CRANIOTOMY
Intracranial surgery is usually done for 3 main conditions
1. Trauma
2. Tumors and
3. Aneurysms

Each category is unique in its management and will be considered individually for a clear understanding of the issues involved.

Anesthesia for Head Trauma
Intracranial hematomas are the most common pathology requiring surgical treatment. It must be kept in mind that head trauma is often associated with spinal cord injury and trauma to various other organs which may produce various problems during anesthesia. You should be aware of any co-existing injuries for better management of these patients.

Treatment of hemorrhagic shock takes precedence over neurosurgical procedures. Patients with head trauma will most likely be in the ICU or Emergency room when you encounter them initially.

1. Control of Airway and Ventilation. The majority of patients with severe head injury will already have an endotracheal tube in place from the ER or ICU. If the patient comes to the OR without tracheal intubation immediate oxygenation and securing of the airway is required. Since all trauma patients are considered to have full stomach and not infrequently
(about 10%) a cervical spine injury, cricoid pressure and in-line stabilization of the cervical spine should be used during laryngoscopy and intubation. Rapid sequence induction is facilitated by pre-oxygenation with 100% oxygen and precurarization with a small dose of nondepolarizing muscle relaxant. An induction dose of sodium pentothal (3-4 mg/kg) and succinylcholine (1-5 mg/kg) are administered and the trachea is intubated. Etomidate (0.2 to 0.3 mg/kg) maybe used in hemodynamically unstable patients. Both induction agents decrease CBF, CBV, and ICP. Since succinylcholine has been shown to increase ICP precurarization is felt mitigates this response. Mechanical ventilation should be adjusted to maintain a PaCO2 around 30-35 mm Hg. The fiO2 should be adjusted to avoid hypoxemia, maintaining a PaO2 above 100 mm Hg. Excessive PEEP should be avoided because the elevation in intrathoracic pressure can compromise cerebral venous drainage and increase ICP.

2. Cardiovascular Stabilization. Systemic hypotension is one of the major contributors to poor outcome after head trauma. Thus it should be quickly corrected by fluid resuscitation. Normal saline has been traditionally used as the crystalloid solution of choice. Lactated Ringer's solution can be used but it's slightly hypotonic to plasma. Routine use of glucose containing solutions is not advised because hyperglycemia might aggravate neurological damage. A plasma level of 80 to 150 mg/ml is desirable; values above 200 mg/dl should be avoided and treated with insulin. If blood pressure and cardiac output cannot be restored with fluid resuscitation, administration of IV inotropes and vasopressors is necessary. A CPP above 70 to 80 mm Hg should be maintained. It is prudent in these cases to put in an A-line and at least one large bore IV for adequate fluid resuscitation.

3. Maintenance of Anesthesia. In general narcotics in clinical doses produce minimal to moderate decrease of CBF and CMR02 and have minimal effect on ICP when ventilation is adequately maintained. Fentanyl is a good choice in this respect and avoids unnecessary use of high concentrations of inhalational anesthetics. Isoflurane is considered the volatile anesthetic of choice as it decreases cerebral metabolism. Nitrous oxide should be avoided if pneumocephalus is present because of its ability to increase the volume of an airspace. Adequate muscle relaxation is necessary to facilitate hyperventilation and reduce ICP. Coughing and straining should be avoided because both can produce cerebral venous engorgement. Most non-depolarizing muscle relaxants have minimal effects on ICP and the choice can be made on an individual basis.
4. Intraoperative Management of Raised ICP

- **Patient's Posture.** Slight head up tilt (15-30) is desirable. The head and neck should not be torqued so as to interfere with venous return.
- **Ventilation.** Maintain mild to moderate hypocapnia (PaCO₂ 30 to 35 mm Hg)
- **Circulation.** Correct hypotension (< 100 mmHg) and hypertension (> 160 mm Hg)
- **Diuretics.** Mannitol will decrease cerebral volume and ICP (1g/kg over 20-30 minutes). Furosemide maybe administered in severe cases and those prone to heart failure.
- **CSF Drainage.** Can be done if an intraventricular catheter is in place.

5. Monitoring. Standard monitoring includes EKG, direct arterial BP, Pulse oximetry, ETCO₂, body temperature, urinary output and neuromuscular blockade. Hypothermia (33-35) is not harmful and might even have beneficial effects by reducing metabolic demands.

