Anesthetic Management Guidelines for Interventional Neuroradiology Procedures

There is currently considerable variability in anesthetic management of interventional neuroradiology procedures at HMC and UWMC, due to a lack of evidence based outcomes research. An increasing focus on Neuroradiology procedures and projected increase in cases, necessitates that this will be an increasing focus and will become one of our major areas for neuroanesthesia in the future. Consequently there is a need for developing general guidelines for anesthetic management of interventional neuroradiology cases. We will be following adherence, times, complications, and communication in this CQI process with goals of process improvement and patient flow optimization.

Please note this document does NOT apply to the “Stroke Codes” requiring anesthesia. FOR ANESTHETIC MANAGEMENT OF “STROKE CODES”, PLEASE REFER TO THE SEPARATE GUIDELINES.

Most procedures requiring anesthesia involvement will be performed under GA although some may be done under monitored anesthesia care. The anesthetic technique should be selected in communication with the interventionalist, based on the type of neuro-intervention and individual patient characteristics.

**Procedures typically requiring GA:** Coiling / stenting of intracranial aneurysm, embolization of AVMs, Tumor embolization, Cerebral angioplasty / intra-arterial therapy for vasospasm, pediatric diagnostic / interventional procedures

**Procedures typically requiring MAC:** Carotid stenting, diagnostic cerebral angiography

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Emergent case

- Probable intervention (Coiling, stenting, embolization)
- Probable general anesthetic
- NeuroMuscular Blocker (NMB) is mandatory
- Allow BP high normal unless aneurysm / AVM as procedures are usually not very stimulating
- Keep patient relaxed i.e. redose frequent boluses of NMB. Document TOF or PTC and TOF before reversal. (See #1 below)

Scheduled or Routine Add On

- Diagnostic Only or Low Probability of Intervention
  - Consider MAC in communication with the interventionalist if patient is able to cooperate, low probability of intervention, and/or lesion is not in critical location and is otherwise appropriate as evaluated by anesthesia provider
  - Allow BP high normal unless aneurysm / AVM, as procedures not very stimulating
  - Convert to GA if needed
General considerations:

1. For cases performed under GA, maintain immobility (to avoid micro catheter induced injury and facilitate imaging) by using neuromuscular blocking drugs (NMBDs) as part of “balanced anesthesia”. Use TOF monitoring to guide administration and reversal of NMBDs.
   - Vecuronium, cisatracurium or rocuronium are all acceptable
   - Achieve deep NMB relaxation in constant communication with Interventional Radiologists/Neurosurgeons well before critical portions of procedures
   - Test TOF watch prior to giving NMBD
   - Use \( \approx \frac{1}{10} \)th of intubating dose to maintain 0-1 TOF (can adjust for known long duration or upregulated drug metabolism). Administer NMBD at 1 TOF to bring it down to 0.
   - Monitor TOF or PTC with TOF Watch, and ensure that thumb or toe can be seen during the procedure, i.e. do not completely tuck one extremity that you can observe continuously. Goal: visual or tactile confirmation of TOF Watch
   - PTC lasts about 6 minutes
   - Document TOF in anesthesia record every 5 minutes.
   - Neurointerventionalists are expected to clearly communicate to the anesthesia provider when deep neuromuscular blockade is no longer needed.
   - Wait for 3/4 or 4/4 return of TOF before 50 microg/kg reversal with neostigmine + glyco. Wait 10 minutes before extubation unless return to a TOF ratio of 80% is confirmed by TOF Watch at thumb
   - Ensure adequate anesthetic while waiting to reverse

2. Use balanced anesthesia incorporating either volatile / intravenous anesthetic agents with judicious use of opioids. Use alarm for MAC with volatile anesthetics.

3. Maintain adequate cerebral perfusion pressure (CPP) and low intracranial pressure (ICP) (procedure and patient specific goals to be discussed during time out)

4. For patients with ventricular drains – ICP should be transduced continuously. CSF should be allowed to drain above agreed ICP threshold (to be discussed during time out). Document CSF volume drained and watch for any sudden change in color / drainage pattern of CSF.

