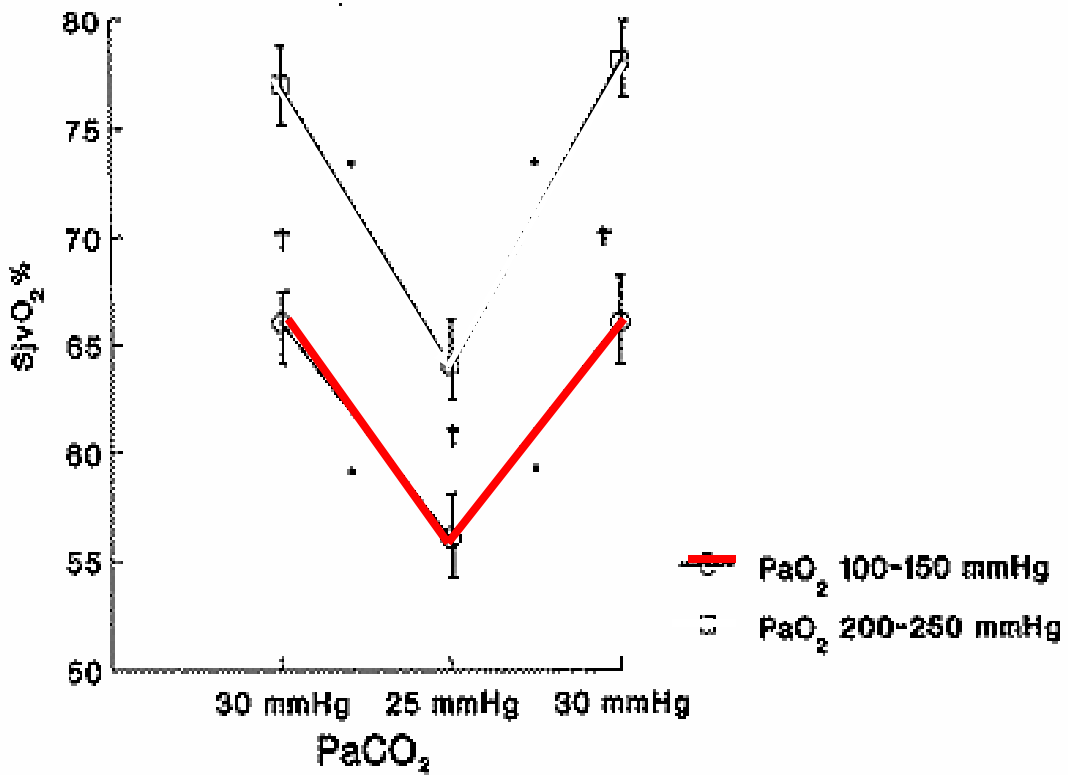
  – Relative risk of poor outcome 0.65 (CI 0.48-.89)

McIntyre LA et.al. JAMA 289:2992-99, 2003

Temperature and TBI

- Hyperthermia of >38^0C in 68% of patients with TBI within 72 hours of injury.
- Independent predictor of poor outcome (OR 4.7) and prolonged ICU admission.
- Increases CBF, tissue hypoxemia, and release of inflammatory mediators.
- Need to be prepared to control Temperature through surface cooling, antipyretics, fluids

Effect of Hyperventilation on Cerebral Perfusion



Hyperventilation does not improve cerebral perfusion.

Current College of Neurosurgery's Recommendation

- Avoid hyperventilation w/o high ICP
- Do not give steroids
- Do not give phenytoin
- Correct if BPsys <90, PaO_2 <70, CPP <60-70
- Monitor ICP as described
- Treat ICP at 20-25
- High dose Barbs maybe for refractory ICP or low $SjvO_2$

Real Life Decisions

Typical Clinical Situation

- 24 year old man who was
  - Thrown from his car, probable period of unconsciousness. Agitated and little confused but has open femur fracture and possible pelvic fracture, hematuria.
  - Ethanol 0.2, Hct 32%
  - Must go to surgery (probably a loooong surgery)
- What do you need to know to provide “best” care?
  - Does he need CNS imaging?
  - Does he need ICP monitoring?
  - Do I modify my anesthetic?
  - Does any of this matter?