6. **Emergence and extubation.** Surgeons might request to awaken patients in order to perform a neurological exam postoperatively. If the patient's preoperative level of consciousness was normal extubation in the OR can be considered after reversal of the neuromuscular blockade. Smooth extubation and emergence are important. Contraindications for extubation in the OR are
  - Patient somnolent preop
  - Brain swelling intraop or expected to occur postop
  - Multiple trauma
  - Hypothermic patients

**ANESTHESIA FOR BRAIN TUMORS**

Preoperative preparation of the patient should include discussion with the surgeon as to the surgical approach, which in turn depends on the size, location and vascularity of the tumor. Knowledge of patient positioning beforehand will help in planning vascular access and monitors for your convenience. Typically supratentorial tumors require a bifrontal approach through sagittal venous sinuses making them at risk for both bleeding and air embolism. Posterior fossa tumors in our hospital are usually done in the prone position.
1. Meningiomas are usually large, vascular and require radical excision for a cure. Hence these procedures are long, technically demanding with significant blood loss.
2. Gliomas on the other hand usually require only simple debulking, have easy surgical access and have little risk of bleeding.
3. Skull base tumors need maximal brain relaxation for exposure. Ensure a type and screen sample is available in the blood bank before any craniotomy.

**Premedication**
Most patients are scheduled electively and you might find that many of them will actually arrive from home on the day of surgery. The decision to administer sedative premedication in the holding area should be approached cautiously. Keep in mind that these patients have a very small requirement especially if they have raised ICP. Over-sedation can lead to hyperventilation, hypercapnia, hypoxia and upper airway obstruction leading to raised ICP. A small dose of midazolam is a good choice for anxiolysis.

**Vascular access**
Two large-bore peripheral IV catheters are typical for craniotomies. Central venous access is usually not required unless there is a substantial risk of air embolism or you are unable to obtain adequate peripheral IV access. Arterial cannulation is obligatory for full craniotomy due to need for close monitoring and control of CPP (MAP-ICP), frequent determination of arterial PCO2, glucose, hematocrit and electrolytes.

**Monitoring**
- EKG
- Pulse oximetry.
- ETCO2
- Temperature.

Urine output
- Neuromuscular block. Do not monitor on hemiplegic extremities as the up regulation of Ach receptors in these parts make them relatively resistant to non-depolarizing muscle relaxants and result in effective overdose for normal neuromuscular units. Contralateral hemiparesis to a supratentorial tumor is not associated with hyperkalemia, as in paraplegic or burn patients, succinylcholine is therefore not contraindicated.
Blood chemistry. Monitor glucose for patients on steroids or diabetics. Hyperglycemia increases neuronal damage during ischemia. Monitor potassium, hematocrit and coagulation as indicated.

**Induction of Anesthesia**
- Pre-oxygenate with 100% oxygen
- Fentanyl 1-2 micg./kg
- Sodium pentothal 3-6 mg/kg/min
- Most nondepolarizers have minimal effect on intra-cerebral hemodynamics and can be used safely. Succinylcholine is usually reserved for difficult airways and rapid sequence induction because of its tendency to raise ICP.
- Patient positioning. Pin holder application is a maximal nociceptive stimulus. Deepen anesthesia at this time with pentothal or local anesthesia infiltration. Esmolol 0.5mg/kg or labetolol 0.15mg/kg can also be used to blunt the cardiovascular response. Remember to pad all pressure points. Fix the ETT securely to avoid accidental extubation. This is especially important in neurosurgery as the head is invariably away from the anesthesiologist and quick access to the airway is impossible. Eyes must be carefully taped, for the same reason, to avoid corneal abrasion. Mild head up position helps venous drainage and mild knee flexion reduces back strain. A lower body bair hugger should be draped on the lower extremities.

**Maintenance of Anesthesia**
The goal of anesthesia for these procedures is to provide adequate depth of anesthesia, maximal muscle relaxation to avoid straining, a lax brain and minimal cardiovascular instability. How you choose to go about it is largely between you and your attending. You will be exposed to different styles and techniques and all are acceptable if the goals are kept in mind. It is a good idea to go through normal cerebral physiology and the effects of different drugs on cerebral metabolism and CBF/ICP from a standard textbook at this time.

