

Below are the **anesthetic protocols** for some of the **common neurosurgery cases**. However, they need to be individualized and might need modifications accordingly (discuss with your attending).

Note: do **NOT** use Lactated Ringer (LR) for any neurosurgery cases (except spine) as it is hypotonic to plasma and can increase intra-cranial pressure (ICP). Use slightly hypertonic fluids such as NS or isotonic fluids such as Isolyte.

Management of Increased Intracranial Pressure (ICP)

- Do not use inhalational anesthetic, i.e. use TIVA with propofol.
- Give mannitol 20% or 25% 0.5 – 1.0 g/kg (depending on what surgeon asks) when making initial incision or draping patient
- Hyperventilate to EtCO₂ of 30 mmHg. Check ABG and confirm the actual PaCO₂.
- Make sure patient is not coughing or bucking.
- Decadron (dexamethasone) 6-10 mg (depending on surgeon's request)
- Note: can do a neurological exam in awake patient to evaluate for increased ICP
- Elevate the head end to 30 degrees.
- If patient has EVD, you could drain 5-10 ml of CSF. Discuss with surgery.

Causes of Seizures

- Some causes of seizures include hypoglycemia, electrolyte disturbances, endocrine disorders, vasculitis, **mass effect** from **tumors**, blood and drug withdrawal.

Head Pinning

- **Mayfield head pins** support the head without any direct pressure on the face, however, they place the neck in a rigid position and if any patient movement occurs serious cervical spine damage and/or scalp laceration can occur
- Additionally, application of Mayfield pins can cause significant pain due to periosteal stimulation
- Make sure patient doesn't move when in pins, either by keeping them deep with anesthetic agents and remifentanyl (if NM blockers are not possible due to need for neuromonitoring) or by using NM blockers if there are no contraindications.

Miscellaneous comments

- Patients with sudden increase in the ICP due to head trauma, intracranial bleed or rupture of aneurysm or AVM and patients with stroke present with hypertension. It is important not to suddenly decrease this BP. High BP is needed to maintain cerebral perfusion. If you decide to treat HTN, use only *short acting* agents.
- Pulse pressure variation (PPV) is not an accurate representation of volume status if patient is on phenylephrine gtt or in prone patients but you can go by the trend.
- Don't let the etCO₂ raise very high during extubation in patients with high ICP, this can affect their wake up.
- Majority of patients coming for brain tumor resection or spine cases with Spinal cord compression, keep the MAP>85.
- In long cases with TIVA, we usually switch to gas towards the end of the case (when neuromonitoring is no longer needed). While switching gas keep the mac around 0.6 mac as patient will still have residual propofol for several minutes to hour along with Remifentanyl.
- If neuro patient starts bleeding and if you decide to give blood, don't wait too long to give FFP and platelets. By the time Hgb drops from 14 to 9 and you decide to give PRBCs, you should consider giving FFP and platelets to keep ratio 1:1. Send coag profile and cbc proactively . Consider using POC like rotem in big bleeding cases. Goal is to keep INR<1.3, Platelets>100K.

Commonly Used Drugs and their Doses

1. **For treating hypertension**, we prefer nicardipine or clevidipine. Esmolol or labetalol also can be used. Discuss with your attending before giving Labetalol as its effect can last longer. Nitroglycerin and sodium nitroprusside (SNP) are usually avoided as they tend to increase the cerebral blood volume and hence intracranial pressure (ICP).
 - a. **Cleviprex** (found in pump room)

- i. Comes in 0.5mg/mL concentration
 - ii. Works really fast and should be given in 0.125 mg (0.25 mL) doses at a time. Can be repeated every 5 mins if needed
 - b. **Nicardipine** comes as a 2.5 mg/mL (25 mg/10mL vial) stock solution and should be diluted to 250 mcg/mL by mixing 1mL from vial with 9 mL of NS. Can give 250 or 125 mcg as bolus. Typical infusion rate is 5 – 15 mg/hr
 - c. **Esmolol**: 0.5- 1 mg/kg bolus
 - d. **Labetalol**: 10-20 mg bolus repeat every 10 mins as needed
- 2. Treating Hypotension**
Phenylephrine or **norepinephrine** gtt or bolus
- 3. Remifentanyl**
- a. Bolus @ 1-2 mcg/kg just before head pinning from the syringe pump, it can also be used during induction at 1-2 mcg/kg bolus to avoid using neuromuscular blocker .
 - b. Maintenance: Run @ 0.05-0.12 mcg/kg/min throughout the case
 Avoid using high doses as this can cause hyperalgesia postoperatively
- 4. Propofol**: 25-150 mcg/kg/min. Titrate and decrease the dose for long cases after 2-3 hours as the context sensitive half-life increases with increase in the duration of the infusion
- 5. Dexmedetomidine**: 0.2- 1.4 mcg/kg/hr
- 6. Drugs that can be bolused to blunt sympathetic response before head pinning**
- a. Remifentanyl: 1-2 mcg/kg
 - b. Esmolol: 0.5-1 mg/kg along with some Propofol. (2-5 ml)

Neuroanesthesia Protocols for Common Neurosurgery and Neuro IR Cases

- **Open Carotid Endarterectomy (CEA)**
 - GETA with good IV access + A-line + Hotline
 - Occasionally done awake
 - BIS monitor (optional but recommended) + L & R cerebral oximetry monitors (highly recommended)
 - Make sure T&S is up to date
 - Ancef

