

Neuroanesthesia Checklists

Contents:

1. Surgical resection of Arteriovenous Malformation (AVM)
2. Deep Brain Stimulation (DBS)
3. Flexible Endoscopic Intubation
4. Checklist: Prone Positioning Lumbar Spine Surgery
5. Moyamoya / Extra- Intracranial Bypass
6. Lidocaine Infusions for Trigeminal Nerve Neurolysis in Neuroradiology Suite
7. Checklist for Stroke – Endovascular Therapy
8. Craniotomy for Resection of Supratentorial Tumor
9. SNACC Neuroanesthetic Emergencies Critical Event Treatment Guides



Surgical resection of Arteriovenous Malformation (AVM)

Surgical characteristics	
Duration of surgery	Variable. Between 6 to 12 hours.
Expected blood loss	Variable. Potential high blood loss during the procedure. Blood group confirmation is mandatory.
Positioning	Depending on the location of AVM
Antibiotic therapy	As per surgical protocol.
Anesthesia	
Pre-Anesthesia	Optimize pre-existing medical conditions. Review the size, location and characteristics of AVM. Was endovascular embolization performed prior to surgery?
Mode of Anesthesia	Usually general anesthesia. Consider TIVA (Propofol).
Airway	Standard management / avoid sympathetic response to laryngoscopy.
Ventilation	Normoventilation. Mild hyperventilation (paCO ₂ 28-33 mmHg) may be indicated in selected cases.
Target MAP	Initially maintain normotension. Discuss BP management with surgeon, often deliberate hypotension needed.
Blood Gases	Perform frequently – and as needed to control pCO ₂ .
Temperature	Maintain normothermia. Use Bear Hugger blankets. Avoid hyperthermia.
Transfer	Consider ICU for postoperative BP control
Special considerations	Potential major blood loss during procedure. Be prepared to provide deliberate hypotension. Consider e.g. Esmolol (1 mg/kg, 0.5 mg/kg/min infusion), Labetalol, Nitroglycerin infusion. Often intraoperative angiogram. Indocyanine green dye sometimes used.
Patient monitoring and vascular access	
Patient monitoring	Standard CAS monitoring.
Peripheral IV access	Minimal 2 peripheral IV lines, one suitable for rapid infusion. Connect Hotline to large bore IV.
Central venous line	Consider placement for BP control peri-operative. Order chest x-ray post-op.
Arterial line	Mandatory. Can be placed after induction of anesthesia.
Foley catheter	Post induction. Keep euvolemia. Urine output 0.5 - 1 mL/kg/hour.
Pain therapy	
Acute pain service	Not necessary in most cases.
Post-op pain therapy	Scalp block is indicated for postoperative pain control. Use opioids and acetaminophen as per protocol.
Material / Devices needed in room	
Arterial line set up	Connected to monitor, cannula for catherization.
Central line set up	Double lumen central line usually sufficient.
Ultrasound machine	Mandatory for central line placement. Helpful for arterial line placement.
Hotline	Ready and connected to large bore IV. Blood-giving-set, extension and hotline tubing.
3 syringe pumps	For Remifentanyl, Propofol, Antihypertensives / Vasopressors
1 Baxter pump	For Propofol TIVA



Deep Brain Stimulation (DBS)

Surgical characteristics	
Duration of surgery	Variable. Be prepared for longer duration for Stage I (bilateral DBS insertion): between 4 to 7 hours. Stage II (stimulator): usually 1 hour.
Expected blood loss	Usually minimal. Verify blood group confirmation.
Positioning	Stage I: Semi-sitting / beach chair position, head fixed in stereotactic frame. Stage II: Supine.
Antibiotic therapy	As per surgical protocol.
Anesthesia	
Pre-Anesthesia	Optimize pre-existing medical conditions. Intensive discussion with patient re: process for awake surgery. Know individual clinical manifestations of underlying disease (Parkinson, Epilepsy). Consider ranitidine pre-op to reduce aspiration risk. Neurosurgery positions stereotactic frame on skull pre-operatively in radiology. Patients with parkinsons discontinue anti-parkinson's medications pre-operatively. Continue anti-epileptic medications.
Mode of Anesthesia	Stage I: Sedation. Consider use of Dexmedetomidine (400mg; needs to be ordered one day before surgery, delivery to OR desk at 7:00 AM on the day of surgery). Propofol and Remifentanil syringe pumps in the room. Stage II: General anesthesia
Airway	Stage I: Oxygen delivery via Nasal prongs / Mask. Airway backup available at bedside: consider LMA ProSeal. Intubation endoscope in the room "ready to go" in expected difficult airway situations. Stage II: Endotracheal intubation or LMA
Ventilation	Stage I: Measure respiratory rate with capnometry. Stage II: Normoventilation.
Blood Gases	Perform as needed.
Target MAP	Normotension. Avoid hypertension and hypotension.
Temperature	Maintain normothermia. Use Bear Hugger blankets. Avoid hyperthermia. Ask about patient comfort frequently.
Post-op Disposition	PACU
Special considerations	Patient in stereotactic frame. Avoid interference of anesthetics during microelectrode recordings and macrostimulation.
Patient monitoring and vascular access	
Patient monitoring	Standard CAS basic monitoring
Peripheral IV access	2 peripheral IV lines, one suitable for rapid infusion.
Arterial line	Always used.
Central venous line	Only special circumstances.
Foley catheter	Commonly used. Consider sedation for placement (e.g. Propofol). May cause agitation especially in male patients. Consider use of condom catheter.
Pain therapy	
Acute pain service	Not necessary in most cases.
Post-op pain therapy	Scalp block always used