The choice of inhalational anesthetic is largely yours though traditionally isoflurane has been used for its ability to reduce CMR more than others. Surgeons will let you know when mannitol is required and this is usually given prior to opening of the duramater. One dose of steroids is also usually given at the surgeon's request. Antibiotics are also given prior to incision. APPENDIX 1 is a list of all the antibiotic preferences for each surgeon.
Crystalloid administration should be minimal to prevent brain edema. Normal saline is the solution of choice for fluid maintenance. Mild to moderate hypocapnia is usually the rule, PC02 of 30-35 mm Hg. ETC02 is still the best monitor we have for air embolism and any sudden and precipitous drop in ETC02 should be investigated and treated especially if associated with cardiovascular changes. Auto regulation allows you to maintain a MAP of 50-100 mm Hg with little change in CBF. Surgeons will usually tell you the range they would like you to keep the BP, to reduce surgical bleeding. Hence it is mandatory for you to have SNP and phenylephrine infusions ready so as to maintain tight control of BP. Good muscle relaxation is key to ideal surgical operating conditions and hence neuromuscular monitoring is mandatory in these patients. In these cases it is better to err on the higher side than under dose these patients. Keep an eye on blood loss and hematocrit and transfuse if necessary, though our surgeons are excellent and transfusion is rarely needed for standard craniotomies.

Surgery on or near the brainstem (e.g., during acoustic neuroma surgery) can produce abrupt, often profound, cardiovascular responses that may signal potential damage to the brain stem. Stimulation of the floor of the fourth ventricle, medullary reticular formation, or trigeminal nerve results in hypertension, usually in association with bradycardia. Bradycardia also results from stimulation of the vagus nerve. If such changes occur, the surgeon should be alerted immediately so that he or she can avoid the manipulation that provokes the response.

Emergence from Anesthesia
Rapid emergence is ideal to permit early assessment of surgical results and postoperative neurological follow-up. It should however be attempted only when the following criteria are fulfilled
- Adequate preop state of consciousness
- Cardiovascular stability, normal body temperature and oxygenation
- Limited brain surgery, no major brain laceration
- No extensive posterior fossa surgery involving cranial nerves 11 and 12
- No major arteriovenous malformation removal (avoiding malignant postoperative edema)

If situations where the above cannot be ensured it is prudent to delay emergence and the patient should be transported to the ICU/ACU intubated with adequate sedation and analgesia with short-acting drugs like a propofol infusion under full monitoring.
If all criteria are met and an early emergence is planned maintain intra/extracranial homeostasis (MAP-CPP-CBF-ICP, CMR, PaCO2, PaO2, temperature). Avoid factors leading to intracranial bleeding and/or an increase in CBF/ICP (e.g., coughing, intratracheal suctioning, ventilator fight, increased airway pressure). The patient should be calm, cooperative, and responsive to verbal commands soon after emergence.

ANESTHESIA FOR INTRACRANIAL ANEURYSMS

The anesthetic management of the surgical treatment of intracranial aneurysms is designed to:
· Facilitate the conduct of the operation and the patient's recovery.
· Minimize the risk of aneurismal rupture, cerebral ischemia, neurological deficit, and associated systemic morbidity to improve functional survival.

90% of aneurysms occur on the anterior circulation i.e., posterior communicating, anterior communicating and middle cerebral artery bifurcation. 10% occur on the posterior circulation, most commonly the basilar apex. Rate and volume of bleeding affect neurological condition at hospital admission and determine outcome. Patients who remain conscious and complain only of severe headache after SAH do better than patients who are comatose on arrival. Old age, poor general health, evidence of clots in the brain substance or ventricles, and repeat hemorrhage all affect outcomes adversely.

Complications of SAH
1. Rebleeding. Rebleeding is highest (4%) during the first 24 hours after SAH. Surgical obliteration of the aneurysm is the only definitive means of preventing rebleeding. Early operation (within 24-48 hrs. after SAH) is therefore favored because of its association with improved outcome. Treatment before operation includes prevention of hypertension. Use short-acting antihypertensives (esmolol, labetolol, SNP) to control BP. For this reason these patients are monitored in an ICU setting preoperatively with an arterial line.
2. Vasospasm. Vasospasm is the reactive narrowing of the larger arteries on the subaracnoid space that are surrounded by clot after SAH. All patients have a 50:50 chance of developing significant vasospasm. The incidence of vasospasm peaks between the 4th and 9th day after SAH and decreases over the next 2-3 weeks. Hence it is not uncommon for these patients to remain in the ICU for almost 10 days post-bleed to monitor for vasospasm.
Management of vasospasm is beyond the scope of this manual and you are advised to read this important topic from a standard textbook.

3. Intracranial hypertension. Normal auto regulation is disrupted and patients experience a decrease in both CBF and CMR. The response of the cerebral vasculature to changes in PaCO2 is preserved after SAH. The SAH induced hematoma and edema all have the potential for causing intracranial hypertension. After SAH, the patient's clinical grade reflects the ICP. Refer APPENDIX 4. Grade 1 and 2 patients have normal ICP whereas grade 4 and 5 patients have intracranial hypertension.