- Carrier fluid drip
- Phenylephrine drip
- Remifentanyl drip
 - Not mandatory but makes the case go smoother and assists with smooth extubation
- Nicardipine, Nitroglycerin or Clevidipine for IV pushes (not infusion)
- Heparin
 - Vascular surgeons will ask anesthesiologist to give heparin
 - Start at 100 U/kg
- Protamine will be given at the end of surgery
 - Discuss with surgeon
- If patient has good enough collaterals, vascular surgeons are not going to do a shunt, otherwise they will
- Some **vascular surgeons** check stump pressure, you need male-to-male connector for your A-line (surgeons will provide anesthesiologist with tubing)
- **Neurosurgeons** doing CEA usually use neuromonitoring (EEG and SSEP).
 - You will need propofol and remifentanyl along with phenylephrine drips.
 - Can keep patient paralyzed
- Keep BP 20% above the baseline during vascular clamping (which can last up to 25-30 min), then back to baseline or even slightly lower after the anastomosis is finished to avoid cerebral hyperperfusion
- If patient becomes bradycardic when **vascular surgeons** are manipulating the carotid bulb, notify them so they can inject lidocaine to blunt sympathetic response.
- Not a very painful procedure
 - Use narcotics cautiously as they decrease respiratory drive, which is a problem especially if CEA is bilateral, i.e. CEA performed previously on contralateral side
 - Give Ofirmev
 - Avoid long-acting narcotics
 - Ketamine can cause delirium and most of these patients are old, so do not give ketamine to every patient
- Deep extubation (ideally) to avoid coughing/bucking, alternatively can extubate on remifentanyl to achieve the same effect

- See craniotomy for intracranial neoplasm (or epileptogenic focus excision) for extubation on remifentanyl
- Have drugs available to treat HTN during extubation
 - Important to keep BP at baseline or slightly below to prevent cerebral edema due to hyperperfusion

- **Endovascular CEA**

- MAC vs. GA with good IV access + A-line + Hotline
- Severe bradycardia or asystole may occur due to stretching of the carotid body
 - If patient develops bradycardia during inflation of the balloon, the device should be quickly deflated
 - If bradycardia persists, intravenous atropine (0.5–1 mg) is administered
 - In rare cases, a pacemaker may be required for refractory bradycardia
- Persistent hypotension is possible following the angioplasty which responds to fluid boluses because the source of hypotension is generally vasodilation
 - If fluid boluses are unsuccessful and hypotension persists, a vasopressor drip with either dopamine or norepinephrine should be initiated

- **Craniotomy for Intracranial Neoplasm (or Epileptogenic Focus) Excision**

- GETA with good IV access + A-line + Hotline
- Make sure T&S is up to date
- Patient with head 90 or 180 degrees away and may be prone depending on desired surgical exposure
 - Important to stay near patient's head while surgeon is fixing the head to keep an eye on ETT and to make sure positioning is done right. Excessive flexion/extension or turning of the head can impair jugular venous drainage and can lead to brain swelling. (Make sure you have at least one finger breadth between the neck and chest)
- Typically no Versed for neurosurgery patients but can be given in highly anxious patients.

- TIVA if neuromonitoring or for patients with high ICP, TIVA helps to reduce the ICP
 - *Neuromonitoring is used if tumor involves eloquent cortex or for some skull base tumors*
- Keep the patient paralyzed throughout except in rare cases where they monitor cranial nerves or MEPs
- Regardless of whether there is neuromonitoring, have the following drips
 - Carrier fluid gtt
 - Phenylephrine gtt (for cerebral perfusion)
 - Remifentanil gtt
 - Run @ 0.05-0.12 mcg/kg/min throughout the case
 - Bolus @ 1-2 mcg/kg just before head pinning
- Mannitol (20%) 0.5-1 g/kg over 10 min (given shortly prior to craniotomy, e.g. when surgeon is scrubbing)
 - Can cause hyponatremia and hyperkalemia
 - Check with surgeon before giving it as it's not always needed
- Keppra 1 g , Dexamethasone (10 mg) are usually given (confirm with the surgeon)
- Keep the MAP >85 esp in patients with elevated ICP.
- Note: sevoflurane < 1.0 MAC does not increase ICP, propofol can decrease ICP (with or without hyperventilation), so can use propofol gtt instead of sevoflurane if concerned about increased ICP.
- Use age-adjusted MAC of 0.7 when remifentanil gtt is running
- Additional analgesics to consider
 - Magnesium 30-50 mg/kg before incision (NMDA antagonist), e.g. for 80 kg patient give 3g (1g x3 spaced 5 min apart). Remember that magnesium is a vasodilator
 - You can request surgeon to inject extra local anesthetic towards the end along the incision in long cases. They usually inject in the beginning of the case.
 - Ofirmev shortly before wakeup
 - Fentanyl after wake up
 - Avoid long acting pain medications like dilaudid. (we have been using methadone for some of the craniotomy cases and it works well but proper selection of patients is very important).

