General Principles of Operative Neurosurgery

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NEUROANESTHESIA

BLOOD PRESSURE

- determines CPP.

- may need to be manipulated:
  a) **reduced** - when working on aneurysm
  b) **increased** - to enhance collateral circulation during cross clamping
- arterial line is most accurate; for intracranial procedures, arterial line should be calibrated at external auditory meatus to most closely reflect intracranial blood pressure.
- only vasopressor which reduces CSF production (→ ICP↓) is NOREPINEPHRINE.

JUGULAR VENOUS PRESSURE

- influences ICP

VENTILATION

- goal - end tidal CO_2 ($ETC0_2$) 25-30 mmHg with correlating $PaC0_2$ of 30-35 mmHg.

N.B. Keep pCO_2 low for cranial procedures but use with care for *stereotactic procedures* to minimize shift of intracranial contents!!!

HEMATOCRIT

Low Hct - improved blood rheology but decreased oxygen carrying capacity.

TEMPERATURE

- mild hypothermia provides some protection against ischemia.

Each 1° C drop → cerebral metabolic rate of oxygen ($CMRO_2$) drops by 7%

BLOOD GLUCOSE LEVEL

- hyperglycemia exacerbates ischemic deficits.

CEREBRAL METABOLIC RATE OF OXYGEN ($CMRO_2$)

- reduced with certain neuro-protective agents and by hypothermia.

ANESTHETICS

INHALATIONAL

general principles – see p. 3905 >>

- most reduce cerebral metabolism (except NITROUS OXIDE) by suppressing neuronal activity.
- disturb cerebral autoregulation and cause cerebral vasodilatation → CBV↑ → ICP↑.
- if administration > 2 hrs → CSF volume↑ → ICP↑.
- most agents increase CO_2 reactivity of cerebral blood vessels → affect intra-operative EP monitoring.

NITROUS OXIDE (N_2O s. "LAUGHING GAS")

- major component of general anesthesia - **minimally influences respiration & hemodynamics**.
- low blood & tissue solubility - rapid induction and emergence.
- due to movement speed, N_2O may retard oxygen uptake after N_2O anesthesia termination → **diffusion hypoxia** (H: 100% O_2).
  N.B. at least 20% oxygen always must be co-administered!
- **potent analgesic** but weak general anesthetic! no respiratory depression, no muscle relaxation!

  - provides ***only PARTIAL anesthesia*** (MAC - 104%) - no sufficient potency to be used alone (used in combination with potent volatile agents - permits lower dose of them).
  - 80% N_2O cannot produce surgical anesthesia (add *opioids* for analgesia, *thiopental* for narcosis, *neuromuscular blocker* for muscle relaxation).
  - 30% N_2O + O_2 is useful analgesia in dental surgery.
- potent vasodilator → CBF↑↑↑
- minimally ***increases cerebral metabolism***
- least c/v effects, least hepatotoxicity – **safest inhalational anesthetic**!!!
- high incidence of postoperative ***nausea & vomiting***.
- most important clinical problem - ***nitrous oxide is 34 times more soluble than nitrogen*** and diffuses into closed gas spaces faster than nitrogen diffuses out → nitrous oxide increases volume / pressure in these spaces;

  nitrous oxide is contraindicated in presence of ***closed gas spaces***:
  1) pneumocephalus - may convert to "tension pneumocephalus" (prevention: filling cavity with fluid + turning off $N_2O \geq 10$ minutes prior to dural closure)
  2) pneumothorax, pulmonary cysts
  3) small bowel obstruction
  4) middle ear blockage
  5) retinal surgery (intraocular gas bubble is created).
- in chronic abuse may cause leukopenia.

HALOGENATED AGENTS

- all suppress EEG activity (except enflurane) - some degree of cerebral protection.

ISOFLURANE general aspects see p. 3905 >>

- can produce isoelectric EEG without metabolic toxicity - improves neurologic outcome in cases of incomplete global ischemia (although in experimental studies on rats, amount of tissue injury was greater than with thiopental).

DESFLURANE general aspects see p. 3905 >>

- cerebral vasodilator (increases CBF and ICP) but decreases CMRO (compensatory vasoconstriction).

SEVOFLURANE general aspects see p. 3905 >>

- mildly increases CBP and ICP, and reduces CMRO.

ENFLURANE general aspects see p. 3905 >>

- induces **epileptiform EEG changes** (relatively contraindicated in seizure disorders).

INTRAVENOUS

Barbiturates
- see p. S50 >>

KETAMINE
- see p. Rx3 >>

PROPOFOL
- see p. Rx3 >>

MIDAZOLAM (Versed®)
- see p. Rx3 >>

ETOMIDATE
- see p. Rx3 >>

DEXMEDETOMIDINE (Precedex®)
- see p. Rx3 >>

OPIOIDS

- see p. 3905 >>

NEUROMUSCULAR BLOCKERS

- see p. 3905 >>

MEDICATIONS

ANTIBIOTICS

N.B. if operating for suspected infection – skip antibiotics until cultures are sent!