4. Hydrocephalus. Develops in 10% of patients from obstruction of CSF drainage pathways by intraventricular or intraparenchymal blood and development of aracnoidal adhesions that prevent reabsorption of CSF. This usually necessitates ventricular drainage to normalize ICP.

5. Systemic sequelae.
   - Fluid and electrolyte balance. Most patients develop a decrease in intravascular volume after SAH and hyponatremia occurs with the release of atrial natriuretic factor from the hypothalamus. Hypokalemia and hypocalcemia requiring replacement is also not uncommon. Treatment includes hydration with normal saline and rarely hypertonic saline.
   - Cardiac sequelae. EKG changes occur in 50-100% of cases. The most common are T wave inversion and ST segment depression. Various rhythm disturbances also are not uncommon. This is attributed to injury to the posterior hypothalamus with release of nor epinephrine and resultant subendocardial ischemic changes and electrolyte disturbances.
   - Respiratory system. Cardiogenic and neurogenic pulmonary edema, pneumonia, ARDS and PE are major causes of morbidity and mortality in these patients.
   - Other medical complications. Hepatic dysfunction, renal dysfunction, thrombocytopenia and even GI bleeding can occur in these patients.

Preoperative preparation
   - Review H&P, neurodiagnostic studies including CT, MRI and angiogram and all other lab work including EKG.
   - Cross-match 4 units of blood and make sure 2 units are available in the OR.
   - An A-line should be in place prior to induction.
   - 2 large-bore IVs should be inserted in the holding area.
· Premedication can be given to allay anxiety but can be omitted in lowgrade patients unless an ET tube is insitu in which case they might require muscle relaxation, sedation and BP control.

In completely elective aneurysm clippings it is good to know beforehand the site and side of surgery to plan IV and A-line placement for easy access to the patient.

**Monitoring**
- EKG
- IABP
- NM blockade
- ETC02
- ABGs, glucose, electrolytes and hematocrit
- Temperature
- Urinary output

**Induction of anesthesia**
- The induction period is critical because rupture of the aneurysm at this juncture can be fatal. The incidence of rupture ranges from 0.5-2% and the mortality is 75%. Smooth induction requires limitation of the hypertensive response to laryngoscopy and intubation, obliteration of coughing and straining on the ETT. Most anesthesiologists choose to use a narcotic based induction very similar to cardiac cases. This confers loss of consciousness while maintaining cardiovascular and intracerebral stability during catecholamine-stimulating maneuvers. Labetolol and esmolol block the chronotropic and ionotropic effects of sympathetic stimulation without affecting CBF and ICP.
- For muscle relaxation vecuronium is a good choice as it neither increases the heart rate or BP. Succinylcholine increases ICP and there has been incidences of ventricular fibrillation in patients after SAH. In poor grade patients rocuronium maybe more appropriate for RSI.

**Maintenance of anesthesia**
- Your goal at this time should be to prevent aneurismal rupture, optimize cerebral perfusion, protect against cerebral ischemia and edema, minimize brain retractor pressure through cerebral relaxation, manipulate blood pressure, and facilitate rapid emergence and timely neurological assessment.
Nitrous oxide is avoided in patients who have decreased intracranial compliance and is introduced only after instituting hypocapnia.

Though isoflurane has long been the inhalational anesthetic of choice for neuroanesthesia, desflurane and sevoflurane maybe used to facilitate rapid emergence and prompt postoperative neurological evaluation.

A narcotic based technique can be employed or narcotics can be used as an adjuvant with inhalational anesthetic.

Moderate hyperventilation to a PaCO2 of 30 to 35 mm Hg is maintained

Fluid Management

Since patients have an SAH-induced decrease in circulating blood volume, they require hydration before the induction of anesthesia and the use of controlled hypotension to preserve cerebral perfusion. Full restoration of the intravascular volume to a state of modest hypervolemia occurs after the aneurysm has been clipped to optimize CBF and prevent postoperative vasospasm.

All crystalloid administration should be glucose-free because both focal and global ischemic deficits are exacerbated by hyperglycemia. Normal saline is ideal for its isotonicity.

Mannitol, an osmotic diuretic is administered on the request of the surgeon to reduce intracranial pressure.

Temporary proximal occlusion

Temporal proximal occlusion of the parent vessel is now favored by neurosurgeons to reduce the risk of rupture during aneurismal manipulation. The application of temporary clips produces "local hypotension" and reduction of transmural pressure.