Material / Devices need in room	
Arterial line set up	Connected to monitor, cannula for catherization.
Ultrasound machine	Optional. Helpful for arterial line placement.
Hotline	Ready, but usually not needed. Have blood-giving-set, extension and hotline tubing available.
3 syringe pumps	For Dexmedetomidine, Remifentaniil, Propofol, Antihypertensives

Created: R. Noppens

Verified: Neuroanesthesia Group

Revision planed: July 2020



Flexible Endoscopic Intubation (non-anesthetized patient)

Indication
<p>Expected difficulties in mask ventilation and/or intubation</p> <ul style="list-style-type: none"> • History of difficult intubation • ENT tumors • Limited cervical spine mobility, neck injuries, high Mallampati grade or Patil test
Patient preparation
<ul style="list-style-type: none"> • Venous access • Topical anesthesia (max. total dose lidocaine: 7 mg/kg bw) <ul style="list-style-type: none"> ○ <u>Nasal</u> intubation: application of nasal drops (lidocaine + phenylephrine, consider use of MAD device) ○ <u>Oral</u> intubation: on arrival in the OR: spray oropharynx with lidocaine pump spray (attn: 12 mg / spray). Spray laryngopharynx with e.g. lidocaine 2% / 4% (MAD device, ask for deep inhalation, attn: accidental overdoses reported with lidocaine 4%). • Connection of monitoring (minimum: ECG, SaO₂, NiBP)
Preparation of flexible intubation endoscope
<ul style="list-style-type: none"> • Technical function test of endoscope (adults: usually 5 mm OD), light source and monitor • Attach selected endotracheal tube to the insertion part of the endoscope (tape, rubber band); consider use of armored tube • Prepare the topical anesthetic (2-3 ml lidocaine 2% in a 10 ml syringe with 7-8 ml air), connect to working channel port • Apply anti-fogging agent to the lens, clean lens
Nasal endoscopic intubation of non-anesthetized patient
<ul style="list-style-type: none"> • Endoscopic check of both nostrils for biggest space to pass endoscope / tube • Application of 3 l O₂/min via nasal cannula / prongs • Titration of opioid (e.g. i.v. Sufentanil (< 60 kg: 5 ug, 60-90 kg: 10 ug, > 90 kg: 15 ug), repeat in 5 ug doses if required; Remifentanil syringe pump (e.g. 0.1 - 0.35 µg/kg/min); Fentanyl (e.g. 50 ug boli)) • Advancing the endoscope via larger nasal passage • After reaching the vocal cords: application of the first topical anesthetic dose (e.g. 2-3 ml lidocaine 2%), the patient is asked to take a deep breath • After the onset of action (wait ca. 2 min.) pass the vocal cords, apply second local anesthetic dose (2-3 ml lidocaine 2%) into the trachea, ask patient to take a deep breath • Consider retracting the tip of the endoscope in front of the vocal cord plane • After 2 minutes: pass vocal cords, advance into the trachea until bifurcation becomes visible • Nasal tube passage: <u>no</u> obstructive tumors of the respiratory tract and/or <u>no</u> critical airway: mild sedation (no hypnosis) with e.g. 0.5 - 1 mg/kg bw Propofol iv • Advancing the endotracheal tube (lubricate the nasal passage with e.g. lidocaine gel) • If the endotracheal position of the tube is confirmed, remove endoscope • Connect to ventilator (etCO₂). Consider cuff inflation after induction of anesthesia (avoid coughing) • Induce anesthesia



- Start ventilator, initiate maintenance of anesthesia

Oral endoscopic intubation of non-anesthetized patient

- Oral: insert a bite guard
- Application of 3 l O₂/min via nasal cannula / prongs
- Titration of opioid (e.g. i.v. Sufentanil (< 60 kg: 5 ug, 60-90 kg: 10 ug, > 90 kg: 15 ug), repeat in 5 ug doses if required; Remifentanil syringe pump (e.g. 0.1 - 0.35 µg/kg/min); Fentanyl (e.g. 50 ug boli))
- Advancing the endoscope through the mouth (bite guard!)
- After reaching the vocal cords: application of the first topical anesthetic dose (e.g. 2-3 ml lidocaine 2%), the patient is asked to take a deep breath
- After the onset of action (wait ca. 2 min.) pass the vocal cords, apply second local anesthetic dose (2-3 ml lidocaine 2%) into the trachea, ask patient to take a deep breath
- Consider retracting the tip of the endoscope in front of the vocal cord plane
- After 2 minutes: pass vocal cords, advance into the trachea until bifurcation becomes visible
- Advance endotracheal tube, rotation maneuver is often helpful to pass larynx
- If the endotracheal position of the tube is confirmed, remove endoscope
- Connect to ventilator (etCO₂). Consider cuff inflation after induction of anesthesia (avoid coughing)
- Induce anesthesia
- Start ventilator, initiate maintenance of anesthesia