- These are not very painful procedures and we want patient to be awake for neurological examination.
- Antiemetics Decadron, Pepcid and Zofran. Add Scopolamine if needed.
- Have nicardipine available to make a drip
- Deep extubation for intra-parenchymal tumors is preferred but always discuss your extubation plan with the attendings
 - Alternatively, can extubate on remifentanyl to achieve the same effect
 - To extubate on remifentanyl, give neuromuscular blockade reversal, blow off anesthetic gas, then wake up on 0.08 – 1.0 mcg/kg/min of remifentanyl.
 - Note: half-life of remifentanyl is 6-7 min
- Treat HTN pre-emptively with labetalol 5-10 mg during extubation unless there is CI, as most of these patients develop some hypertension
 - Goal is to keep SBP < 160 mmHg

- **Meningioma Resection**

- Same as above, more likely to bleed compared to intraparenchymal tumors, so watch for bleeding and be prepared

- **Cerebellopontine Angle Tumor Resection**

- Similar to craniotomy for intracranial neoplasm excision, usually involves neuromonitoring and cranial nerve monitoring including cranial nerve X, so special ETT(NIMS) is needed. Use Glidescope to confirm the correct positioning of the cuff for NIMS tube.
- TIVA
 - Need to avoid neuromuscular blockers if cranial nerve monitoring is involved. Usually ok to give NMB during induction but we don't re dose.
- Positioning: prone or lateral
- Tendency for hemodynamic instability/bradycardia during surgery due to proximity to brainstem
- Make sure T&S is up to date, with good IV access + A-line + Hotline
- If prone cases- try to limit crystalloids to 2-3 L. can give albumin. But if patient has made lot of urine, make sure to keep them normovolemic.
- **Extubation:** In patients with large tumors and/or long cases, need to discuss with the surgeon before extubation as some patients will have

decreased respiratory drive/loss of protective reflexes due to proximity to respiratory center.

- **Pituitary Neoplasm (e.g. Adenoma) Resection via Transsphenoidal Approach**

- Usually done together by ENT and Neurosurgery
- GETA with good IV access + A-line + Hotline
 - **Airway: difficult in patients with acromegaly**
 - A-line needed for multiple reasons: frequent blood draws for diabetes insipidus (DI) evaluation, for cases with increased blood loss, etc. depending on tumor type
 - If DI suspected
 - May need to send labs
 - Treat accordingly some patients might need DDAVP
 - Discuss with the surgeon
- Make sure T&S is up to date
- Head may be pinned and bed is 90 degrees or 180 degrees away
- Tape ETT to L corner of the mouth or use oral RAE
 - ENT exposure is always from R side
- Remifentanyl gtt
 - Helps control initial painful stimulation during exposure but is not a must
 - If remifentanyl drip not used, limit other narcotics. Give Ofirmev early on
- Keep SBP normotensive to minimize blood loss
 - Phenylephrine is often needed
 - Keep SBP > 85 mmHg in patients with compression of optic chiasm or vision problems
- Although surgeons don't need patient to be paralyzed, keep patient paralyzed for safety as surgical site is in a sensitive area
- Not a painful procedure
 - Avoid long acting pain medications
 - Can consider multimodal analgesia such as ketamine 0.1- 0.2 mg/kg every hour, and magnesium, IV Tylenol to minimize use of narcotics
- Patients are more prone to PONV

- Use multidrug regimen
 - Scopolamine patch for patients with motion sickness
- Suction blood from the stomach with OG prior to extubation
- Deep extubation (if there are NO contra-indications, e.g. difficult bag mask ventilation)
 - Suction airway well before deep extubation
 - If laryngospasm suspected, use 10-20 mg of succinylcholine as the initial treatment to avoid positive pressure application
 - Avoid positive pressure ventilation (PPV) after extubation unless patient is hypoxic
- **Translabrynthine Removal of Acoustic Neuroma Using Stryker Navigation System**
 - GETA with good IV access + A-line + Hotline
 - Make sure T&S is up to date
 - Facial nerve monitoring is done so need to avoid muscle relaxants -> good to have phenylephrine and remifentanil gtt
 - Ancef
 - Dexamethasone 10 mg
- **Suboccipital Craniectomy, Cervical Laminectomy (and Duraplasty) for Chiari I Malformation**
 - GETA vs. ½ TIVA and 0.5 MAC gas (if neuromonitoring) with good IV access + A-line + Hotline
 - Have a Glidescope available
 - Patient prone with head pinned and 180 degrees away
 - Usually OK to paralyze the patient (check with neuromonitoring staff)
 - Remifentanil drip, phenylephrine drip, carrier fluid drip (even if GA)
 - Multimodal analgesia
 - Precedex 0.3 mcg/kg before incision and can run infusion at 0.2 mcg/kg/hr.
 - Don't give the entire dose as a single bolus as it can cause bradycardia and/or hypertension
 - Ketamine: loading dose 0.3mg/kg, then 0.2-0.3 mg/kg/hr thereafter
 - Magnesium 30- 50 mg /kg bolus over 10 mins.

- Watch out for bradycardia/asystole (due to brainstem compression)
- If TIVA, switch to gas towards the end of the case (when neuromonitoring is no longer needed) for faster wakeup. While switching gas keep the mac around 0.6 mac as patient will still have residual propofol for several minutes to hour .
- **Laser Ablation of Brain Tumors**
 - GETA with good IV access
 - Usually no need for A line
 - Patient may go to CT first then come back to OR then go to MRI for laser ablation, in which case extubation is done after MRI scan, so keep phenylephrine and propofol gtt
- **Craniotomy with Trigeminal Nerve Decompression**
 - GETA with good IV access, A line.
 - Some do neuromonitoring along with cranial nerve . Use 0.5 mac gas with low dose propofol and remifentanil gtt .
 - Head is pinned with Mayfield pins
 - Similar to intracranial tumor resection, less risk for bleeding
 - Risk for reflex bradycardia . Communicate with the surgeon .
- **Awake Craniotomy**
 - **Need thorough planning and discussion with the patient as preoperative patient preparation is very important**
 - **Need to know the indication, type of lesion, location, patient's symptoms, and their ability to cooperate with directions**
 - Note: ask patient to use nasal decongestants prior to starting sedation as most patients will require nasopharyngeal airways (nasal trumpets) to maintain airway patency
 - A-line (after some sedation)
 - Remifentanil gtt
 - Start at 0.08 mcg/kg/min, titrate down to 0.03-0.05 mcg/kg/min
 - Precedex gtt
 - Start around 1.0- 1.4 mcg/kg/hr and decrease to 0.2-0.5 mcg/kg/hr
 - Propofol gtt