The risks of distal ischemia and infarction, cerebral edema, and damage to the parent vessel are directly related to the duration of the temporary occlusion and the integrity of the collateral circulation. The chance of developing a new neurological deficit after temporary proximal occlusion is exacerbated by older age, poor preoperative neurological status, and aneurysms involving distributions of the basilar and middle cerebral arteries.

The duration of temporary occlusion should be limited to less than 20 minutes since most studies have shown a higher incidence of neurological deficits and infarction postoperatively when the duration exceeds 20 minutes.
To enhance collateral circulation during temporary proximal occlusion, the patient's blood pressure is maintained in the normal range. This may require use of a pressor like phenylephrine.

Dr. Malek likes to use etomidate to extend the duration of occlusion and hence it is good to have it on hand during application of temporary clips. Etomidate causes cerebral vasoconstriction and reduces CMR02 (by as much as 50%), CBF and ICP while maintaining cardiovascular stability and CPP.

Emergence

· Good grade patients maybe awakened in the operating room and extubated with care avoiding coughing, straining, hypercarbia and hypertension is essential.
· Poor preoperative status or a catastrophic intraoperative event (e.g., brain swelling, aneurysmal rupture, ligation of feeding vessel) requires continued intubation, sedation, and postoperative ventilatory support.
· The persistence of diminished responsiveness or a neurological deficit for 2 hours after surgery requires a CT scan to diagnose the presence of hematoma, hydrocephalus, pneumocephalus, infarction or edema. An angiogram might demonstrate a vascular occlusion.

ANESTHESIA FOR SPINE SURGERY

1. Spinal Cord Injuries

Preoperative assessment

· Neurological examination and rapid assessment for other injuries. Cervical injuries are frequently associated with head injury, thoracic fractures with pulmonary and cardiovascular injury, and lumbar fractures with abdominal and long bone injuries.
· The patient should be examined immediately for signs of respiratory insufficiency, airway obstruction, rib fractures, and chest and facial trauma.
· The fifth cervical segment is perhaps the most important in providing clinical evidence of spinal cord injury. It controls motor function of the deltoid, biceps, brachialis and brachioradialis muscles. If these muscles are involved there will be partial diaphragmatic paralysis. A complete lesion at the fourth cervical segment is not compatible with life unless artificial respiration is initiated.

Airway management
Critical in patients with cervical cord injury. Respiratory failure is the most common cause of death.

All patients with severe trauma or head injury should be assumed to have an unstable cervical spine until proven otherwise radiologically. During transport the patient should be moved on a spine board with the neck immobilized to prevent further injury.

Fibreoptic intubation of an awake patient maybe necessary. In an emergent situation oral intubation with direct laryngoscopy can be done with minimal flexion or extension of the neck.

**Steroid therapy.**
Methylprednisolone in an initial dose of 30 mg/kg is followed by an infusion of 5.4 mg/kg/hr for 23 hours. This is of benefit only if given within 8 hours of the injury. Surgeons will request you to continue this regimen in the OR if already started in the ER or may ask you to initiate the process in the OR. In the interest of the patient you should also remind them!

**Monitoring**
- EKG
- Pulse oximetry
- Capnography
- Temperature
- NIBP
- Urine output
- IABP maybe required for unstable patient with significant blood loss.
- ABG and other labs
- Early use of pulmonary artery catheters during spinal shock is appropriate. Measurement of intracardiac pressures (CVP, PCWP, LVEDP), in conjunction with cardiac output and blood pressure is necessary to differentiate hypovolemia from low SVR. The information obtained is helpful in determining the appropriate form of management (fluid vs. vasopressors) as well as monitoring the response to therapy.
  (a) Patients with low SVR may be treated with titrated infusions of a direct-acting alpha agonist such as phenylephrine.
  (b) Patients who are hypovolemic can receive fluid boluses.