**Checklist: Prone Positioning Lumbar Spine Surgery**

Surgical characteristics	
Duration of surgery	2 – 6 hrs (depending on how many levels are involved)
Expected blood loss	Minimal – 500 ml (depending on levels and surgical technique)
Positioning	Prone position, arms lateral to head (“surrender position”). Wilson frame / Jackson table often used. Induction of anesthesia in supine position on the stretcher. Secure endotracheal tube and lines: risk of losing airway and lines! Transfer to prone position on OR table. After turning patient: re-connect circuit, ensure no kinking of tube (pharynx?), check lines. Use special head rest pillow, frequent visual inspection of eyes, ears, nose and neck for absence of pressure. Check pressure points arms, use pads. Abdomen should be free to move.
Antibiotic therapy	30 - 60 min before surgical incision
Anesthesia	
General anesthesia	Consider TIVA if intraoperative neuro monitoring (IONM) is planned; consider use of short acting anesthetics to facilitate early post-op function testing.
Airway	Oral endotracheal intubation; tube should be positioned in right corner of the mouth. Ensure tube is well secured.
Warming	Upper body bear hugger warming blanket. <u>No</u> standard use of HOTLINE® fluid warmer
Transfer	PACU
Special considerations	<ul style="list-style-type: none"> • Problems: difficult ventilation due to positioning, decreased cardiac output, postoperative vision loss, peripheral nerve injury due to poor positioning, face swelling, oropharyngeal swelling causing airway obstruction. • Maintain adequate blood pressure (perfusion of retina). • Keep Stretcher outside OR for emergency turning • Consider Mayfield pins for prolonged surgery to avoid pressure to facial structures
Physiologic Targets	Maintain adequate blood pressure (perfusion of retina). HR, EtCO ₂ , etc. according to individual patient needs.
Patient Monitoring and vascular access	
Patient monitoring	According to CAS guidelines to the practice of anesthesia
Peripheral i.v. access	Consider two peripheral i.v. cannulas
Central venous line	Usually not required
Arterial line	Consider for > ASA III / multiple level surgery



Foley catheter	Expected longer surgical duration (e.g. > 2 hours)
Pain therapy	
Acute pain service	Usually not required, but consider for chronic pain or opioid dependent patients
Post-op pain therapy	Initiate early pain therapy in adequate dose.
Material / Devices needed in room	
<ul style="list-style-type: none"> • Arterial Line Setup • Head rest pillow • Gel bolsters or Wilson frame or Jackson table • 2 arm boards 	<ul style="list-style-type: none"> • If TIVA (INOM!): Baxter Infusion Pump • Bear Hugger for upper body warming • 3x pillows (under legs) • HOTLINE blood warmer (not prepared)

**Moyamoya / Extra- Intracranial Bypass**

Surgical characteristics	
Duration of surgery	Variable. Between 6 to 12 hours.
Expected blood loss	Variable. Usually no more than 500 mL.
Positioning	Supine with the head in pins.
Antibiotic therapy	As per surgical protocol.
Anesthesia	
Pre-Anesthesia	Do not stop aspirin.
General anesthesia	Consider volatile agent plus remifentanil (e.g. Sevoflurane)
Airway	Standard management / avoid sympathetic response to laryngoscopy.
Ventilation	Normoventilation at upper physiologic limit. Avoid significant hypo- or hyperventilation.
Temperature	Maintain normothermia. Use Bear Hugger blankets. Do not overheat the patient!
Transfer	ICU for medical or surgical indications.
Special considerations	Maintain adequate intravascular volume. Avoid hypovolemia. Maintain hematocrit between 30-42%.
Targets MAP	Keep mean BP at or above baseline (10%) throughout the entire procedure. Use norepinephrine (e.g. 1mg/50 ml in syringe pump) or other vasopressor infusions AND/OR boluses is adequate.
Blood Gases	Perform frequently – and as needed to control paCO ₂ .
Patient monitoring and vascular access	
Patient monitoring	CAS basic monitoring plus invasive arterial blood pressure.
Peripheral IV access	Large bore (if possible) peripheral IV line post induction. Fluid warmer only when larger iv volumes or blood transfusion.
Central venous line	Consider if multiple vasopressors are likely to be needed and CVP measurement is needed. Order chest x-ray post-op.
Arterial line	Always pre-induction arterial line. Use local anesthetic.
Foley catheter	Post induction. Keep patient well hydrated. Urine output > 2 mL/kg/hour. Consider urinary catheter with temperature probe.
Pain therapy	
Acute pain service	Not necessary in most cases.
Post-op pain therapy	Scalp block is indicated for postoperative pain control. Use opioids and acetaminophen as per protocol.
Material / Devices needed in room	
HOTLINE blood warmer always in room	Bair hugger, lower body warming blanket or full body warmer. Water blanket system is also useful.
Syringe pumps prepared with Remifentanil and Vasopressor of choice	

Lidocaine Infusions for Trigeminal Nerve Neurolysis in Neuroradiology Suite

(Dr Andrew Parrent's patients)

1. Use only Lidocaine bag with 4 mg/ml

Eg either use pre-made pharmacy bag 0.04% (4 mg/ml) located in Core B Pyxis, or use 2% Lidocaine from anesthesia cart: 10 cc 2% lidocaine (200mg) added to 40 cc Normal saline to give 4mg/ml.