Preop: What do you need?

- Good Neurologic examination
- Vital signs & ABG/SpO_2
  - Intubation?
- Tests
  - CT/MRI Scan
    - GCS 13-15
      - Had LOC, vomiting, amnesia, significant subgaleal swelling, drug impairment
    - GCS 12 or less - Everyone gets one

Indications for Intubation

ABSOLUTE

Hypoventilation

- PaO_2 < 70 torr, SpO_2 <90%, $PaCO_2$ >65 torr

Loss of airway reflexes

Obstructed airway

Expanding mass mouth or neck

Need to sedate

Hemodynamic instability

GCS ≤8

Surgery

RELATIVE

Progressive tachypnea

Flail Chest

Pulmonary aspiration

Combative behavior

Hypothermia

Seizures

Increased ICP

Mild hypoxia, hypercarbia

pHa <7.25

Intubation: Do it yourself

- Rapid sequence Intubation in field by paramedic
  - Compared historic matched controls with study group
  - Paramedic intubated group had
    - INCREASED MORTALITY
    - DECREASE IN GOS
- Cause
  - Hypoxia/hypercarbia and BP changes with intubation
  - Hyperventilation by paramedic after intubation
  - Increases in spinal cord injury
- Snatch and transport improves outcome.

Biochicchio GV et.al. J Trauma Injury Infect Critical Care 30:2619-26, 2002

Induction Issues

- Associated Injury
  - 2-21% have cervical spine injury
- Type of Intubation
  - Oral vs nasal, fiberoptic vs direct
- Full stomach
  - Crichoid pressure: Risk vs Benefit
- Drugs
  - Prevention of hypotension, hypoxia, aspiration and maybe hypertension, tachycardia
  - Hypnotic: propofol, thiopental, etomidate, ?ketamine?
  - Muscle Relaxant: succinylcholine vs rocuronium

Do what you do best!!!!

Imaging

- Indications for
  - Confusion in ER
  - Drugs use
  - Loss of consciousness at scene
  - Any indication of head or neck trauma
  - Prolonged surgical procedure

- Why Not???????

What to look for on a CT/MRI Scan?

- Injury Grades
  I. Diffuse injury no shift
  10% mortality
  II. ↓5mm shift, cistern present
  14% mortality
  III. ↓ 5 mm shift, no cisterns, diffuse edema
  34% mortality
  IV. ↑ 5 mm shift, no cisterns, diffuse edema
  56% mortality
- Space Occupying Lesion-intraparenchymal
  48% mortality

Englander J et.al Arch Phys Med Rehab 84:214-221, 2003.

Going to the OR: Monitoring Possibilities

- Intra-arterial BP
- CVP
- ICP
- Swan
- Non-invasive CO
- $SjvO_2$
- TCD

Indications for ICP Monitoring

- <50% chance of having ICP above 20 mm Hg
- GCS≥8 + abnormal CT scan
  - If normal CT scan but has 2 or more adverse outcome indicators: Age >40 years, Posturing, Known hypotension/hypoxia
- Inability to monitor neurologic status for prolonged period of time or going to the OR
- Circumstances with a high probability of secondary insult

  (e.g.. High blood loss procedure=fluid shifts, hypotension)

Probability of Increased ICP

GCS less than 9
54%

CT Scan Abnormal
60%

CT Scan Normal
13%

2 adverse indicators
60%

1 Adverse Indicator
4%

Directed Management: ICP vs CPP

- Severe head injured with GCS of 8 or below.
- Goal either low ICP <20 or CPP>70
- Kept ICP 27±12 mm Hg or maintain CPP above 83+14 mm Hg, mBP 109±14 mm Hg.

- Outcome: "Survival" and functional level increased 35-50% over predicted in CPP GROUP.