- antibiotic prophylaxis not indicated for EVD insertion or drains.
- intraoperative redosing - to ensure adequate serum and tissue concentrations if:
  a) procedure duration exceeds 2 half-lives of antibiotic
  b) excessive blood loss during the procedure
- postoperatively (order 1st dose now) – for 24 hours

STANDARD

CEFAZOLIN (Ancef®)

Parameter	Manufacturer's labeling	American Society of Health-System Pharmacists, Infectious Diseases Society of America, Surgical Infection Society, Society for Healthcare Epidemiology of America (ASHP/IDSA/SIS/SHEA)
Dose	1 g IV or IM	2 g IV (1 g if patient < 60 kg; 3 g if patient > 120 kg; 30 mg/kg for kids)
Initiate	30-60 minutes prior to surgery	within 60 minutes prior to surgical incision
Re-dose intraop (T½ 1.2-2.2 hrs)	0.5-1 g after 2 hours	in 3-4 hours
Postoperatively	0.5-1 g every 6-8 hrs for 24 hrs	

ALLERGY TO PENICILLINS

Type I Hypersensitivity (i.e. anaphylaxis) only!

- type 1 reactions occur 30–60 minutes after administration.
- CEPHALOSPORINS and CARBAPENEMS can safely be used in patients with an allergic reaction to penicillins that is not type 1 reaction (e.g. anaphylaxis, urticaria, bronchospasm) or exfoliative dermatitis (Stevens-Johnson syndrome, toxic epidermal necrolysis).

VANCOMYCIN

Parameter	Value
Dose	15 mg/kg (e.g. 1 g) IV; same for kids
Initiate	within 120 minutes of incision*
Re-dose intraoperatively (T½ 4-11 hrs)	after 6-8 hours
Postoperatively	1 g every 12 hrs 2 doses

*The Society of Thoracic Surgeons recommends over 60 minutes with completion within 1 hour of skin incision!

- for patients colonized with MRSA, single 15 mg/kg preoperative dose may be added to other recommended agents.

CLINDAMYCIN

- 600 mg (20 mg/kg for kids) IV 30-60 minutes before procedure with no follow-up dose needed.

Table 1.
Recommended Doses and Redosing Intervals for Commonly Used Antimicrobials for Surgical Prophylaxis

Antimicrobial	Recommended Dose: Adults[a]	Recommended Dose: Pediatrics[b]	Half-life in Adults With Normal Renal Function, hr[19]	Recommended Redosing Interval (From Initiation of Preoperative Dose), hr[c]
Ampicillin–sulbactam	3 g (ampicillin 2 g/sulbactam 1 g)	50 mg/kg of the ampicillin component	0.8–1.3	2
Ampicillin	2 g	50 mg/kg	1–1.9	2
Aztreonam	2 g	30 mg/kg	1.3–2.4	4
Cefazolin	2 g, 3 g for pts weighing ≥120 kg	30 mg/kg	1.2–2.2	4
Cefuroxime	1.5 g	50 mg/kg	1–2	4
Cefotaxime	1 g[d]	50 mg/kg	0.9–1.7	3
Cefoxitin	2 g	40 mg/kg	0.7–1.1	2
Cefotetan	2 g	40 mg/kg	2.8–4.6	6
Ceftriaxone	2 g[e]	50–75 mg/kg	5.4–10.9	NA
Ciprofloxacin[f]	400 mg	10 mg/kg	3–7	NA
Clindamycin	900 mg	10 mg/kg	2–4	6
Ertapenem	1 g	15 mg/kg	3–5	NA
Fluconazole	400 mg	6 mg/kg	30	NA
Gentamicin[g]	5 mg/kg based on dosing weight (single dose)	2.5 mg/kg based on dosing weight	2–3	NA
Levofloxacin[f]	500 mg	10 mg/kg	6–8	NA
Metronidazole	500 mg	15 mg/kg Neonates weighing <1200 g should receive a single 7.5-mg/kg dose	6–8	NA
Moxifloxacin[f]	400 mg	10 mg/kg	8–15	NA
Piperacillin–tazobactam	3.375 g	Infants 2–9 mo: 80 mg/kg of the piperacillin component Children >9 mo and ≤40 kg: 100 mg/kg of the piperacillin component	0.7–1.2	2
Vancomycin	15 mg/kg	15 mg/kg	4–8	NA
Oral antibiotics for colorectal surgery prophylaxis (used in conjunction with a mechanical bowel preparation)				
Erythromycin base	1 g	20 mg/kg	0.8–3	NA
Metronidazole	1 g	15 mg/kg	6–10	NA
Neomycin	1 g	15 mg/kg	2–3 (3% absorbed under normal gastrointestinal conditions)	NA

LOCAL ANESTHETICS

Pharmacology - see p. 2229 >>

- for **craniotomies:**
  - *inject* local anesthetic with epinephrine *after prepping but before going to scrub arms* – gives time for epinephrine to work (excellent hemostasis).
  - inject in two layers (skin, under pericranium) – excellent hemostasis!