- Start around 75-100mcg/kg/min and decrease to 30-50 mcg/kg/min once patient is more asleep
- Phenylephrine gtt
- Surgeon or anesthesiologist can do a scalp block (0.5% bupivacaine with 1% lidocaine with epi).
- Give dexamethasone, Pepcid, Zofran, and Ofirmev early on while starting sedation
- After achieving deep sedation, patients are carefully positioned with patient facing the anesthesiology team
 - Care should be taken to achieve the best operative positioning for the surgeon while maintaining adequate jugular venous drainage and airway patency
- Some patients might need mannitol (20%) 0.5-1g/kg
- Stop all infusions after craniotomy, i.e. once the bone flap is out
 - Discuss timing with surgeon
- Once patient is awake, do a focal neurological exam
 - Some patients might need low dose Precedex and/or remifentanyl gtt during awake phase to keep them comfortable but make sure they are still able to cooperate for neuro exam
- Infusions restarted for closure
- Vigilance and thorough planning to deal with any untoward complications are paramount
 - Emergence agitation/delirium can be particularly frightening to a patient with the head fixed in rigid pins with unsecured airway
 - The need to secure the airway emergently, possible nausea and vomiting management, patient movement prevention, emergence agitation/delirium prevention may all have to be dealt with
 - Even mild hypoxemia or hypercarbia can impair brain relaxation and surgical exposure
- **Sitting Craniotomy (Comments on Blood Pressure Monitoring)**
 - Raising or lowering the height of an arterial blood pressure transducer relative to the patient or estimating a blood pressure at a different level from the transducer results in a **blood pressure change** of

approximately 7.5 mm Hg per 10 cm height difference (1 cm H₂O ≈ 0.75 mm Hg)

- Raising the transducer or estimating a pressure at a level higher than the transducer lowers the pressure reading. Lowering the transducer or estimating a pressure at a level lower than the transducer raises the pressure reading
 - Mean arterial pressure (MAP) = 2/3 diastolic + 1/3 systolic
 - If blood pressure is measured to be 120/60 mm Hg with the transducer at the level of the heart (hence the MAP at the level of the transducer 80 mm Hg), the MAP at 10 cm above the level of the transducer will be approximately 73 mm Hg (80 – 7.5 = 72.5 mm Hg ≈ 73 mm Hg)
 - Arterial catheter position/height relative to transducer or heart does not matter
- **Craniectomy or Craniotomy, Evacuation of Intracranial Hemorrhage (ICH) or SDH.**
 - Patients are usually hypertensive before the craniotomy due to high ICP but BP drops significantly after craniotomy
 - High BP is needed to maintain cerebral perfusion and if you need to treat hypertension, use only short acting agents
 - GETA with good IV access + A-line + Hotline
 - TIVA in patients with significant elevation in ICP
 - Keppra
 - Check with surgeon if needed
 - Phenylephrine gtt PRN
- **Burr Hole Drainage/Evacuation of Subdural Hematoma (SDH) or Epidural hematoma.**
 - GETA with good IV access
 - No A-line is needed unless necessitated by patient factors
- **Mini-craniotomy**
 - GETA with good IV access
 - No A-line is needed unless dictated by patient factors
- **Craniotomy for Aneurysm Clipping**

- Similar to craniotomy for excision of intracranial tumor. Important to keep the BP under control. Keep short acting vasoactive agents handy. Some patients, may be better to get preinduction A line. Usually neuromonitoring is done (SSEP and EEG)
- GA, 0.5 age-adjusted MAC of gas, low dose propofol (50 mcg/kg/min) and remifentanyl 0.08-0.1 mcg/kg/min
 - Full TIVA can also be done
 - Keep the patient paralyzed.
- Good IV access + A-line + Hotline
- Smooth induction and intubation
 - Avoid any significant HTN to prevent rupture of aneurysm
- Surgeon might place temporary clip .
 - Keep the BP 20% above baseline during this time
 - Keep track of timing
 - This usually takes less than 5 mins
 - Some surgeons will request burst suppression before placing the temporary clip
 - Need to communicate closely
- If phenylephrine drip requirements become high, switch to levophed
- Some cases, surgeon will request for adenosine. Discuss early on .
- Might need to manage EVD and drain CSF as per surgeon's request intermittently during the case
- Be prepared for intraoperative rupture of aneurysm
 - Always have 2 units cross matched
- Might need IV indocyanine green (ICG) to confirm the correct placement, 5 ml IV push
 - Communicate before injecting
- Smooth extubation

- **Craniotomy for Arteriovenous Malformation (AVM) Excision**

- Similar to craniotomy for aneurysm clipping but AVM is resected in contrast to aneurysm which is clipped
 - Very important to keep the BP at baseline or slightly below the baseline after embolization (discuss with Surgeon)
- These patients are high risk for cerebral edema due to normal perfusion pressure breakthrough (NPPB) after embolization of AVMs