5. Avoid HYPERTENSION in patients with aneurysms and AVMs and HYPOTENSION in patients with vasospasm / occlusive cerebrovascular disease / tumors. Hemodynamic goals pre and post intervention to be discussed during time out; consider slaving groin sheath for hemodynamic monitoring if possible

6. Anticipate hypotension – phenylephrine / norepinephrine should be in line ready to infuse.

7. Maintain normocapnea (no hyperventilation unless acute intracranial hypertension)

8. Manage anticoagulation in communication with the interventionalist

9. Maintain euglycemia using institutional protocol

10. Maintain fluid and electrolyte balance

11. Maintain normothermia using underbody hot air warmer

12. Treat and manage complications (e.g. hemorrhage or vascular occlusion)

13. Facilitate early and smooth emergence from anesthesia at the end of procedures (with special attention to avoidance of coughing and bucking to avoid groin hematoma formation)

14. After emergence avoid groin flexion to prevent clot dislodgement and hematoma formation. Pediatric patients may require sedation and mechanical ventilation in the ICU to avoid inadvertent movement. This should be discussed with the interventionalists ahead of time.

15. Observe radiation safety; wear lead apron, radiation badge and thyroid shield at all times. Stand behind lead shield whenever possible.
**Procedure specific anesthetic considerations:**

**Embolization of intracranial arteriovenous malformation (AVM):**
1. Avoid hypertension in ruptured AVMs – likely to bleed. Possible need for deliberate hypotension with nicardipine, esmolol, nitroprusside, and/or propofol as needed. Discuss goals for magnitude, duration, and timing with the Neurointerventionalist.
2. Possible need for transient cardiac standstill using adenosine but only if discussed and planned Attending to Attending ahead of time. (refer to separate guidelines for this)
3. Potential risk of pulmonary embolization with the embolization glue.
4. Risk of post-embolization Normal Perfusion Pressure Breakthrough (NPPB). Keep systolic blood pressure 20% lower than the patients best known baseline using nicardipine (consider adding esmolol / labetolol or other agents if needed)

**Embolization / Stenting of Cerebral aneurysms:**
1. Keep systolic blood pressure < 120 mmHg to avoid rebleeding from aneurysm.
2. Manage external ventricular drain (EVD) to monitor ICP and drain CSF if needed.
3. Continue ongoing fluid, electrolyte and glycemic management.
4. Allow relaxation of blood pressure parameters following successful embolization.

**Cerebral angioplasty / intra-arterial vasodilator therapy for cerebral vasospasm:**
1. Avoid hypotension – continue to maintain preoperative blood pressure goals. The goals will need to be reset in agreement with interventionalist after successful treatment.
2. Anticipate the need for one or more vasopressor infusion
3. Avoid hyperventilation

**Embolization of intracranial tumor:**
1. Maintenance of CPP, avoid increase in ICP
2. Continue steroid /anticonvulsant treatment

**Carotid artery stenting:**
1. Usually performed under MAC / sedation
2. Avoid hypotension
3. Anticipate and be prepared to treat acute bradycardia (glycopyrrolate and atropine ready)

**Pediatric cases:**
1. General blood pressure goal to avoid hypotension – systolic blood pressure > 70+2*Age
2. Specific hemodynamic goals should be discussed during time out
3. Anticipate the need to leave the patient intubated / sedated post intervention to avoid groin movement and resulting hematoma formation.
**Preparation:**
1. This should involve routine set-up with special attention to:
   i) Potential need for invasive arterial blood pressure monitoring as below.
   ii) Vasoactive medications
      (1) Phenylephrine, nicardipine and ephedrine pre-filled syringes. Consider drawing up esmolol as well for quick effect.
      (2) Norepinephrine, phenylephrine, esmolol, nicardipine infusions (as needed)
   iii) Heparin & Protamine
   iv) Glucometer and regular insulin
   v) Mannitol on call from anesthesia techs if needed