2. Before start of procedure: bolus of 1-1.5mg/kg, lidocaine infusion rate (syringe pump) 2 mg/kg/h. Continue infusion throughout the procedure. Patient in pain after the procedure: continue for 1 hr in PACU (attn: delayed discharge, prolonged PACU stay)

3. If infusion is used in PACU: order Lidocaine infusion (under acute pain orders in powerchart)

4. Consider adding Magnesium 1g to the Lidocaine syringe.

Created: R. Craen

Verified: Neuroanesthesia group

Revision planed: July 2020



Checklist for Stroke – Endovascular Therapy

Interventional Neuroradiology must inform Anesthesia as soon as possible	
Page Anesthesia: #13830	Page nursing OR Coordinator #14891 (phone 32659) Anesthesia resident: #19855
Anesthesia calls AA / RT for assistance:	Weekday: 7:00 – 21:00: phone AA (#35888) After 21:00 / weekend: page RT (#19993)
Stroke tPA nurse / Neurology	
Patient history	Allergies? Fasting time? Previous anesthetics? GERD? Cardiac history? Respiratory history/OSA? Current Medication? Height? Weight? Previous chart?
Connect Pt to monitors	5 Lead ECG, pulse oximeter, non-invasive blood pressure set to every 5 mins
Connect Pt to wall oxygen: goal SpO ₂ > 92%	nasal prongs with CO ₂ port (e.g. 4 L/min) or plastic oxygen mask (e.g. 8 L/min)
2 nd iv cannula	NaCl 0.9%, to keep vein open
Anesthesia Assistant / Respiratory Therapist	
Prepare anesthesia machine + suction	Checked and functional: anesthesia machine + Yankauer suction
Set-up for arterial line	Have 3ft extension tubing available
Ensure anesthesia drugs are available	Propofol, Succinylcholine, Atropine, Ephedrine, Phenylephrine, Dimenhydrinate (Gravol)
Prepare equipment for airway management	Face Masks, Laryngeal Masks (ProSeal; sizes #3, #4, #5), Laryngoscope (#3, #4 blades), endotracheal tubes
Anesthesia	
Bring opioids (Pyxis)	Consider: Remifentanyl
Communicate	Neurology, stroke nurse; is AA / RT informed?
Consider sedation first	Consider: Dimenhydrinate (Gravol), Remifentanyl 0.03-0.1 µg/kg/min preferably no benzodiazepines (e.g. no Midazolam)
Consider general anesthesia	e.g. risk of aspiration, airway obstruction, SaO ₂ ≤ 92% despite Oxygen, GCS ≤ 8, agitated patient; consider volatile anesthesia
Blood pressure control: Avoid hypotension	Consider infusions of vasopressors (phenylephrine, norepinephrine) Allow permissive hypertension before revascularisation, unless tPA given then target: syst BP 160 – 180 mmHg. Consult with Neurology. Avoid hypertension after vessel recanalization (e.g. Syst BP 130 – 150 mmHg)
Arterial line for BP monitoring	Avoid delays with radial artery cannula. If possible, use the femoral sheath for arterial blood pressure / sample blood gases.
Avoid hyperventilation	Aim for normo- capnia at upper limit (e.g. EtCO ₂ : 40-45 mmHg)
Foley catheter	Rarely needed. Can be inserted after revascularisation.



Material / devices needed in Neuroradiology Angio Suite 24 / 7. Call RT to check / restock

Fully stocked anesthesia cart with drugs

Face masks and Laryngeal Mask Airways (LMA Proseal)

Checked and prepared: anesthesia machine w long circuit, suction tubing and Yankauer, Laryngoscope handle with sizes #3 and #4 blades

Fresh art. line set up, extension for piggy back femoral sheath

Bear hugger with upper body blanket

O₂ Masks, Nasal prongs with CO₂ measurement

2 B.Braun syringe pumps with chargers and with tubing

Re-stock after each case!!! Consider exchanging cart to fully stocked cart (OR)



Craniotomy for Resection of Supratentorial Tumor

Surgical characteristics	
Duration of surgery	Between 3 to 12 hours.
Antibiotic therapy	As per surgical protocol.
Special considerations	<ul style="list-style-type: none"> • Be prepared for major blood loss and to manage venous air embolism • Positioning depends on the location of the tumor, often supine with head turned.
Anesthesia	
Preoperative preparation	<p>Assess the mass effect of the tumor</p> <p>Review the location, size and eloquence of the tumor, and its proximity to adjacent vascular structures (e.g sagittal sinus)</p> <p>Optimize pre-existing medical conditions</p> <p>Check group & screen and ensure blood/blood products are available.</p> <p>Ensure preoperative steroid and anti-convulsant medications are continued</p>
Mode of anesthesia	<p>Usually general anesthesia. Consider TIVA-based maintenance (Propofol) especially for deep-seated tumor or in patients with high intra-cranial pressure</p> <p>May require awake craniotomy or direct cortical mapping (under neuromonitoring) for tumor in eloquent cortex</p>
Airway	Standard management
Ventilation	<p>Maintain normocarbica (PaCO₂ 35-38 mmHg).</p> <p>Consider mild hyperventilation (PaCO₂ 30-33 mmHg) may be indicated in patients with high intra-cranial pressure</p>
Targets MAP	Maintain normotension during the procedure
Arterial Blood sampling	Perform regularly for CO ₂ control and Hb monitoring
Temperature	Maintain normothermia. Avoid hyperthermia
Patient monitoring and vascular access	
Patient monitoring	Standard CAS monitoring
Peripheral IV access	2 nd or 3 rd large-bore IV
Arterial line	Mandatory. Can be placed after induction.
Central venous line	Consider in high risk case to allow infusion of vasoactive drugs and aspiration of air in the case of venous air embolism
Foley catheter	Mandatory. Consider urinary catheter with temperature probe.
Postoperative Management	
Disposal	Neuro-Obs unit
Acute pain service	Consult in selected cases
Post-op pain therapy	Use opioids and acetaminophen as per protocol
Material / Devices needed in room	
<ul style="list-style-type: none"> • 1 HOTLINE (blood-giving set with extension and blood warmer) • 2 Syringe pumps (for remifentanyl and vasoactive drugs infusion) • 1 Baxter pump (TIVA) • 1 Arterial line set-up • 1 CVC set-up (double or triple lumens) and ultrasound machine (if required) • Bair hugger. • BIS / cerebral oximetry. • 3% Hypertonic saline and/or 20% mannitol. 	