- Definitely keep nicardipine or Clevisrex IV boluses or labetalol handy to prevent BP surge during emergence
- Many of these patients undergo IR AVM embolization the day prior and might come to OR on nicardipine gtt
- Depending on the AVM grading some patients are at high risk for bleeding so important to discuss with the surgeon early on.
- Patient may arrive on esmolol (e.g. 25-300 mcg/kg/min) and/or nicardipine (e.g. 5-15 mg/hr) drips
- **Transcatheter Embolization of Cerebral Aneurysm (Neuro IR)**
 - GETA with good IV access + A-line +/- Hotline
 - Avoid narcotics except for intubation
 - Induce on the gurney
 - If patient's aneurysm has ruptured, their ICP may be higher and they might come with EVD which needs to be managed
 - Example BP goals: SBP 100-160 mmHg
 - **Always check with neuro IR about BP goals for a specific case**
 - Have phenylephrine gtt in the pump
 - Patients often develop hypotension after induction as it is not a very painful procedure
 - Keep the age-adjusted MAC between 0.7 to 1.0
 - Have Clevisrex or nitroglycerine or nicardipine available for IV pushes to treat hypertension (e.g. during extubation)
 - Avoid rapid changes in MAP or ICP with induction and surgical stimulation
 - Have Heparin available to administer when asked by interventional radiologist (IR)
 - Therapeutic target activated clotting time (ACT) is 200 seconds
 - Communicate with IR attending before touching the patient for any reason during sensitive parts of the procedure
 - **Keep patient well paralyzed, sometimes it's not possible to check TOF, so just give rocuronium pre-emptively (e.g. 10 -20 mg every 40 mins)**
 - Be prepared for possible intraoperative aneurysm rupture
 - Check twitches and give Sugammadex (if no contraindications) prior to extubation
 - Deep extubation (if no contraindications and if you are comfortable), although this is not always requested by neuro IR

- **Transcatheter Embolization of Cerebral AVMs (Neuro IR)**

- Similar to transcatheter aneurysm embolization
- Usually done one day pre op prior to AVM resection/excision
- Very important to keep the BP at baseline or slightly below the baseline after embolization (discuss with proceduralist)
- These patients are at high risk for cerebral edema due normal perfusion pressure breakthrough (NPPB) after embolization of AVMs
 - Definitely have nicardipine or Cleviprex or labetalol IV boluses handy to prevent BP surge during emergence

- **Extracranial to Intracranial Bypass**

- Performed to restore, or "revascularize," blood flow to the brain
 - The brain's equivalent of a coronary bypass in the heart
 - The surgery connects a blood vessel from outside the brain to a vessel inside the brain to reroute blood flow around a damaged or blocked artery
 - The goal of bypass surgery is to restore blood supply to the brain and prevent strokes
- Setup is similar to aneurysm clipping
- Very important to avoid hypotension and hyperventilation as these patients are at risk for cerebral ischemia until bypass
- Usually neuromonitoring is involved (EEG and SSEP). Okay to keep the patient paralyzed

- **Angiogram of Cervicocerebral Arch / Carotid Artery (Neuro IR)**

- A candidate for this procedure for example is a patient with SAH 2/2 ruptured ACOM aneurysm s/p endovascular coil embolization who has a vasospasm
 - Can be done under light sedation (without anesthesiologist present)
 - Patient will likely be on Keppra for seizure prophylaxis and nimodipine for vasospasm prevention
- **GETA** with good IV access (apnea will be needed for pics)
 - Preferred if there are other comorbidities, e.g. patient is septic on vasopressors

- Can also do **MAC** with good IV access if patient is mentally alert and cooperative
 - Most of the time a little propofol for access is all that's needed
 - If we keep patient awake, they can hold breath for pics
- If vasospasm is bad, patient will already have an A-line (most of the time) as they are on some vasopressor therapy for induced hypertension. If there is no A-line, consider placing it
 - The only thing we do now from triple H therapy is induced hypertension (maintain SBP between 140 and 180 mmHg)
- Keep patient euvolemic
- Watch for hypotension if IR injects IA verapamil or nicardipine
 - Verapamil drops BP less than nicardipine
 - Work with IR proceduralists to coordinate bringing the BP up in anticipation of administration of these medications
- Keep patient euvolemic
- Have lead available

- **Cranioplasty (with or without Custom Titanium Implant), Possible Scalp Flaps**

- GETA with good IV access
- No A-line is needed unless necessitated by patient factors
- Remifentanyl drip (e.g. @ 0.08 mcg/kg/min) may be used
- Phenylephrine drip PRN
- EBL can be as high as 500 mL

- **Ventriculoperitoneal Shunt (VP) Shunt Creation/Revision**

- GETA with good IV access
- Sometimes done together by Neurosurgery and ACS (if laparoscopic for obese patients)
- Sometimes head is pinned and Stryker Navigation is used (small ventricles)
- Head 180 degrees away, but no straight connector needed as circuit can run on the side of the bed, not through the middle
 - ETT taped on the side opposite of planned tunneling
 - Can roll patient in "head first" if 2 experienced anesthesiologists are present or patient already intubated
- Patient's neck rotated away to the side for surgical positioning

- Usually a Foley is placed despite the case being less than 2 hours
- Place EKG leads on the sides so they don't get in the way of surgical exposure
- Keep patient paralyzed
- Tunneling is the most painful part -> can give a propofol/esmolol bolus if needed
- Overall, not a painful procedure, except for tunneling
 - Ofirmev before extubation
- **Lumboperitoneal (LP) Shunt Creation/Revision**
 - Similar to VP shunt creation/revision
 - GETA with good IV access
 - Patient in lateral decubitus position
 - A bean bag may be used for patient positioning
- **Endoscopic Third Ventricle Surgery**
 - Performed to treat obstructive hydrocephalus
 - Similar to intracranial neoplasm excision
 - GETA with good IV access, +/- A line depending on the size and type of the lesion and patient's ICP level
 - Keppra if needed
 - Check with surgeon
 - Keep the patient well paralyzed
- **Stereo-Electro-Encephalography for Placement of Intracranial Electrodes**
 - GETA with good IV access
 - No A-line necessary unless dictated by patient factors
 - Give small bolus of esmolol/propofol before head is clamped/pinned by surgeons
 - In rare cases, might involve monitoring of microelectrode recordings (MER)
 - Avoid midazolam as it can interfere with MERs
 - Propofol can attenuate MERs, it is rapidly titratable
 - Keep patient well paralyzed throughout
 - Because these patients are on anti-seizure medications, they require higher doses of rocuronium
- **Intracranial Electrode Removal**