**Pre Procedure Evaluation**
Common co-morbidities include: Hydrocephalus / elevated ICP (usually will have external ventricular drain); Cardiac abnormalities (ischemic changes on EKG, arrhythmias, troponin bump – can extend to cardiogenic shock); Pulmonary problems – increased incidence of acute lung injury and pulmonary edema; Seizures; Cerebral vasospasm (onset day 3, peak effect day 7); Cerebral infarction / focal neurological deficits / decreased GCS; Cerebral Salt Wasting (hyponatremia and hypovolemia); SIADH (hyponatremia and euvoolemia); and other electrolyte abnormalities (K+, Mg2+).

**Communication:**
During Time Out, entire team including Anesthesiology Attending, CRNA/Resident and Neurointerventionalists to discuss and agree specifically on:
   i. Location of lesion and planned procedure
   ii. Anesthetic technique: MAC vs GA
   iii. Current hemodynamic status and blood pressure, ICP goals during and after intervention.
   iv. Any specific considerations
   v. Notifying anesthesia providers in advance or during critical phases, i.e. stent deployment, Onyx injection, multiple coils, aborted procedures, complications etc, and any other major concerns

**Anesthetic Technique:**
The choice of anesthetic technique and pharmacological agents should be individualized based on clinical characteristics of each patient, in communication with the neurointerventionalist. **NOTE: These cases often are not very stimulating and do not need a 1.0 MAC anesthetic (undesirable cerebral hemodynamic effects with high dose volatile anesthetics).**

**Monitored Anesthesia Care (MAC):**
a) Patients who can protect their airway and are cooperative with minimal comorbidities
b) Supplemental oxygen
c) All patients should have continuous pulse oximetry and capnography and may need intermittent monitoring of PaO2 and PaCO2
d) Anesthesia team should be ready to rapidly convert MAC to GA at any time during neurointervention if needed
General Anesthesia:

a) Patients for definite coiling, embolization or stenting, impaired ability to protect airway, respiratory compromise, agitated uncooperative patients and those already intubated.

b) Blunt hypertensive response to laryngoscopy and intubation with propofol and/or nicardipine and/or esmolol and/or fentanyl and/or lidocaine

c) Invasive monitoring: Do **NOT** always place dedicated arterial lines as a routine. Groin access for intervention may be shared with the anesthesia team and used for lab work and blood pressure monitoring. Monitor non-invasive BP every 3 min if no invasive monitoring. This will avoid delays in definitive endovascular intervention and can save arterial line sites for the OR.

e) Accurately document “anesthesia start”, TOF and “anesthesia ready” times. These will be examined as institutional Quality Improvement elements.

Intraoperative Maintenance:

- a. Control blood pressure carefully, balancing risk of rupture with unsecured aneurysms (systolic > 120mmHg), with risk of ischemic stroke to injured areas of brain with marginal perfusion and impaired autoregulation. Allow high normal unless aneurysm / AVM as these procedures is not very stimulating.

- b) After the aneurysm is secured, blood pressure goals may be liberalized to systolic of 120-140 mm Hg – discuss with the interventionalist. Tighter control after embolization for AVMs usually advisable to avoid hyperperfusion syndromes.

- c) PaCO₂ – aim for normocapnia (PaCO₂ 35-45 mmHg)

- d) Opioids: avoid long acting opioids and use fentanyl sparingly until initial post-extubation neurological assessment has been performed.

- e) **Heparin** is frequently required during neuroradiology interventions. Commonly 2000 to 5000 units (IU) is given as an initial dose followed by intermittent boluses or an infusion to keep ACT 2–3 times baseline; ACT is monitored half-hourly / as needed and should be documented. Use close loop communication for heparin dosing and administration.

