Anesthetic consideration for Interventional Neuro Radiology(INR) procedures.

The anesthesia providers play a crucial role in facilitating neuroradiological procedures, and this requires an understanding of specific neuroradiological procedures, their potential complications, and their management. The objectives of anesthesia are to: (1) provide a physiologically stable and immobile patient; (2) provide prompt neurologic assessment when needed and after the procedure for cases done under GA. (3) optimally manipulate systemic blood pressure as dictated by the needs of the procedure and patient's underlying condition and (4) provide emergent care for any catastrophic complications.

Procedures amenable to INR can be broadly classified based on the aim of treatment.

(a) **Closing or occluding procedures**: Coiling of aneurysms, Flow diverting stents for large aneurysms , embolization of arterio-venous malformations (AVM) and fistulae of the brain and spine, preoperative embolization of vascular tumors such as meningiomas, temporary or permanent occlusion of arteries intra- or extra-cranially.
(b) **Opening procedures**: treatment of vasospasm or stenosis by angioplasty and stenting or Verapamil injections, chemical and mechanical thrombolysis in stroke.

Imaging technology
Neuro-angiography and intervention requires high-resolution fluoroscopy and high-speed digital subtraction angiography (DSA) with road mapping functions. The road mapping function enables the radiologist to observe the advance of the catheter against the background map of the patient's cerebral vessels in real time. DSA enables visualization of only those vessels that are opacified by contrast injection. DSA involves subtraction of images obtained before and after injection of radiocontrast. Any displacement of the cerebral vessels because of movement of the head profoundly degrades DSA images.

Radiation safety
The sources of radiation in the neuroradiology suite includes: direct radiation from the X-ray tube, leakage radiation through the collimators and protective shielding, and scatter radiation that is reflected from the patient and the surrounding area. It is important to realize that DSA delivers considerably more radiation than fluoroscopy.

Radiological vascular access and methods
INR usually involves introducing catheters into the arterial circulation of the head, neck, or spine. The transfemoral arterial approach is usually used, although direct carotid or brachial puncture may be used in special circumstances.
A large introducer sheath, usually 6.0- 7.5 F is inserted into the femoral artery. Through this introducer, an end-hole catheter (4.0–6.0 FG) is then manipulated, under fluoroscopic control, into the carotid or vertebral arteries. A 1.2–2.8 FG superselective microcatheter is introduced through the catheter into the cerebral circulation which can be used to deliver drugs or embolic agents or balloons to distal regions of the brain.

Materials used for embolization or infusion

1. Solid embolic agents: coils, PVA particles, detachable balloons, and gelfoam
2. Liquid embolic agents: NBCA, EVOH (OnyxTM)
3. Thrombolytic/antiplatelet agents: tissue plasminogen activator, streptokinase/ urokinase, abciximab (Reopro), and aspirin
4. Vasodilators: nimodipine, nicardipine, verapamil, papaverine, and nitrates
5. Chemotherapeutic agents for tumours.

Anaesthetic considerations.

Preoperative assessment

Detailed patient evaluation and understanding of the underlying neuropathology are essential. In addition to the normal pre-anesthetic evaluation and investigation, a careful neurological examination to identify any deficits should be performed. Baseline arterial pressure and cardiovascular reserve should be evaluated, as should renal insufficiency. As anticoagulation is employed during most procedures, evaluation of coagulation is important. Some patients will be on antiplatelet drugs pre-operatively.
Any history of protamine allergy, contrast reaction, Iodine and shellfish allergies are important. It should also be borne in mind that arthritis of neck, back, or other joints will influence the patient's ability to lay supine and the potential for airway compromise with sedation. Cross matching may be needed for some of the therapeutic procedures.

Anesthetic technique

One should consider the needs of the neuroradiologist and the procedure as well as patient's mental status and the underlying medical condition while choosing the anesthetic technique. For cases done under MAC, the patients must be able to follow instructions during the procedures for neurologic testing, such as hold their breath and remain immobile to reduce image artifacts. Many INR procedures such as diagnostic angiography, carotid stenting, thrombectomies, and tumor embolization can be undertaken with minimal intravenous sedation while others require GA. Often, the choice of anesthetic technique is a collaborative decision by the radiologist and the anesthesiologist, based on the individual patient assessment. Very rarely some of the INR procedures might require neuromonitoring (EEG, SSEP and MEPs).