- Usually done a couple of weeks after placement
- GETA with good IV access
- **Insertion of Responsive Neurostimulation (RNS) Device and Electrodes**
 - Surgical approach to treating seizures not controlled by medication
 - GETA with good IV access + A-line + Hotline
 - Ancef
 - Phenylephrine drip PRN
 - Ofirmev
- **Vagal Nerve Stimulator (VNS) Placement**
 - Used for treatment of epilepsy and depression
 - GETA with good IV access
 - Patient s on multiple seizure meds.
 - Risk for bradycardia
- **Deep Brain Stimulator (DBS) Generator and Lead Placement**
 - Done at East campus
 - Done for patients with Parkinson's disease or tremors
 - Similar to awake craniotomy
 - Patient needs to be asleep for initial craniotomy and closure but awake in between during testing and lead placement.
 - However, it involves small craniotomy (most commonly burr hole), patients are mostly old and have trouble handling secretions and have OSA.
 - Be very careful while sedating
 - Low dose Propofol and/or Precedex gtt are usually used. Avoid midazolam.
 - Don't need to be very deep as in awake crani for tumor resection cases.
 - After placement of DBS leads, generator placement is done under GETA
- **DBS Generator Replacement**
 - MAC with good IV access (can do IV propofol pushes only)
 - Versed PRN
 - Ancef

- Fentanyl
- **Removal of DBS Generator and Leads**
 - GETA with good IV access
- **Trigeminal Percutaneous Balloon Compression Using Stryker Navigation System**
 - Used for treatment of trigeminal neuralgia
 - GETA with good IV access and standard ASA monitors
 - Usually a quick case
 - Have lead available
 - Tape ETT to the side opposite that of the operative site
 - Watch out for bradycardia/asystole during balloon compression
 - Glycopyrrolate is better than atropine for treating bradycardia if there is concern for central anticholinergic syndrome (CAS)
 - Can give 20- 30 mg of Ketamine for pain (in addition to fentanyl given for induction)
 - Patients' pain usually improves after the surgery
 - They should not require lot of pain medications

Anesthetic Management of Spine Surgeries

- **Multimodal Pain Management(discuss with your attending before)**
 - Other than ACDF and lumbar discectomy, most of the spine surgeries needing instrumentation are painful and most of the patients are on chronic opioids
 - For multi-level instrumentation, epidural catheter may be placed by the surgeon's towards the end. Discuss with them.
 - Single shot spinal morphine injected by surgeon is another option
 - IV methadone 0.2-0.4 mg/kg (IBW) can be given at the beginning of the case and can be repeated after 4 hours in long cases.
 - For cases where we can't do epidural or spinal, consider multi modal drugs
 - Consider Tylenol and gabapentin pre-operatively
 - Ketamine: 0.3-0.5 mg/kg bolus followed by 0.2 mg/kg/min infusion

- Magnesium (Mg): 30-50 mg/kg bolus followed by 10 mg/kg/hr infusion
- Dexmedetomidine 0.2 mg/kg bolus followed by 0.2 mg/kg/hr infusion
- It is possible to mix ketamine, Mg, Dexmedetomidine in the carrier solution (100 or 250 ml bag) and run through the pump
 - Pay attention to the dosages
- Most of these patients have remifentanyl running throughout the case. Titrate fentanyl or hydromorphone towards the end. Don't give long acting meds if patient has received methadone or spinal, epidural anesthesia
- **Blood Transfusion and Fluid Management**
 - Cell saver can be requested for spine instrumentation cases but not for spine tumors
 - Give 1g TXA before incision and run 2-3 mg/kg/hr infusion for cases where expected EBL is > 500 mL
 - Limit crystalloids for prone cases to 2 L and use Albumin instead unless patient is making lot of urine. Transfuse blood as needed.
- **Extubation for Long Prone Cases**
 - Put the patient's back up or in a sitting position after flipping to supine position unless there are contraindications
 - This will reduce facial edema significantly within 10-15 mins
- **Positioning Considerations**
 - Make sure pressure points are padded
 - Check the peak airway pressure after positioning prone as some increase in PAP is normal
 - Adjust the chest rolls as needed. Do recruitment (VC) breaths after positioning and also in between, especially in obese patients
- **Neuromonitoring Considerations**
 - In adults, for [surgeries above L1 \(cervico-thoracic\)](#)
 - SSEP, EMG and MEP monitoring
 - Needs full TIVA