**Intraoperative management.**
· The sympathetic function and volume status of spinal cord patients are unpredictable and hence etomidate is a good induction agent in these patients for its cardiovascular stability.
· During induction, maintenance of a spinal cord perfusion pressure of at least 50 mm Hg (ideally 70-90 mmHg) is essential. If the patient is in the early phase of spinal shock with a high cord injury, the patient is at risk of developing bradycardia or asystole.
· These patients develop a super sensitivity to depolarizing muscle relaxants. With muscle denervation, the number of postsynaptic acetylcholine receptors increases greatly and amplifies any small neuromuscular signal that maybe present. When depolarized by succinylcholine, pores on the neuromuscular junction open maximally allowing the massive egress of stored intracellular potassium enough to cause ventricular fibrillation on occasions. The time course for the development of extrajunctional receptors may be as short as 24 hours hence succinylcholine is best avoided in recently injured patients. It is also important to realize that the magnitude of potassium release is more a function of the amount of muscle mass affected than the actual dose of the depolarizing agent.
· Positioning is most often in the prone position. Patients can be anesthetized on the bed or stretcher and then logrolled onto the operating room table. It is important to maintain the head and neck in the neutral position, providing adequate padding to the chest, abdomen, head and extremities and avoiding excessive neck flexion or extension. Special attention should be given to the ETT as significant movement or obstruction can occur with positional changes. In addition sudden changes of position are avoided because they may have significant hemodynamic consequences due to lack of adequate compensatory vasoconstrictor and cardiac reflexes to maintain venous return and cardiac output.
· Fluid administration is based on estimated preoperative fluid deficits, intraoperative blood and fluid losses, and knowledge of the effect of spinal cord injury on cardiac and pulmonary function. Meticulous fluid management is essential since patients with high thoracic and cervical spine injury have an increased propensity for developing pulmonary edema. In addition cervical spine injury can cause cardiac dysfunction with decreased inotropy and chronotropy (due to reduced sympathetic neural input to the heart). Avoid glucose-containing solutions, as they are known to exacerbate spinal cord injury.
These patients also have impaired thermoregulation below the level of injury. Hence a bair hugger, warmed intravenous fluids, humidification of the respiratory circuit, and a low flow technique are all helpful in maintaining body temperature.

Postoperative care
Because of the potential difficulty in reintubating the trachea of the spinal injury patient one should be extremely conservative in determining the appropriate time for extubation.
Extubation criteria include:
(a) Blood gases:
1. Ph>7.3
2. PaO2 > 60 mm Hg
3. PaCO2 < 50 mm Hg
4. Alveolar - arterial oxygen difference < 350 mm Hg (FiO2 = 100%)
5. Arterial to alveolar ratio > 0.75

(b) Pulmonary functions:
   a. Maximal inspiratory pressure < -20 cm H2O
   b. Vital capacity > 15 ml/kg
   c. Respiratory rate < 25/minute
   d. Dead space - to - tidal volume ratio < 0.6

   (c) Other
   1. Patient is conscious and oriented
   2. Stable cardiac function
   3. Optimal intravascular fluid volume and electrolyte status
   4. Absence of infection
   5. Unlabored breathing

2. Spinal Reconstruction and Fusion

Preoperative Assessment
Patients presenting for spinal reconstruction most commonly will have either idiopathic or acquired scoliosis. Nonscoliotic patients presenting for this surgery may have spinal instability as a result of trauma, metastatic carcinoma or infection (e.g., TB)
Scoliotic patients may have a restrictive pattern of respiratory disease. Both TLC and VC are reduced. Hence Cxray, ABG's and PFT's are
important preoperatively. If VC > 70% predicted, respiratory reserve is adequate. If VC < 40% postop ventilation is usually required.

- Increased pulmonary vascular resistance and a high incidence of congenital heart disease and MVP may be seen in these patients. An EKG, ECHO and cardiology consult maybe required if cardiovascular impairment is present.
- Some surgeons may request that the patient be awakened intraop to test anterior (motor) cord function. Practice wakeup testing preop to reveal any baseline deficits and reassure the patient that no pain will be felt during intraop testing. Careful preop documentation of the neurological status is essential as surgery may worsen these symptoms.
- Hemoglobin/hematocrit and clotting profile are essential preop. Blood loss can be substantial and blood should be on hand for transfusion. Consider use of intraop hemodilution, controlled hypotension and cell saver. IV access with large gauge IV catheters is important.

Monitoring
- EKG
- Arterial line for measurement of BP as well as intraop lab tests.
- Pulse oximetry
- Capnography
- Neuromuscular monitoring
- Urine output
- Serial Hct, ABG's, coags

Intraoperative care
- Standard induction can be employed. A DL T may facilitate surgical access in the patient undergoing an anterior resection.
- Patient is positioned in the lateral decubitus position, affected side up. The up hip and knee are flexed to relax the psoas and allow its reflection to expose the lumbar vertebral bodies.
- Pressure points must be carefully padded and checked frequently especially during controlled hypotension.
- 3 basic maneuvers can be employed to control blood loss
  (a) Position to prevent venous engorgement
  (b) Controlled hypotension (to MAP =60-70 mm Hg) in the fit patient has been shown to dramatically reduce blood loss, although there maybe some increased risk of spinal cord ischemia.
(c) Deliberate hemodilution to Hct =25% - 28% may prove useful. Maintain UO at 0.5-1.0 ml/kg/hr during controlled hypotension.
· The wake up test is used to assess integrity of motor pathways in the ventral cord. 40-60 min advance warning from surgeons is needed.
(a) decrease inhalational agents.
(b) Reverse muscle relaxants (and narcotics, if necessary)
(c) Monitor train of four
(d) Request hand squeeze and if present, elicit bilateral foot movement.
(e) Reinduce anesthesia with STP or propofol.