MANNITOL

- 1 g/kg bolus.
- timing:
  a) when Foley is in, before even incision (Dr. Broaddus) – maximum action starts after 30 minutes and lasts several hours.
  b) at start of bone work (Dr. Ritter, Dr. Rivet) – mannitol increases bleeding due to hypoviscosity effect.

STEROIDS

Dexamethasone.

- Dr. Broaddus – steroids are best when given before insult!

AED

– if cerebral cortex will be involved; continue 7 days postop.

PATIENT'S POSITION

Watch this at first opportunity:
http://www.neurosurgicalatlas.com/grand-rounds/Patient-Positioning-for-Intracranial-Surgery-A-Guide-for-Residents-an-Fe

- head lowering (Trendelenburg) - increases arterial blood flow, but also increases ICP by impairing venous outflow.
- prone position + excessive fluids:
  1) facial edema (risk factor for posterior ischemic optic neuropathy with blindness)
  2) airway edema (no cuff leak – unable to extubate)
  3) abdominal volume is made pendulous between bars – decreased spinal venous epidural bleeding but also kidney perfusion↓ (decreased UO).
- during procedure, patient's position may change and be unnoticed due to draping.
- Dr. Broaddus likes to avoid any rotations (of head or bed) – everything must be in perpendicular planes – helps with spatial orientation even without navigation.

SKULL CLAMPS

- see p. Op140 >>

N.B. after application of skull clamp, the only allowed patient torso movement is Trendelenburg / Reverse Trendelenburg or Left / Right rotation.

No flexing of torso after pin application – causes stress on pins and neck!

PREP

- no hair clip (Dr. Ritter, Dr. Broaddus) or minimal clip (Dr. Holloway).
- chlorhexidine sponge (general cleaning)* → isopropyl alcohol gauze (degreasing) → mark** skin incision (this way marking stays well) → ChloraPrep x2 (3 minutes apart)***

*Dr. Ritter - not needed if done chlorhexidine towels at home
**no per Dr. Ritter – child's parents do not like it.
***chlorhexidine is contraindicated at age < 2 months

HEMOSTASIS

- brain is vascular organ; 15--20% of cardiac output is distributed to brain.
- much of neurosurgical training is focused on how to avoid and stop bleeding:
  - stray in midline
  - stay on bone ("bone is home" – subperiosteal dissection)
- avoiding bleeding is easier that stopping it.

PREOPERATIVE ASSESMENT

1. History (personal and familial) - bleeding / clotting problems.
2. Laboratory studies: PT/INR, aPTT, platelet count, BUN & creatinine, LFT

HEMATOLOGICAL RESUSCITATION

1. Normalize temperature (patient's and fluids)
2. Correct platelets – goal > 100 (< 50 is absolute contraindication to neurosurgery)
3. Correct ionized calcium
4. Correct INR – goal < 1.4
5. Correct DIC and/or low fibrinogen (< 150) with cryoprecipitate.
   - rapid correction in life-threatening circumstances - use Factor VII
6. Involve anesthesia, hematology (massive transfusion protocol team)

HEMOSTASIS

- obtain proximal and distal control of major vessels early.
- avoid and control bleeding in potential spaces:
  - epidural: tack-ups along craniotomy perimeter, tenting sutures (in middle of craniotomy flap)
  - epidural veins of spine

ELECTRICAL HEMOSTASIS

- see p. Op140 >>

1. Bipolar; irrigation is important!
2. Monopolar

MECHANICAL HEMOSTASIS

a. Finger pressure
b. Elevation to control venous bleeding
c. Skin clips: Raney vs. Michel
d. Warm water
e. Coton (understand why there are so many sizes and shapes of "cottonoids")
f. Contact Agents: surgical flow seal, Oxycel, gel foam, etc., bone wax, thrombin, fibrin glue, peroxide, etc.

SYSTEMIC HEMOSTASIS

TRANEXAMIC ACID (TXA) - synthetic analogue of lysine – inhibits activation of plasminogen to plasmin, slowing the degradation of fibrin

- 10 mg/kg at the start of surgery → 5 mg/kg/hour for 24 hours after surgery.
- used in craniosynostosis surgery.

CHEMICAL HEMOSTASIS

- see p. Op140 >>