The advantages of general anesthesia are, it provides immobile patient with improved image quality, patient comfort, and better control of the respiratory and hemodynamic profile. The disadvantages are the inability to perform neurological assessment intraoperatively; intraoperative hypotension is common requiring phenylephrine infusion while hypertension, coughing and straining which can lead to raised ICP during extubation and emergence.

The benefits of sedation are that it is easier to perform neurological testing repeatedly and the avoidance of hemodynamic changes associated with intubation and emergence. The disadvantages are an unprotected airway with the risk of aspiration and the potential for hypoxemia and hypercapnia if used inappropriately. Sudden patient movements and delays in managing a neurological emergency may also occur.

Hemodynamic goals

BP goals are different depending on the patient's underlying pathophysiology and other coexisting comorbidities. Each patient is unique hence it is important to discuss the hemodynamic goals with the neuroradiologists and maintain BP accordingly. Phenylephrine and nicardipine are the two commonly used infusions and in addition to these, fast acting vasoactive (phenylephrine, epinephrine, atropine) and vasodilators (nicardipine , nitroglycerine, esmolol, labetalol) should be available to administer as iv push to control the hemodynamics quickly.

Since the procedure itself involves very minimal stimulation, majority of these patients drop their blood pressure after the induction and many would require phenylephrine infusion to keep the BP at the optimal level.

Room preparation

The INR suite should be equipped exactly like a standard anesthesia operating room. An extended anesthetic breathing system is necessary. Rapid access to all critical equipment should be possible at all times during the procedure. Induction and emergency drugs must be prepared for immediate use.

Patient positioning

Some INR procedures may last for several hours, it is essential that the patient be made as comfortable as possible before the start of sedation. Soft padded restraints to secure the hands alongside the patient are necessary to avoid any inadvertent contamination of the arterial puncture site. There should be sufficient slack in all monitoring lines, i.v. lines, and airway connections as the patient table may need to move back and forth during imaging and coiling. This should be checked before starting the procedure to ensure adequate length of the circuit and tubing.

Conduct of anesthesia

The anesthetic machine is best located opposite the neuroradiologist and towards the patient's feet. This position keeps it out of the way, and imaging equipment can move freely around the patient's head.
Secure intravenous access should be available to allow drug and fluid administration. Infusions of drugs, such as anticoagulants or remifentanil, should be given through a separate cannula. Adequate intravenous access must be obtained before starting the procedure because of risk of bleeding.
Standard monitoring is required, regardless of anesthetic technique. For interventional procedures, an arterial line is often needed for close BP monitoring and blood sampling. If arterial cannulation is difficult, then a side port of the femoral artery introducer sheath can be used to monitor the arterial pressure.

Catheterization of the bladder is required for most procedures. This assists in fluid management and aid patient comfort. A significant volume of heparinized flush solution and radiographic contrast is often used, and administration of diuretics such as mannitol and furosemide may be required intraoperatively.
Hypothermia can occur in the neuroradiology suite, and measures should be taken to keep the body temperature near normal and core temperature measured.

Anticoagulation
Careful management of coagulation is required to prevent thromboembolic complications during and after the procedure. In general most of the interventional procedures, baseline activated clotting time (ACT) is obtained, i.v. heparin (50-70iu/kg) is given to prolong ACT by two to three times. ACT is monitored at least every hour and if required additional dose of heparin is given.

Complications of interventional neuroradiological procedures

1. **CNS complications**

Hemorrhagic
a) Aneurysm perforation
b) Intracranial vessel injury, dissection.

Occlusive
a) Thromboembolic complications
b) Displacement of coil into parent vessel, coil fracture
c) Vasospasm

2. **Non-CNS complications**

a) Contrast reactions
b) Contrast nephropathy
c) Hemorrhage at the puncture site, groin hematoma, retroperitoneal hematoma.

Complications of interventional neuroradiological procedures
Complications during the INR procedure can be rapid and catastrophic. There should be good communication between the neuroradiologist, anesthetist, and the radiographer for the prompt management of complications that may occur. It is important to know whether the complication is occlusive or hemorrhagic as these require a different approach for successful management.