- f) Protamine is commonly given for reversal of heparin anticoagulation in a dose of 1 mg per 100 units of heparin or dosed according to the heparin dose–response curve. Discuss and agree on a dose. Announce when administering. Give a small test dose first. Protamine reactions range from mild hypotension from histamine release to severe cardiovascular collapse and anaphylaxis mediated by IgE and IgG immunoglobulins, with associated bronchospasm and cutaneous reactions. **CRITICAL Protamine Sulfate injection should be given by very slow IV injection over 10 minutes in a dose not to exceed 50 mg (per instructions on the pamphlet).**

- g) Ensure immobility using NMBDs – document TOF response.

- h) Temperature – aim for normothermia (35<T<37°C) Temperature>37.5°C should be treated by cooling room temperature, Bear Hugger to ambient setting, fluid warmer off; consider applying ice packs to groins if T>38°C. Brain temp is usually 0.5 to 1°C higher than core in setting of CNS injury.

- i) Blood glucose – hourly blood glucose sampling and use institutional protocol

- j) Administer scheduled medications
• **Hemodynamic Management/Monitoring:**
  f) SBP< 120mmHg for unsecured aneurysms – liberalize after successful coiling
  g) Prevent NPPB (Normal Pressure Perfusion Breakthrough) following AVM embolization – SBP 15-20% lower than best known baseline
  h) Vasospasm – avoid any drop in blood pressure prior to angioplasty – reset goals after successful angioplasty

• **Fluid Management:**
  a) Use non-dextrose containing crystalloid – pediatric patients may need dextrose
  b) All Patients who receive general anesthesia will have a Foley catheter placed prior to procedure start

• **Glycemic Management:**
  a) Glucose should be sampled at least once every hour - capillary / venous / arterial blood may be sampled with point of care glucometer or blood gas analyzer.
  b) Maintain glucose in the range of 100-180 mg/dL with insulin treatment initiated for glucose values > 180 mg/dL and treatment for hypoglycemia being initiated for glucose values < 50 mg/dL.

• **Emergence and Extubation:**
  a) In general, all patients who were not intubated prior to arrival to angio suite should be extubatable at the end of intervention in communication with the neurointerventionalist. Note that pediatric patient may need to be sedated / mechanically ventilated to avoid groin hematoma formation. In general, patients with Hunt and Hess grades 1-3 should be extubatable; H+H grade 4+5 should remain intubated post-operatively; Do not undertake deep extubation – extubate on patient obeying commands or localizing to tube.
  b) Call NCCS / ICU 30 minutes prior to end of case, and give report.
  c) Extubated patients are recovered in the NeuroAngio PACU until 5 PM. AFTER 5 PM extubated patients are recovered in PACU West.

**Possible Complications:**

**Neurological:**
  1. Hemorrhagic
     • Aneurysm bleed / rebleed
     • Intracranial vessel injury, dissection (“extravasation of dye” in the brain)
     • Hyperemia (after AVM embolization)
  2. Occlusive
     • Displaced / fractured coil into parent vessel
     • Occlusion of normal cerebral vessel due to glue
     • Cerebral vasospasm

**Non-neurological:**
  1. Allergic reactions: contrast dye, heparin, protamine
  2. Groin hematoma
**Rupture:** If aneurysm ruptures during intervention, anticoagulation may have to be reversed with protamine in communication with the interventionalist. Patient may need to be emergently transferred to the OR in case of massive bleeding. Rupture may be associated with acute hypertension - swift blood pressure control can be accomplished with bolus dose of propofol or nicardipine. Once bleeding is controlled, reassess volume status and resuscitate BP as necessary to maintain perfusion. This may require an interim phenylephrine infusion, to offset propofol effect.

**Seizures:** Immediate treatment with propofol 1-2 mg/kg – controls hypertension and seizure; Administer benzodiazepine (e.g.: midazolam 2-5mg) and ensure anti-seizure medication has been given; consider additional anticonvulsant medications.

**Post-procedure debriefing:**
After completion of the intervention, a quick debriefing should be initiated with anesthesiology and neuroradiology involvement discussing procedural details and further management, including physiological goals and where the patient will be recovered.