Management of intraoperative tight brain (or intracranial hypertension)

- Cerebrospinal fluid drainage if ventricular or lumbar catheter in situ
- Administer osmotic agents
- Hyperventilation
- Augmentation of anesthesia with intravenous anesthetics (e.g. Propofol)
- Ensure adequate neuromuscular relaxation
- Ensure adequate venous drainage (ie. slightly head up, avoid high PEEP)
- Mild controlled hypertension



Neuroanesthetic Emergencies Critical Event Treatment Guides

1	Acute Stroke
2	Aneurysm Rupture in IR
3	Aneurysm Rupture in OR
4	Autonomic Hyperreflexia
5	Bleeding in Spine Surgery
6	Delayed Emergence
7	Increased ICP
8	Loss of Evoked Potentials
9	Seizures During Craniotomy
10	Vasospasm
11	Venous Air Embolism

The cognitive aids that follow were designed to aid in the clinical care of patients. As stated by the American Society of Anesthesiologists:

“Guidelines are systematically developed recommendations that assist in the decision making process. Practice guidelines are not intended as standards or absolute requirements, and their use cannot guarantee any specific outcome. Practice guidelines are subject to revision as warranted by the evolution of medical knowledge, technology, and practice. They provide basic recommendations that are supported by a synthesis and analysis of the current literature, expert opinion, open forum commentary, and clinical feasibility data.”

The purpose of these cognitive aids is to provide a resource for the anesthesia team when faced with a neuroanesthetic emergency. They are not a protocol that anesthesiologists are obligated to follow. Treatment may vary based on clinical decision-making.

These cognitive aids were developed by a SNACC education taskforce. Prior to publication the entire SNACC membership had the opportunity to review and revise.

#1 Acute Stroke

Alteration in level of consciousness or acute neurologic deficit (focal or global). Most common presenting symptoms: hemiparesis, visual loss, dysarthria, facial drop, vertigo, ataxia or sudden decrease in the level of consciousness.

Stabilize Patient:

ABCs

Establish time of onset (time last seen normal).

Supplemental oxygen to maintain saturation >94% (hyperoxia may be detrimental in stroke)

Brain imaging (noncontrast CT scan)

Treatment:

Intravenous thrombolysis with rtPA: indicated within 3 hours of symptoms onset, and may be considered within 4.5 hours, when no contraindication to IV tPA (SBP needs to be ≤ 185 mmHg and DBP ≤ 110 mm Hg).

Endovascular treatment (intra-arterial thrombolysis or mechanical clot extraction): indicated for major stroke within 6 hours, due to occlusion of the middle cerebral artery, especially for those with contraindications for intravenous thrombolysis.

Anesthetic management:

- Choice of anesthesia: General vs. conscious sedation.
 - No difference in neurologic outcomes and no delay in time to reperfusion when comparing both strategies
 - Decision should be individualized (eg. patient cooperation or need to secure airway)
- Hemodynamic management:
 - Preferentially use continuous invasive monitoring (do not delay intervention to obtain arterial access as it can be obtained by the neurointerventionist)
 - Avoid hypotension: maintain SBP > 140 mm Hg and <180 mm Hg.
- Oxygenation and ventilation:
 - Supplement oxygen to maintain SpO₂>92% and PaO₂> 60 mmHg
 - Maintain normocapnia to avoid cerebral vasoconstriction
- Temperature: Target temperature between 35°C and 37°.
- Glycemic management: Maintain BG between 70 to 140 mg/dL. Initiate insulin treatment if BG>140 mg/dL.

Risk Factors:

Hypertension, Diabetes, Tobacco use,
Hyperlipidemia, History of CAD

#2 Aneurysm Rupture- IR

Extravasation of contrast and/or signs of increased ICP

Stabilize Patient:

Increase FiO₂ to avoid hypoxia

Hyperventilate the patient

If possible, elevate head of bed (reverse Trendelenburg)

Drugs:

Protamine: Discuss dosing with Interventionalist and base on most recent ACT

- Typically 1 mg Protamine neutralizes 100 U Heparin
- Less Protamine is needed as times increased from Heparin administration
- Administer test dose and then as slow IVP: can cause hypotension, rarely can result in HTN or anaphylaxis

Mannitol: 0.25- 1 g/kg infused over 15 min

- Caution in setting of CHF and severe renal disease with anuria

Nicardipine: Infusion rate: 2.5-15 mg/h

Treatment:

Be prepared to administer Protamine. **Discuss with Interventionalist first**

Take maneuvers to decrease ICP:

- Consider giving Mannitol
- Maintain blood pressure near baseline levels until bleeding is controlled. Once hemostasis is achieved consider increasing BP to maintain cerebral perfusion pressure in context of increased ICP
- Consider switching to a TIVA

Maintain euglycemia, normothermia, and control seizures

Ensure STAT neurosurgery consult has been placed and EVD kit is being brought to IR suite

Check labs including ACT and consider converting blood status to type and cross

Ensure OR control desk aware of possible emergency case if unable to achieve hemostasis in IR

The patient will likely remain intubated after procedure/surgery

#3 Intraoperative Aneurysm Rupture (IAR)

May present clinically as sudden hypertension followed by bradycardia and arrhythmias, brain bulge or hematoma, or bleeding from the surgical site.