Hemorrhagic complications
Hemorrhage is often accompanied by an abrupt rise in the mean arterial pressure. Immediate reversal of heparin may

be required (1 mg protamine for each 100 units of heparin given). The transient lowering of the systemic arterial pressure, hyperventilation and iv mannitol (0.25–0.5 g/ kg) may be needed to reduce the ICP. Aneurysm perforation is usually treated by packing the defect with coils. Emergency craniotomy and clipping of aneurysm may be required if coiling fails. Patients may develop acute hydrocephalus secondary to new SAH necessitating transfer to theatre, for ventricular drainage.

Occlusive complications

In the event of occlusion, the arterial pressure should be raised to increase collateral blood flow and maintain normocarbia.

Angiographically visible thrombus may be treated by mechanical lysis using a guide wire or local infusion of saline. Thrombolytic agents are commonly used to treat intraprocedural thrombosis, but results have been mixed. Malpositioned coils compromising parent artery are removed by endovascular retrieval and rarely craniotomy may be needed.

Contrast reactions

The most commonly used contrast for INR nowadays is iohexol (non-ionic) with an osmolality of 672 mOsm kg. Although fatal reactions occur at the same frequency as ionic agents (1:10 000 exposures), non-ionic agents have a lower incidence of mild and moderate reactions.

Reactions can be caused by hypertonicity, direct cardiac depression, or idiosyncratic anaphylactoid reactions. For patients with a previous reaction to contrast, pre-treatment with steroids and antihistamines is recommended.

Contrast nephropathy

This is the third most common cause of hospital-acquired renal failure, and accounts for 12% of patients. The risk factors include diabetes mellitus, high dose of contrast, volume depletion, co-administration of nephrotoxic medications, and pre-existing renal disease. A direct correlation between the osmolality of contrast media and nephrotoxicity is well established. Patients with preexisting renal dysfunction were less likely to develop contrast-induced nephropathy when non-ionic contrast media were used. To prevent renal complications, perioperative fluid management should be aimed at maintaining normovolaemia, to offset the diuretic effect of the injected contrast. N-acetylcysteine, 600–1200 mg twice daily, two doses before and after the procedure has shown significant reduction in the incidence and it is acceptable for use in high-risk patients. Isotonic bicarbonate infusion may also reduce the incidence of contrast-induced nephropathy, by alkanizing renal tubular fluid and thereby minimizing tubular damage.

Postoperative care

All patients who have undergone an INR procedure should be intensely monitored during the immediate, post-procedural period.. Neurologic examination should be performed repeatedly during the post-procedural period, and CT or other imaging study is required if any neurologic deficit is detected.

Maintenance of modest hypotension is required post AVM embolization and Carotid angioplasty and stenting to prevent cerebral edema and hemorrhage. The mean arterial pressure should be kept 15–20% below the baseline for 24 h. Antihypertensive agents such as labetolol, nicardipine infusion can be used to the control pressure.

A mean arterial pressure 20–30% above normal may be required in patients with occlusive conditions, coil embolization for ruptured aneurysm and patients with vasospasm to maintain cerebral perfusion pressure. This can be achieved with the use of phenylephrine or norepinephrine.

Maintenance of heparinization in the post-procedure period is recommended if a large surface area of coil is exposed in the parent vessel, or if an embolic complication was encountered during the procedure.

Anesthetic Management of Interventional Neuroradiological Procedures.

Specific procedures:

1. **Diagnostic cerebral angiography**: Most patients requiring diagnostic cerebral angiography are awake, unless their neurological state dictates the use of general anesthesia for airway control or to keep them immobile. Patients must understand the importance of lying still during this procedure and that the room

will be darkened. Patients should be warned that they might experience a hot sensation in their head and face during injection or headache due to traction by the catheter or guide wire during manipulation, especially in external carotid artery branches. Most of the patients can undergo this procedure with very minimal sedation (1-2 mg midazolam or 25-5- mcg of fentanyl).