- Outcome worse if just used vasopressor to maintain BP rather than volume.

J Neurosurg 83:949, 1995.

Fluid Administration

- Crystaloid vs Colloid
  - No data to prove one better than the other as long as not hypotonic
  - NO free water but MAINTAIN VOLUME
  - (Personal Preference-Hextend)
- Maintain Hb/Hct at 10.0/30
  - Maintains oxygen carrying capacity
  - Reduces vasodilitation in response to tissue hypoxia.
  - Reduces “free water”

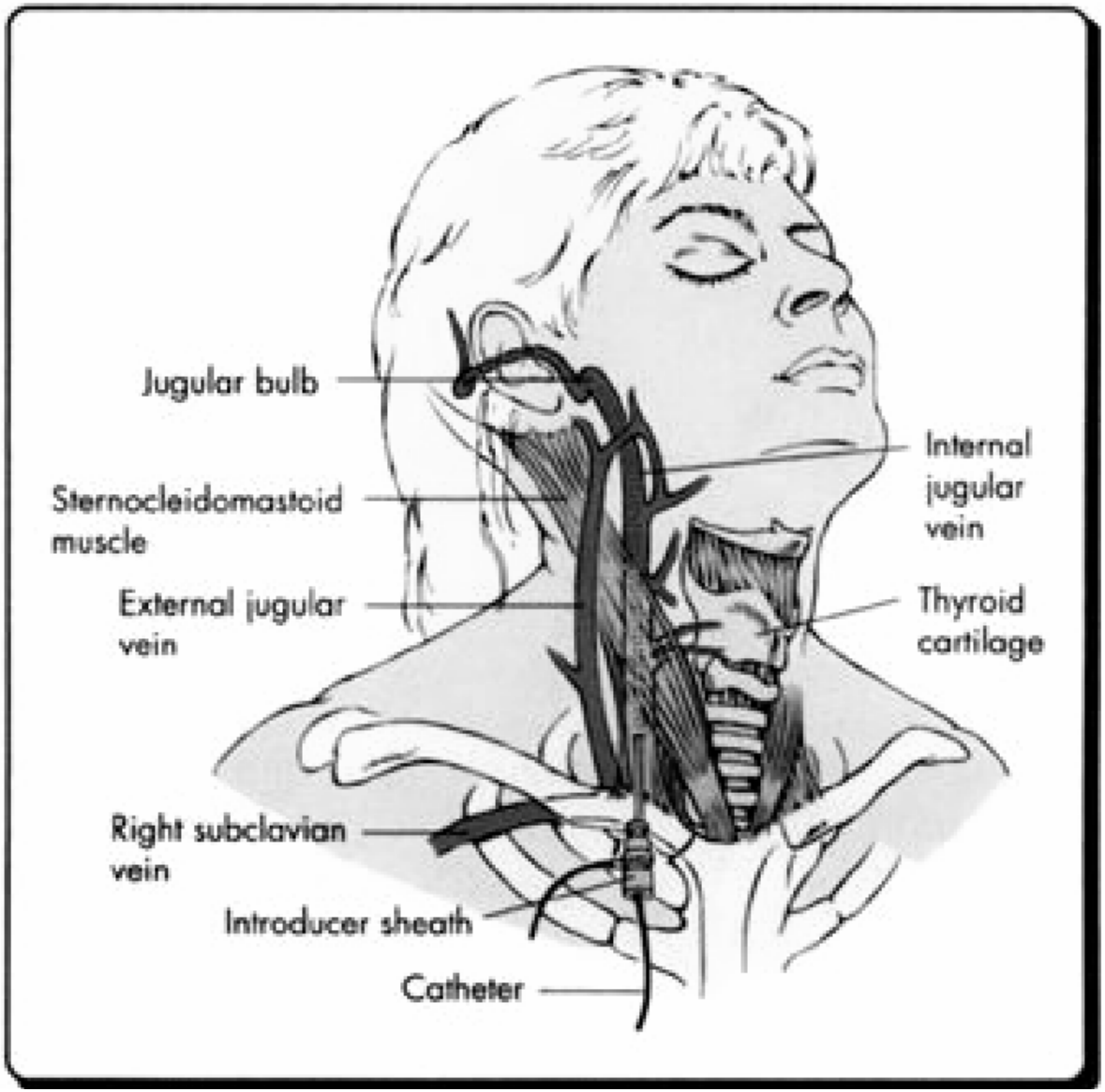
Noninvasive Cardiac Output: LIDCO