- Either induce with sux or use remifentanyl bolus 1-2 mcg/kg or small dose rocuronium.
 - Place a soft bite block separating the jaws to prevent tongue biting during MEP monitoring
 - In adults, for **surgeries below L1**
 - SSEP and EMG monitoring
 - Can use rocuronium for induction, Usually wears off by the time they need to do EMG
 - Don't use sugammadex to reverse it as some surgeons request muscle relaxant for dissection part
 - For maintenance 0.5-0.7 MAC gas (age-adjusted) + remifentanyl gtt Also have Phenylephrine gtt.
 - Consider multimodal
- **Cervical Laminoplasty with Plate Reconstruction or**
- **Anterior Cervical Discectomy and Fusion (ACDF) or Arthroplasty**
 - GETA vs. TIVA with good IV access + A-line + Hotline
 - Most of the surgeons do neuromonitoring and we will need TIVA but some surgeons don't
 - Discuss with surgeon before setting up TIVA
 - Orient (bend and tape) the ETT away from the surgical field, i.e. towards the forehead
 - Not a very painful procedure
 - Patients are high risk for airway edema or hematoma
- **Cervical Corpectomy with Posterior Instrumentation**
 - Full TIVA with good IV access + A-line + Hotline
 - Carrier fluid gtt
 - Propofol gtt
 - Remifentanyl gtt
 - Phenylephrine gtt
 - Make sure T&S is up to date
 - Can have significant bleeding
 - Consider multimodal analgesia
 - Patients are high risk for airway edema or hematoma

- **Thoracic Spine Instrumentation and Fusion / Laminectomy for Thoracolumbar Spine Neoplasm Excision**

- Full TIVA (due to MEP and SSEP monitoring) + A-line + Hotline
 - Intubate with sux or smaller dose rocuronium ($< 0.5\text{mg/kg}$) or remifentanil bolus ($1\text{-}2\text{ mcg/kg}$)
 - Very rarely they might want to get baseline neuromonitoring before flipping the patient prone, in which case either avoid NM blocker or just use sux
 - Although sugammadex can be given to reverse rocuronium, it is not the best option as surgeon might request NM blockage for a short period during muscle dissection
- Make sure T&S is up to date
- Patient prone with head next to anesthesia machine
 - Usually in Super(woman) position -> don't place IVs or A-line in the antecubital fossa because they will likely get kinked
- Ancef
- TXA 1g bolus (10 mg/kg) possibly followed by TXA infusion
 - Check with surgeon about whether infusion is needed before giving it
- Multimodal analgesia for pain management
 - Ketamine, Mg, Ofirmev, opioids, methadone
 - Discuss details with your attendings
 - Ketamine IV pushes, e.g. $0.2\text{-}0.5\text{ mg/kg}$ loading dose, followed by either 10 mg hourly boluses or infusion
 - Can also give magnesium for pain control ($30\text{-}50\text{ mg/kg}$ over 10 mins) , followed by $8\text{-}10\text{mg/kg/hr}$ infusion
- Have albumin 5% available
- If excessive blood loss is expected, Cell Saver will be used
 - Ask the circulator to call the perfusionist if Cell Saver is not already set up in the beginning of the case
- Switch to age-adjusted 0.5 MAC gas towards the end when they're done with neuromonitoring
 - Propofol can linger for several minutes to hours depending on the duration of infusion
 - Discontinue propofol but keep remifentanil running

- Some but not all surgeons (e.g. Chang, Kim, Nelson) inject intrathecal morphine or place epidural catheter
 - Need to discuss and plan accordingly
 - Avoid long acting opioids in that case
 - Epidural catheter is managed by acute pain service, so notify them immediately if it's placed by surgeons
- **Thoracic Lateral Interbody Instrumentation and Fusion**
 - For part I, patient is lateral with head 180 degrees away
 - For part II, patient is prone with head 180 degrees away
 - Same setup as **thoracic spine instrumentation and fusion** above
- **Open Treatment of Thoracic Spine Fractures with Posterior Percutaneous Instrumentation**
 - GETA with good IV access + A-line + Hotline
 - Ancef
 - Phenylephrine drip
 - Multimodal analgesia
 - Fentanyl, Ketamine, Dilaudid, Ofirmev
- **Lumbar Laminectomy with Instrumentation and Fusion**
 - GETA with good IV access + A-line + Hotline
 - Same setup as for thoracic cases, except for surgeries below L1 level neuromonitoring involves mostly SSEP and EMG without MEPS
 - So it is OK to use gas up to 0.7 MAC (age-adjusted)
 - Carrier fluid (e.g. NS), remifentanyl gtt, phenylephrine gtt
 - Patient prone
- **L5-S1 Anterior Lumbar Interbody Fusion (ALIF) with Posterior Percutaneous Screws**
 - Usually done as part 1 of staged surgery followed by posterior fixation
 - GETA with remifentanyl and phenylephrine gtt with good IV access + A-line + Hotline
 - Make sure T&S is up to date
 - Ancef
 - Multimodal analgesia

- Fentanyl, Ketamine, Dilaudid, Ofirmev
- **L2-L3 Extreme Lateral Interbody Fusion (XLIF)**
 - ½ GETA + ½ TIVA with good IV access + A-line + Hotline
 - Make sure T&S is up to date
 - Ancef
 - Multimodal analgesia
 - Fentanyl, Ketamine, Dilaudid, Ofirmev
- **Revision of Intrathecal Pump**
 - Used for chronic pain and spasticity management
 - GETA with good IV access, prone or lateral position
 - Some patients are high risk for baclofen withdrawal if the pump stops working suddenly and will be monitored in ICU
- **Diagnostic Lumbar Puncture (done by IR)**
 - GA via mask or via LMA with good IV access
- **Fluoroscopy-Guided Subarachnoid Injection (done by IR)**
 - MAC vs. LMA with good IV access
 - Versed

Anesthetic Protocol for Endovascular Treatment of Acute Ischemic Stroke (AIS)

Anesthesiologists are involved in sedating, anesthetizing and monitoring the patient, managing hemodynamics, oxygenation, ventilation, glycemic control, and peri-procedure complications. Despite the significance of the anesthetic management, evidence supporting specific practices is limited.