2. **Endovascular treatment of cerebral aneurysm**

Patients, who survive a SAH, have a high risk of rebleed in the first 24 h. These patients are also at risk for vasospasm during the second week after the SAH. Patients, with aneurysmal SAH, should be monitored for increased intracranial pressure (ICP), cerebral ischemia, and hydrocephalus. Tight control of their BP is important as hypertension increases the risk of re-bleed whereas hypotension can lead to cerebral ischemia. BP is usually maintained at <140 mm Hg until the aneurysm is secured. General anesthesia is preferred for coiling of cerebral aneurysm. Aneurysm perforation occurs in 2.3–3% of ruptured aneurysms treated with coiling. The risk of perforation of a previously unruptured aneurysm is ,0.5%. Thrombus can form on the catheter, guide wire, or coil during or after the coil placement. The overall incidence of thromboembolic complication is 2.5–5%. Coil unravelling and coil fracture are also reported. Parent artery compromise due to coil displacement occurs in 2.5% of patients.

3. **Treatment of vasospasm** involves angioplasty and intra-arterial injection of papaverine or Verapamil. Angioplasty is widely considered to be the most effective procedure. It is most effective when done early, within 2 h of symptomatic ischemia. BP is usually maintained 20% higher than the baseline to maintain adequate perfusion.
Complications include vessel rupture (2–5%) and re-bleed from an unprotected aneurysm (5%). Verapamil injection can result in hypotension and bradycardia requiring hemodynamic support. Atropine and epinephrine syringe should be readily available.
However, papaverine has a transient effect (up to 24 h) and is associated with side-effects, including monocular blindness, mydriasis, seizures, transient increase in ICP, hypertension, tachycardia, and paradoxical worsening of vasospasm.

4. **Embolization of AVM**
The two main types of vascular malformations amenable to endovascular treatment are parenchymal cerebral AVM and AVF. Cerebral AVM consist of a vascular convolute with a nidus that is fed by one or more arteries and drained by one or more veins. Capillary vessels are typically missing and arteries and veins are connected by arterio-venous shunts. Approximately 10% of patients with AVM have intracranial aneurysms. Patients can present with spontaneous hemorrhage, seizures, or with neurological symptoms due to local ischemia caused by steal phenomena or venous hypertension. AVF consist of a direct connection between an artery and a vein. This type of shunt is found in the Vein of Galen malformations, carotid-cavernous fistulas, and spinal AVF. Patients may present with symptoms due to cardiac failure, mass effect, bruit, or seizures. Dural AVF are acquired after trauma and are usually high-flow. They can also occur because of venous sinus thrombosis and venous hypertension.
General anesthesia is preferred. Temporary apnea and a Valsalva maneuver can be applied to improve visualization. BP is maintained at normal range during the procedure however, Controlled hypotension or flow arrest, to slow blood flow in the feeding artery of an AVM before glue injection, may be required in some cases.
Post Op : These patients must be monitored closely in the ICU settings. Abrupt restoration of normal perfusion pressure to a chronically hypotensive vascular bed after embolization might overwhelm the autoregulatory capacity and result in hemorrhage or swelling (**normal perfusion-pressure breakthrough**). Therefore, it is desirable to maintain arterial pressure about 15–20% below the patient's normal level after the procedure.
Alternative theories to explain hemodynamic complications include occlusion of the draining venous system in the brain surrounding the AVM, followed by passive hyperemia and stagnation in the feeding artery. Embolization of glue into the draining vein may result in venous outflow obstruction and pulmonary glue embolization.

5. **Carotid angioplasty and stenting.(CAS)**
   Can be done under GA or MAC. MAC is preferred as it allows evaluation of the neurologic function. The selection of anesthetic techniques also depends on the patient's medical condition, his or her ability to cooperate during the procedure, or if there is an anticipated technical difficulty in negotiating the stenosed segment. Patients should have arterial line. BP should be maintained at their baseline intraoperatively . Severe bradycardia or asystole may occur due to stretching of the carotid body. When a patient suffers 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. If hypotension develops, fluid boluses of 500 ml normal saline should be administered because the source of hypotension is generally vasodilation. If fluid boluses are unsuccessful and hypotension persists, a vasopressor drip with either dopamine or norepinephrine is initiated. Patients are maintained on fluids and the vasopressor agent is titrated to maintain the mean arterial pressure targets set by the clinician.
   Cerebral hyperperfusion syndrome (CHS) is characterized by ipsilateral headache, hypertension, seizure, and focal neurologic deficit. CHS often occurs in patients with an increase of more than 100% in cerebral perfusion following the procedure, compared with the baseline. As perfusion is pressure-dependent in patients with CHS, strict blood-pressure control is recommended. The BP goal should be discussed for each patient during the case. The goal should be to adjust the systolic pressure about 80% of the pre-operative baseline systolic pressure.