Dangers
· Uncontrolled patient movement during wakeup test can result III accidental extubation or
II. Dislodgement of spinal instrumentation. III. Unrestrained inspiratory efforts may provoke venous air embolism.

Postoperative management
· Postoperative ventilation may be required in patients with severe respiratory impairment.
· Pulmonary insufficiency, spinal cord ischemia, hypothermia, pneumothorax, fat embolism and dislodgement of internal fixation are all complications of this type of surgery.

ANESTHETIC MANAGEMENT OF INTERVENTIONAL NEURORADIOLOGIC PROCEDURES

The endovascular approach has opened new options in the treatment of vascular and nonvascular intracranial and spinal diseases.
1. Neurovascular access and methods
(a) Vascular access. INR procedures typically involve placement of catheters in the arterial circulation of the head or the neck, usually through the transfemoral route. Transfemoral access is accomplished by the placement of a large introducer sheath into the femoral artery, usually 7.5-Fr in size. Through the introducer sheath a 7.0-Fr coaxial catheter is positioned by fluoroscopic control into the carotid or vertebral artery. Finally, a 1.5-2.8Fr super selective microcatheter is introduced into the cerebral circulation. The super selective catheter can be used to deliver drugs, embolic agents, or balloons to the desired location.
(b) Imaging Technology. Necessary radiological imaging methods include high-resolution fluoroscopy and high-speed digital subtraction
angiography (DSA) with road mapping functions. DSA enables visualization only those vessels that are opacified by contrast injection. The road mapping function enables the radiologist to observe the advance of the catheter against the background map of the patient's cerebral vessels. DSA involves subtraction of images before and after injection of radio contrast. Any displacement of the cerebral vessels due to movement of the head profoundly degrades DSA images. Hence, it is critical that the patient remains immobile during the procedure.

C) Materials for embolization or infusion. Embolic agents include balloons, coils, silastic pellets, and glue.

2. Anesthetic Consideration. In general most INR procedures can be undertaken with intravenous sedation, which ensures patient comfort yet enables repeated neurological assessments. The primary goals for Anesthesia are not only to render the patient immobile but also to control the level of sedation and manipulate hemodynamics. Children, uncooperative patients, and prolonged procedures such as those on the spinal cord might require GA.

The three primary functions of the anesthesiologist in the INR suite are
I) Provision of a physiologically stable and immobile patient.
2) Manipulation of systemic BP as dictated by the needs of the procedure. 3) Emergent care of catastrophic complications.

(a) Preoprative assessment.
· A careful assessment of the airway has to be made. A history of snoring may suggest that partial airway obstruction might occur with sedation. Snoring results movement artifacts that may degrade the quality of images during cerebral angiography.
· Patients with the history of adverse reaction to contrast dye require pretreatment with steroids and antihistaminic drugs.
· Patients on oral hypoglycemic drugs should abstain from their usual daily dose.

(b) Preoprative Investigations
· Routine labs
· Baseline coagulation screen since anticoagulation will be required for the procedure.

(c) Premedication
· Anxiolytics can be used
Minimal premedication is required for INR procedures.

(d) Room Preparation
- Long or extension tubing from the anesthesia circle is desirable.
- The rapid access of all critical equipment and drugs should be possible at all times.

(e) Patient positioning
- Procedures may last for several hours and the patient should be made comfortable prior to sedation.

(f) Intravenous access
- Since the patient is often moved towards the image intensifier and away from the anesthesiologist it is important there is adequate IV access and sufficient length of tubing.
- 2 large bore IV's is usually adequate
- SNP and phenylephrine should be in line for manipulation of the circulation when necessary.

(g) Monitoring
- IABP
- 5 lead EKG
- ETCO2
- Temperature
- Pulse oximetry
- Urinary output. Increased diuresis might occur during the procedure due to an increase in intravascular volume as a result of continuous flushing of the intravascular lines and osmotic load due to radio contrast or mannitol injection.
- ACT (activated clotting time). Careful management of coagulation is required to prevent thromboembolic complications due to the presence of foreign bodies (catheters) and endothelial injury due to the passage of microcatheters. After placement of the femoral introducer sheath, a baseline ACT is obtained. Heparin (5000 uno kg) is given and another ACT obtained. The target ACT is 2 to 3 times the baseline value.