1. **Quick Preanesthetic Evaluation**
 - a. Pertinent PMH/PSH/Medications/Presenting symptoms and signs/NPO/pertinent labs, EKG. Quick examination (first 5-10 mins).
2. Transfer the patient to fluro table first so that IR team can start prepping as we are getting the patient ready.
3. **Monitoring:** ECG, SpO2, RR, ET CO2, NIBP. Continuous intra-arterial BP monitoring is recommended, as long as cannulation of the artery will not delay the endovascular therapy. Alternative options are noninvasive

continuous BP (ClearSite) and femoral artery cannulation by the neurointerventional team.

4. **Quick time out** to stress on the important aspects of patient's care like hemodynamic goals and procedural needs.

5. **Anesthetic Options:**

a. **Local anesthesia** with/without sedation - in cooperative patients who can protect their airway

i. Be prepared to rapidly convert to GA if needed

b. **General Anesthesia**

i. **Indications:** decreased level of consciousness, compromised protective airway reflexes, active nausea/ vomiting, hypoxic or hypercarbic, and airway obstruction under sedation

6. **Anesthetic and Hemodynamic Goals**

a. **Avoid hypotension, hypoxia during induction. RSI may be needed.**

i. Diluted phenylephrine, vasopressin, nicardipine, and esmolol syringes should be handy to control hemodynamics

b. **Hemodynamic Goals**

i. $SpO_2 > 92\%$

ii. Normocapnia ($PaCO_2$ - 35 to 45 mmHg)

iii. Target systolic blood pressure (SBP) > 140 mmHg and < 180 mmHg, target diastolic blood pressure (DBP) < 105 mmHg

c. **Patients are often hypertensive at presentation but** often require infusion of vasopressor (e.g. phenylephrine) after induction. However consider individual patient characteristics while choosing the vasopressors

d. **Post thrombectomy**

i. BP parameters will depend on the thrombectomy results. Hence needs to be discussed with the neuro radiologists. Ideally aim for SBP 120-160 mmHg

7. **Fluid Management**

a. Maintain euvolemia

b. Use isotonic fluids like NS, avoid LR and glucose containing fluids unless treating serum glucose values of < 50 mg/dL

8. **Glucose management**

a. Avoid hypoglycemia

- i. Treat hyperglycemia to achieve blood glucose levels in a range of 140 to 180 mg/dL

9. Recommendations for Temperature Management

- a. Maintain target temperature between 35°C and 37°C
- b. Treat with antipyretics if febrile.

10. Periprocedural Management of Anticoagulation

- a. Be prepared to administer heparin throughout the procedure as requested by the IR team. Will have to reverse with protamine in case of an ICH or iatrogenic SAH

Comments from TrueLearn Notes

2898) Keyword: Neurosurgery: Fluid Management. Neurosurgical patients should be kept euvolemic or slightly hypervolemic in order to maintain their cerebral perfusion pressure (CPP) allowing the cerebral blood flow (CBF) needed for oxygenation. Euvolemia should be accomplished with an isotonic fluid to avoid brain edema. Large volume hypotonic fluids should not be used as this can lead to cerebral edema and hypertonic fluids are known to dehydrate the brain.

There is no evidence that colloids (e.g. albumin) have any benefit over crystalloids.

2123) Keyword: Cerebral Aneurysm Clipping: Anes Mgmt. The goals of anesthetic management for cerebral aneurysm clipping include: avoidance of rapid changes in mean arterial pressure (MAP) or intracranial pressure (ICP) with induction and surgical stimulation, large-bore IV access for resuscitation if rupture occurs, adequate brain relaxation (brief hyperventilation, mannitol), maintenance of cerebral perfusion pressure (CPP), and rapid wakeup if possible.

Prior to clipping the surgeon may temporary occlude the feeding vessel and the patient's blood pressure may need to be augmented in order to improve collateral circulation. Controlled hypotension prior to application of the aneurysm clip is less favored now because there is a risk for regional ischemia. This "controlled" hypotension can occur through positioning (head up), increasing anesthetic concentrations, or cardiovascular medications. Adenosine administration allows temporary circulatory arrest for 30-45 seconds facilitating clipping. It may also be used to assist the surgeon with temporary hemorrhage control after aneurysm rupture.

If **aneurysm rupture** occurs, the anesthetic plan should be to **avoid** wide fluctuations in CPP or **dangerous increases** in blood pressure, as may occur with a **phenylephrine bolus**. **Cooling to 33 degrees Celsius** and **administration of propofol bolus** will decrease cerebral metabolic requirements and may act as "brain protection." Cessation of blood flow may be required and can be accomplished by **administration of adenosine bolus**. Adenosine should be used only when absolutely necessary because it may increase cerebral ischemia and can lead to arrhythmias. A decrease in cerebrospinal fluid (CSF) volume will increase the transmural pressure across the wall of the aneurysm in a patient with an intracranial aneurysm. The transmural pressure is the difference between the arterial pressure and the CSF pressure. Increasing the transmural pressure makes rupture more likely.

Additional Resources (for the Brave)

The following website is an excellent resource for Neuro Anesthesia. The link takes you to the home page. Under the "Education" tab there are Neuroanesthesia quizzes and practice questions. These quizzes are great to do while on your neuro anesthesia rotation or prepping for upcoming exams.

<https://www.snacc.org/>

The link will be added to our lluanesthesia.com website under the Neuro anesthesia education portion.