6. **Acute Ischemic Stroke.**

   For patients coming for IR procedures for Ac Ischemic stroke, procedure can be done under MAC with very minimal sedation if there is no contraindication. Majority of patients presents with hypertension during the acute phase.

Per the 2013 Guidelines of the American Heart Association (AHA) for the early management of patients with acute ischemic stroke, an ideal BP range during acute ischemic stroke has not been determined but probably depends on patient-specific factors. Hence important to discuss the BP goals with the neuro radiologists before starting the procedure.

1. For patients who are brought for intra-arterial recanalization therapies after receiving intravenous (IV) tissue plasminogen activator (tPA), SBP should be maintained at <180 mm Hg and diastolic BP (DBP) at <105 mm for up to 24 hours following IV tPA.
2. In some patients necessitating angioplasty and/or stenting of an artery suspected to have chronic flow-limiting stenosis, the target BP may be lowered further depending upon the clinician's concern about reperfusion syndrome.
3. In patients not receiving IV thrombolytics or intra-arterial recanalization therapies, the AHA recommends withholding antihypertensive therapies unless SBP is >220 mm Hg or DBP is >120 mm Hg. AHA guidelines also state that it is reasonable to lower BP by 15% during the first 24 hours after stroke onset. Lower BP targets are often initiated if there is evidence of end-organ damage due to elevated BP or if an elevated pressure is thought to be exacerbating a comorbid condition.

Post thrombectomy: BP parameter will depend on the thrombectomy results. Hence needs to be discussed with the neuro radiologists.

7. ***Carotid occlusion test***
   The carotid occlusion test is primarily used to test the adequacy of the cerebrovascular collateral circulation before electing to occlude the carotid artery, by showing whether the patient can tolerate temporary or permanent occlusion. This may be necessary during surgery for tumors involving the internal carotid artery, either at skull base or intracranially, or for giant internal carotid and vertebrobasilar aneurysms. Combining the carotid occlusion test with controlled hypotension (10–20% of baseline) increases the predictive value of the test. The patient must be awake for the procedure, as continuous neurological evaluation is required to assess the effects of occlusion. The most common complications during the performance of occlusion test are bradycardia, hypertension, and loss of consciousness.

8. ***Superselective anaesthesia functional examination and Wada test***

The Wada test consists of behavioral testing after the injection of an anesthetic agent, such as sodium amobarbital or sodium methohexital, into the internal carotid arteries. The test is conducted with the patient awake, to determine the dominant side for vital cognitive functions, namely speech and memory. Typical uses of the test include the lateralization of language abilities before surgery.
Superselective anesthesia functional examination (SAFE) is an extension of the Wada test. It is carried out before therapeutic embolization, to exclude inadvertent placement of the tip of the catheter proximal to the origin of normal vessels supplying important regions in the brain or spinal cord. The patient should be awake before performing the test. Sodium amytal is injected into the vascular territory planned for occlusion and repeated neurological examination is made to exclude any functional involvement.

9. ***Tumor embolization***
   Preoperative embolization is used for meningioma, glomus tumor, and juvenile nasopharyngeal angiofibroma, spine tumors. The primary goal of embolization is to reduce tumor vascularity before surgery to minimize blood loss and to facilitate dissection. This is best achieved with PVA particulate embolization. The procedure is usually performed with the patient awake.

Infusion Medications used during the NIR procedure

1. Remifentanil 0.05 - 0.2 mcg/kg/min
2. Nicardipine 5-15 mg/hr.
3. Propofol 10 - 50 mcg/kg/ min
4. Dexmedetomadine 0.2 – 1.5 mcg/kg/hr
5. NTG 0.5 - 5 mcg/min
6. Norepinephrine 1 - 15 mcg/min
7. Epinephrine 1 - 15 mcg/min

Placement of 2 “spiders” at end of a peripheral IV to infuse the 4 drip meds.

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March 2017.

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