Stabilize Patient:

Communicate with the surgeon regarding anticipated blood loss and surgical visibility

Initiate vasopressor support, infuse volume, increase FiO₂ as needed, and consider transfusion

Verify blood products availability, consider MTP

Call for extra help

Drugs:

Adenosine: 0.3-0.6 mg/kg provides flow arrest of 12-50 seconds

Mannitol: 0.25- 1 g/kg infused over 15 min
- Caution in setting of CHF and severe renal disease with anuria

Propofol: 20-60 mg bolus, >125 mcg/kg/min infusion

Treatment:

Rupture before dural opening (IAR mainly occurs during hemodynamic swings and rapid changes in transmural pressure):

- Control abrupt increases in ICP with modest hyperventilation
- Immediate blood pressure control
- Minimize CMRO₂ using IV anesthetic agents (propofol, barbiturates)
- Surgical decompression
- Osmotherapy with mannitol or 3% saline

Rupture after dural opening (IAR mainly occurs during dissection or clip placement):

- Reduce MAPs to ~50s acutely to decrease bleeding, improve visualization and soften aneurysm neck for clipping
- Consider Transient Flow Arrest with Adenosine
- Minimize CMRO₂ using IV anesthetic agents (propofol, barbiturates)

* Hypothermia is not recommended regardless of Hunt and Hess Grade

* Reduction in MAPs must be balanced with maintaining perfusion of ischemic regions of the brain with impaired auto regulation

Common Causes:

Anesthetic factors: Response with intubation and emergence, coughing/gagging
Hypertension

ICP (sudden decrease): hyperventilation, use of large dose mannitol, CSF drain

Maneuvers: Valsalva, application of PEEP

Comorbidities: COPD, CAD, and hyperlipidemia

#4 Autonomic Hyperreflexia

Hypertensive episode, which can escalate to hypertensive crisis with reflexive bradycardia and dysrhythmias
Patients with spinal cord injury at T6 or higher are at increased risk (can appear 2-3 weeks after injury, typically will manifest within 1 yr)

Stabilize Patient:

Immediately inform the surgeon and ask the surgeon to stop operating
Deepen level of anesthetic
Increase FiO₂ to avoid hypoxia

Drugs:

Nitroglycerin: Consider bolus 50-100 mcg and titrate to effect. Infusion rate: 10-100 mcg/min

Nicardipine: Consider bolus of 0.1-0.2 mg and titrate to effect. Infusion rate: 2.5-15 mg/h

Treatment:

Administer short-acting, rapid onset anti-hypertensive

- Consider Nitroglycerin, Nicardipine, or Nitroprusside

Eliminate stimulus if applicable (i.e. empty bladder or bowel) and maintain deeper plane of anesthesia

Position patient with head up

Monitor for signs of: MI, hemorrhage, seizure, dysrhythmias (can progress to heart block) and treat accordingly

- Consider invasive monitoring

Differential Diagnosis:

Pain, inadequate anesthetic depth, uncontrolled baseline HTN, pre-eclampsia

Common Causes:

Visceral stimulus: bladder or bowel distention

Surgical stimulus

Infection: UTI, Pressure ulcers

Uterine contractions

#5 Bleeding During Spine Surgery

Verify Diagnosis: Increase in Blood Loss, Hypotension, Tachycardia, Oliguria

Stabilize Patient:

Control bleeding (surgical)
Replace plasma volume
Maintain BP with vasopressors as needed
Verify blood product availability, consider MTP

Drugs:

Tranexamic Acid: *Institutional protocols may vary and should be followed

- Low Dose: Load 1 mg/kg Infusion 1 mg/kg/hr
- High Dose: Load 30 mg/kg Infusion 1-10 mg/kg/hr

Treatment:

Confirm blood loss (suction canister, sponges, under drapes, etc.) and exclude other causes for hemodynamic problems
Ensure adequate vascular access if not secured already, communicate with blood bank re need for blood products
Consider use of red cell salvage techniques
Check labs: (ABG, Hct/Hb, thromboelastography)

- Correct deficiencies as indicated
- Goal Hb >8.0 (may vary based on patient co-morbidities)

Consider temporary wound packing until patient stabilized
Restore plasma volume and temporize with vasopressors
Ensure normothermia 36.0-37.9 °C
Consider antifibrinolytics (Tranexamic Acid) and Factor VIIa

Differential Diagnosis:

Overdose of anesthetic, pulmonary embolism, anaphylaxis, other forms of shock, or transfusion reaction.