- Initial lithium dilution calibration
- Requires IV in forearm
- Restricts timing of muscle relaxant
- Add at any time
- Good Trend
- Within 85% of invasive measures

Transcranial Doppler (TCD) Detects Hypoperfusion and Predicts Outcome

	Outcome (%)		
Condition	**↓CBF**	**→CBF**	**↑CBF**
Vegetative/Dead	84	59	57
Good recovery	16	41	43

Placement of Jugular Bulb Catheter



Complications

- IJ sort
- Difficult localization
- Infection

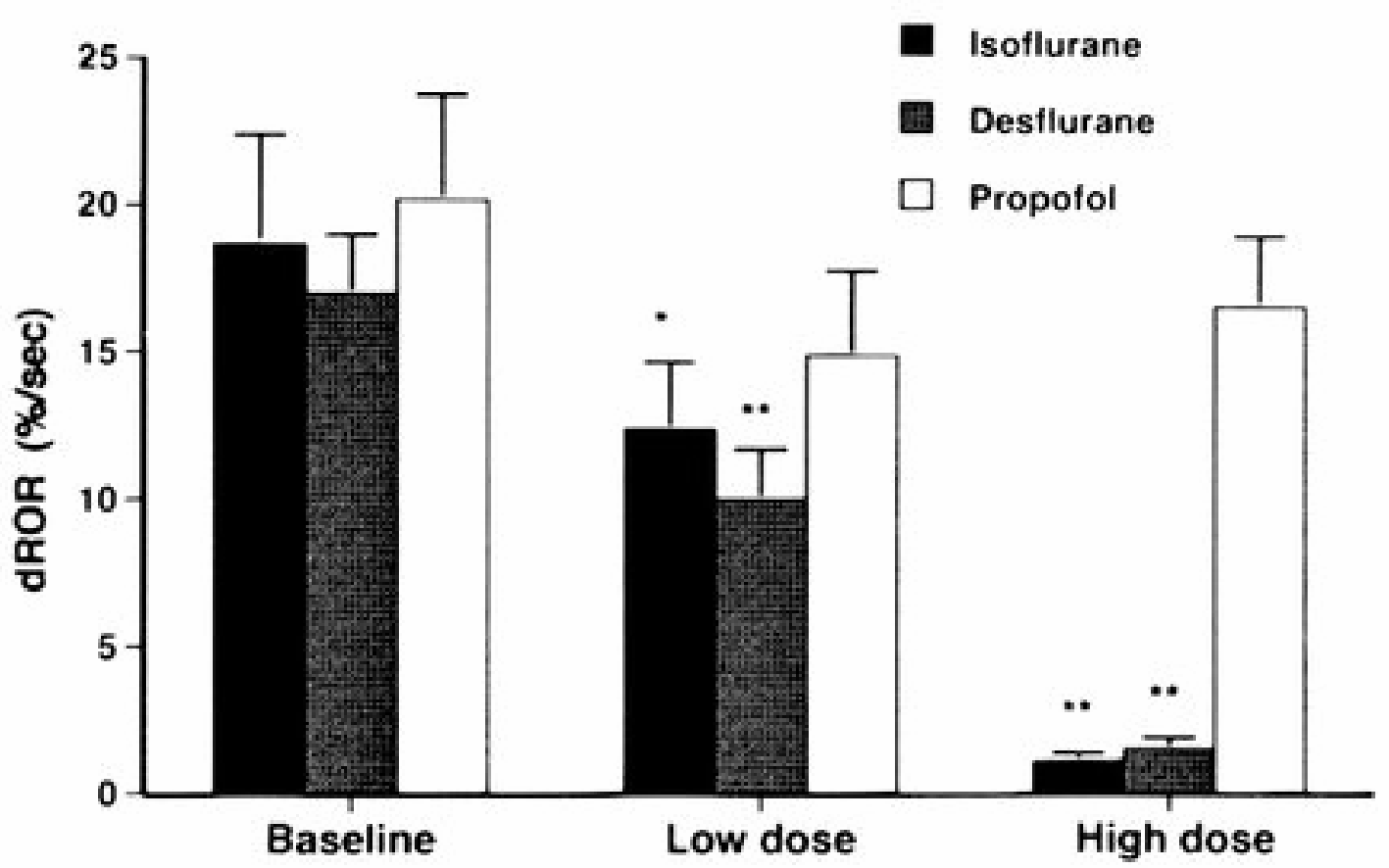
Causes and Effect of $SjvO_2$ Reported Desaturation