(h) Intraoperative care
- If sedation is chosen for anesthesia one must allow a rapid decrease in the level of sedation when neurologic testing is required.
- The primary reason for GA is to reduce motion artifacts and to improve the quality of images. Because chest excursions during positive pressure
ventilation can interfere with road mapping, the surgeon/radiologist frequently requests apnea for DSA for spinal procedures. When embolizing spinal cord lesions under GA with ETT an intraoperative "wakeup test" may be requested.

Endovascular obliteration of the aneurysmal sac is usually done using detachable coils. Several coils may be required to obliterate a large aneurysm. The procedures may be prolonged and require GA with ETT. The anesthesiologist should be prepared for aneurysmal SAH spontaneously or as a result of intravascular manipulations. Even after coil placement there may be areas of the dome that are still in contact with arterial blood. Therefore blood pressure control is warranted even postprocedure.

Angioplasty for cerebral vasospasm is usually undertaken in patients who develop vasospasm after SAH and have significant neurologic symptoms. These patients arrive from the ICU very often intubated and are on a deliberate hypertensive regimen. A balloon catheter is guided under fluoroscopy into the spastic segment and inflated to distend the constricted area mechanically. After angiographic demonstration of a significantly widened spastic segment, blood pressure should be reduced to the normal range.

Carotid stenosis can be treated with balloon angioplasty or stenting. Deliberate hypertension might be required for augmenting collateral blood flow.

Angioplasty carries the risk of distal thromboembolism and vascular dissection.

(i) Radiation safety

There are 3 sources of radiation in the INR suite.

1) Direct radiation from the x-ray tube
2) Leakage through the collimator's protective shielding
3) Reflected from the patient and the area surrounding the body part to be imaged.

The amount of exposure drops off proportionally to the square of the distance from the source of radiation (inverse square law).

DSA delivers considerably more radiation than fluoroscopy.

While working in the INR suite all persons should wear lead aprons and thyroid shields.

G) Management of neurologic catastrophes
Complications arising from cerebrovascular instrumentation can be rapid and dramatic.

- Secure airway immediately
- Emergency drugs and equipment should be on hand
- Protamine should be available for immediate injection if the decision is made to reverse heparin.
- Communicate with the INR team to determine if the problem is occlusive or hemorrhagic.

1) In case of vascular occlusion, a method to increase distal perfusion either by blood pressure augmentation or by thrombolysis is the primary strategy. Both therapies may be combined. Thiopental may provide some degree of cerebral protection despite vascular occlusion.

2) Bleeding catastrophes might be heralded by headache, nausea, vomiting, and vascular perforation. The radiologist/surgeon might see the contrast extravasate seconds before the patient becomes symptomatic. In the case of heparin reversal before withdrawing the offending wire or the catheter back into the lumen of the vessel will keep the perforation partially blocked until the hemostatic function is restored. As soon as an ICH is diagnosed, immediate reversal of heparin is indicated. Protamine (1 mg for every IOU of heparin) is given without undue regard to systemic blood pressure. Later an ACT may be done to adjust the final dose. With active bleeding the blood pressure should be kept as low as possible. Once bleeding is controlled the target blood pressure should be discussed with the radiologist/surgeon. If vascular occlusion has been used to control hemorrhage deliberate hypertension may be requested.
Physical Examination
~ Evaluation of trauma patients should include all injuries. Evaluation of the ABC's (Airway, Breathing and Circulation) is crucial. The Glasgow coma scale has stood the test of time for assessing neurological functions. A GCS score of < than or = to 9 is usually an indication for intubation and ventilation.

<table>
<thead>
<tr>
<th>Glasgow Coma Score</th>
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<tbody>
<tr>
<td><strong>Eye Opening</strong></td>
</tr>
<tr>
<td>Spontaneous</td>
</tr>
<tr>
<td>To Speech</td>
</tr>
<tr>
<td>To Pain</td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td><strong>Verbal Response</strong></td>
</tr>
<tr>
<td>Oriented</td>
</tr>
<tr>
<td>Confused Conversation</td>
</tr>
<tr>
<td>Incomprehensible words</td>
</tr>
<tr>
<td>Incomprehensible sounds</td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td><strong>Best Motor Response</strong></td>
</tr>
<tr>
<td>Obeys</td>
</tr>
<tr>
<td>Localizes</td>
</tr>
<tr>
<td>With draws</td>
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<tr>
<td>Abnormal Flexion</td>
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<tr>
<td>Extensor Response</td>
</tr>
<tr>
<td>None</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
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