Common Causes:

Multilevel spine surgery, tumor resection, trauma, infection
Revision surgery
Patient age, obesity, known coagulation defects

6 Delayed Emergence after Craniotomy

Failure of emergence or resumption of baseline mental status after expected time frame of recovery from anesthetics has elapsed

Stabilize Patient:

Immediately correct hemodynamic instabilities (hypotension, hypoxia, hypercapnia, etc.) or hypothermia
Notify surgeon, perform neurological assessment in OR

Drugs:

Naloxone: 0.04 mg-0.1 mg, IV every 2-3 minutes PRN for reversing an opioid overdose
Flumazenil: 0.2 mg IV, repeat at 1 min intervals PRN. usual dose: 0.6-1 mg for reversing a benzodiazepine overdose (caution for seizure precipitation)

Treatment:

Check and reverse residual anesthetics if possible:

- Opioid: reverse with naloxone
- Benzodiazepines: reverse with flumazenil
- Nondepolarizing neuromuscular blockade: reverse with anticholinesterases or sugammadex (for rocuronium and vecuronium)
- Volatile agent, barbiturates, propofol, other sedatives like ketamine, lidocaine: allow adequate time for recovery

Correct metabolic/endocrinological derangements: *send* blood gas, drug screen or other relevant tests

- Hypo-/hyper-glycemia, hyponatremia, hypermagnesemia, severe acid-base disturbances, etc.
- Hyperammonemia, uremia, severe hypothyroidism, central anticholinergic syndrome, drug intoxication, etc.

If neurosurgical causes are suspected:

- Prepare for transporting patient for emergent CT/MRI or angiogram
- Keep OR available for potential emergent re-exploration or angiogram
- Consider EEG to rule out seizures

Differential Diagnosis:

- Residual anesthetics (see "Treatment" section)
- Metabolic/endocrinological derangements (see "Treatment" section)
- Neurosurgical causes: cerebral ischemia and vascular occlusion, intracranial hemorrhage, elevated intracranial pressure, cerebral edema, hydrocephalus, postictal state after intraoperative seizures, tension pneumocephalus, surgical trauma, etc.

#7 Management of Intraoperative Increased ICP

Verify clinical picture. **Subjective** (surgeon's visible judgment), **objective** (Hypertension, bradycardia, ICP monitoring) and **radiological** evidence(CT scan) of cerebral edema are the most common indications to institute intraoperative ICP lowering treatment

Stabilize Patient:

Maintenance of cerebral perfusion pressure with mild hypertension as indicated.

Ensure adequacy of oxygenation: PaO₂ >100mmHg

Ensure adequacy of ventilation: EtCO₂ ~35 mmHg

Glucose control: BG 140-180 mg/dL

Avoidance of hyperthermia: Temp <38C

Drugs:

20% Mannitol (0.25-2g/kg) in IV boluses, typical dose is 1g/kg

Hypertonic saline(1.6-7.5%) continuous infusion (0.1 to 1.0 mL/kg/hr)

IV Furosemide (5-20mg)

Steroids (tumors/vasogenic edema)

Barbiturate coma- only in special circumstances.

Pentobarbital, 10 mg/kg over 30 minutes (load), 5 mg/kg/hr for 3 hours, then 1 mg/kg/hr.

Treatment:

Optimize patient position to improve venous drainage (elevate head)

Maintenance of adequate anesthetic depth and analgesia

- IV anesthetic preferred: Propofol
- Adequate muscle relaxation in an intubated patient and prevention of coughing, bucking or straining on the end tracheal tube

Hyperventilation to lower ICP

- Should not be prophylactic

Check labs to evaluate for metabolic causes

CSF drainage

- Consider Intraoperative drainage of CSF with a ventriculostomy

Treat seizures

- Cold saline irrigation by surgeon

Assessment for treatable surgical causes

Common Causes:

Intracranial hemorrhage: Epidural, subdural, intracerebral hemorrhage

Subarachnoid hemorrhage from an aneurysm rupture

CSF flow obstruction: hydrocephalus

Increase in venous pressure: venous thrombosis, heart failure

Metabolic causes: hyponatremia, hypoosmolality, hepatic, or uremic encephalopathy

#8 Loss of Evoked Potentials in Spine Surgery

Threshold for alarm is based on monitoring modality and surgery being performed (It is a team decision) However for SSEP a decrease in amplitude >50% or an increase in latency >10% is generally considered significant. MEP >80% amplitude decrease is considered significant.

Stabilize Patient:

Notify all members of the OR team

Neurophysiology technician should check lead placement to make sure nothing has become dislodged

Anesthesia team will verify that no sudden changes to the anesthetic have been made and will ensure the patient is not hypoxic

Surgical team should consider reversal of any high-risk maneuvers performed prior to loss of signals

Treatment:

Increase MAP \geq 85mmHg for adolescents and adults. For younger children, the MAP should be 20% above their baseline.

Turn off volatile anesthetics/switch to TIVA (notify neurophysiology team you are doing this)

Ensure normothermia 36.0-37.9 °C

Ensure normocarbia

Check patient limb positioning

Check an ABG

- Correct acidosis if present
- Transfuse pRBCs if Hb is <8.0

Re-evaluation of evoked potentials should be ongoing while corrective actions are being made.