Condition	Desaturation Episodes	
	None	≥2
GD/MD	77 %	23 %
SD/V	70 %	30 %
Death	31 %	69%

What drugs to use?

- Volatile *still* increase CBF, CBV and usually ICP in a dose dependent manner.
- When ICP is high, propofol infusion is most likely to support brain perfusion.
- All synthetic narcotics are equivalent
  - Remifentanil is good when high dose narcotic with immediate wake up (i.e. GCS 9 at outset) is best.
- Provide CPP driven care
  - Support blood pressure as necessary but be sure you are increasing perfusion—stroke volume and cardiac output not just providing vasoconstriction.

Effect of Anesthetics on CBF



*dROR= Dynamic rate of regulation; Anesth 83:66, 1995

Patient Physiology in the OR

- Respiratory Dysfunction
  - From 1^0 injury - fat emboli
  - From TBI - neurogenic pulmonary edema,
  - From resuscitation - fluid overload
- Cardiac Dysfunction
  - From mild arrhythmias to true myocardial injury
  - ~80% will have elevated cardiac enzymes with GCS <8
- Metabolic Abnormalities
  - Elevated Glucose leads to acidosis, lipolysis, free radicals, glutamate, cell death
- Coagulopathy
- Endocrine

Coagulopathy: DIC

- Intravascular Coagulation
  - Initiated by endothelial injury, hemolysis, platelet consumption
- Contributing factors from Brain Injury
  - cAMP release
  - Thromboplastin
  - Hypothalamic stimulation to release factor VIII
- Severity correlates with amount of brain cellular death and overall outcome (never good)

Endocrine

Endocrine gland	Hormones	Change in secretion
Anterior pituitary	ACTH	Increases
	Growth hormone	Increases
	TSH	May increase or decrease
	FSH and LH	May increase or decrease
Posterior pituitary	AVP	Increases
Adrenal cortex	Cortisol	Increases
	Aldosterone	Increases
Pancreas	Insulin	Often decreases
	Glucagon	Usually small increases
Thyroid	Thyroxine, tri-iodothyronine	Decrease

Vasopressin/ADH Abnormalities

- Associated with basilar skull fracture, facial trauma, fat emboli, hypotension
- Normal release and inhibition of release varied
- Clinical manifestations

  Deficiency—hypernatremia, excessive urine output

  Rx: Vasopressin 5-10 U IM q4-6hr; DDAVP 10-20 mg intranasal or 2-5 mg IV q12-24 hrs

  Excess—hyponatremia, hypoosmolar, urine concentrated with normo or hypervolemia

  Rx: Free water restriction, diuretic, rare hypertonic saline

In Summary

- There is no place for hypotension and hypoxia in neuroanesthesia.
- Brain injury patients can exhibit a wide variety of responses to maneuvers designed to maintain CPP.
- $SjvO_2$ or some other method of monitoring the consequences actions is desirable but none are entirely reliable or available to general anesthesiologist.

Maintaining CNS perfusion and oxygenation are the ONLY goals of therapy!!