If abnormality remains consider:

- Wake-up test
- Emergent spinal cord imaging

Common Causes:

Surgical: distraction of spinal cord, derotation or deformity, screw misplacement, osteotomy, patient positioning

Anesthetic: Drug boluses, deep stage of anesthesia

Physiologic: hypotension, hypothermia

Technical: electrode disconnection

#9 Seizure During Craniotomy

Awake craniotomy: loss of consciousness, fluttering eyelids, repetitive/rhythmic jerking movements of head or limbs, stiffness and convulsions. Characteristic EEG or ECoG changes during GA

Stabilize Patient:

100% O₂, may perform bag-mask ventilation with oral airway or place LMA if necessary (for awake craniotomy)
Notify surgeon, halt surgical manipulations, place ice-cold saline on the cortical surface
Treat hemodynamic instabilities (hypotension, hypoxia, hyperthermia, etc.)

Drugs:

Midazolam 1-5 mg, diazepam 5-10 mg, lorazepam 2-5 mg IV
Propofol: IV in 0.5-1 mg/kg increments
Phenobarbital: 10-20 mg/kg IV, max 30 mg/kg, rate < 60 mg/min
Phenytoin: 20 mg/kg IV at up to 50 mg/min
Fosphenytoin: load 15-20 mg PE/kg IV at up to 150 mg PE/min

Treatment:

If seizure is mild and self-limited => surgery may be continued with cautions. Supplement O₂ and closely monitor airway patency, ventilation/oxygenation, consciousness (if awake) and vital signs

If seizure is not self-limited, administer incremental doses of IV propofol, midazolam or barbiturate to halt seizures

If airway patency or adequate ventilation/oxygenation are not maintained:

- Place LMA or endotracheal tube (if awake), consider video laryngoscope or fiberoptic bronchoscope to help with airway visualization
- Suction oropharyngeal area and consider OGT to prevent aspiration
- Place bite blocker and protect patient from traumatic injury

Work on the underlying causes:

- Metabolic derangements: hypoglycemia, hyponatremia, alkalosis/hyperventilation, severe hypocalcemia or hypomagnesemia
- Drug toxicity or withdrawal, inadequate serum anticonvulsant levels
- Surgical insults: cortical stimulation, brain injury, cerebral hemorrhage or ischemia, etc.
- Anesthetics with epileptogenic potential should be avoided

Consider EEG or ECoG monitoring if feasible

Discuss administration of antiepileptic drugs (e.g. phenytoin, keppra) with surgical team

Prepare for delayed emergence and prolonged mechanical ventilation after surgery

Differential Diagnosis:

If awake: dystonia, shivering (hypothermia), nonepileptic seizures, anxiety spells, migraine headaches, syncope, etc.

If under GA (not paralyzed): dystonia, shivering (hypothermia), etc.

#10 Cerebral Vasospasm

Changes in neurological exam after SAH, often blood pressure dependent. Diagnosis via TCD followed by CT angiography

Stabilize Patient:

Avoid hypotension, hyperthermia, hyperglycemia, hypovolemia, and hyponatremia.

Ensure euvolemia

Consider securing the airway

Drugs:

Nimodipine 60mg PO q 4hrs x 21 days *standard of care

Nicardipine 0.075 – 0.15 mg/kg/hr IV *consider if unable to give nimodipine

Treatment:

Modified Triple H therapy if vasospasm confirmed and aneurysm secured, otherwise risk of re-bleed.

- Hypertension by volume expansion and possible addition of vasopressors (Phenylephrine, Norepinephrine, Vasopressin, etc.).
- Hemodilution with either crystalloids or colloids, aim for Hct 30 – 35% (optimal balance between low viscosity and O2 carrying capacity)
- Euvolemia in combination with induced hypertension

Vasorelaxation:

- Calcium Channel Blockers: (Nimodipine 1st line, Nicardipine 2nd line)
- Magnesium: no difference in outcome

Experimental and less efficacious medical therapies:

- Endothelin Receptor Antagonists: Clazosentan (conflicting results and increased risk of pulmonary edema, hypotension and anemia)

Free Radical Scavengers: Tirilazad, Nicaraven, Ebselen

Thromboxane Inhibitors: Ozagrel

Anti-Inflammatory Treatment: Nafamostat, Methylprednisolone

Interventional Therapies:

- Intra-arterial medical therapies: Papaverine, Verapamil
- Mechanical treatment

Differential Diagnosis:

Aneurysmal rebleed, acute stroke, hydrocephalus, seizures

Common Causes:

Day 2 – 15 after subarachnoid hemorrhage, usually resolving between weeks 2 – 5 post hemorrhage

#11 Venous Air Embolism

Sudden decrease in EtCO₂, hypotension, decreased oxygen saturation, mill-wheel murmur on Doppler. Dyspnea/respiratory distress if awake.

Stabilize Patient:

Switch to 100% O₂

Notify surgeon, flood field with saline

Treatment:

Attempt to halt further air entry by getting the surgical site below the level of the heart

- Identify source (IV or central line vs. surgical source)
- Trendelenburg and/or left lateral decubitus (beware of Mayfield stabilizer in sitting cervical cases)
- Valsalva or bilateral jugular compression have been used to halt ongoing embolism

Chest compressions may help break up air lock

Turn PEEP off (may facilitate paradoxical embolism in patients with PFO)

Maintain systemic arterial pressure with fluid and inotropic agents as needed

Cardiac Collapse should be treated with ACLS protocols

Consider:

- Central line with attempted aspiration of air
- Arterial line placement (if not already present)
- TEE

Differential Diagnosis:

In the absence of Doppler or TEE confirmation of air:
Anaphylaxis, Acute MI, Bronchospasm, and Pulmonary Embolism.

Common Causes:

Caused by air entering the venous system potentially leading to RVOT obstruction.