Review Article
ISSN (Print): 2394-6954
ISSN (Online) : 2394-9775
Karnataka Anaesthesia Journal Vol 17(3&4), July-December 2019, p. 55-61 DOI: 10.4103/kaj/2019/v17i3-4/166131

Anaesthetic Considerations for Neuro-Endovascular Procedures: A Narrative Review

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Abstract

The spectrum of neurological conditions amenable to endovascular treatment has increased over the last several years and increased the volumes of patients anesthetized outside the operating room. Anaesthetic management of patients undergoing neuro-endovascular procedures pose several challenges such as emergent nature of interventions, significant co-morbid conditions, not adequately optimized neurological status, and concerns and considerations associated with providing anaesthesia services at remote locations. In this review, general aspects of care of patients undergoing neuro-endovascular procedures are detailed at the beginning such as pre-anaesthetic evaluation, radiation concerns, challenges with providing anaesthesia at remote locations and anaesthetic techniques commonly used which includes monitored anaesthesia care, procedural sedation and general anaesthesia. This is followed by discussion on management of individual neurological pathologies, common procedural complications and their management, and post-procedural care.

Keywords: Coiling, Endovascular, Neuroanaesthesia, Remote Location

1. Introduction

Neuro-endovascular procedures have seen a rapid rise in the last few years. The complexity and spectrum of procedures necessitate suitable tailoring of anaesthetic and post-procedural management. Interventional neuroradiology suite poses unique challenges for anesthesiologists. This article provides an overview of anaesthetic and post-procedural considerations for patients undergoing neuro-endovascular procedures. Specific considerations for individual pathologies and interventions are also briefly discussed.

For this narrative review we considered articles published in neurosciences journals including clinical trials, observational studies, case reports, and reviews. We identified articles by searching the PubMed database and reference lists of respective articles using key words "anaesthesia", "neurointervention", "endovascular", "complications", aneurysm", "arterio venous malformation", "stroke", "carotid artery stenosis", "Vein of Galen malformation", and "neuromonitoring". Only articles published in English and relevant to the review topic were considered for this review.We also considered book chapters on this topic. The search was restricted to those published in the last 15 years.

2. Common Neuro-endovascular Procedures and their Advantages and Disadvantages

The common diagnostic and therapeutic neuro-endovascular procedures performed are listed in Table 1. While endovascular approach to neurological problems offers several advantages, there are few limitations as well. These are summarized in Table 2.

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Table 1. Common diagnostic and therapeutic neuro-endovascular procedures

Diagnostic neuro-endovascular procedures	*Therapeutic neuro-endovascular procedures*
1. Digital Subtraction Angiography (DSA) of cerebral and spinal vasculature 2. Balloon Occlusion Test 3. WADA test 4. Super-selective anaesthesia functional examination (SAFE)	1. Intra-arterial therapy (nimodipine, milrinone) 2. Aneurysm treatment- Coils, Flow diverter, Occlusion 3. Embolization of arterio-venous malformation (AVM), arterio-venous fistula (AVF), Vein of Galen malformation (VOGM), tumor feeders 4. Angioplasty for stenosis or vasospasm 5. Stenting for carotid stenosis, transverse sinus stenosis 6. Stroke treatment with thrombolysis or thrombectomy

Table 2. Advantages and disadvantages of neuro-endovascular procedures

Advantages	*Disadvantages*
1. Minimally invasive 2. Less cardio-respiratory instability 3. Minimal blood loss and transfusion 4. Minimal pain and infection risk 5. Shorter procedure & hospital stay 6. Better cognitive function	1. Cost 2. Expertise and Experience 3. Uncertain duration 4. Associated interventions not possible (hydrocephalus, blood) 5. Complications- rapid, catastrophic

3. General Considerations Relevant to Anaesthesia for Neuro-endovascular Procedures

3.1 Remote Location suite

The remote location of the interventional neuro-radiology (INR) suite presents certain challenges for the anaesthesia team which are different from that seen in the operating room (OR). These include inadequate lighting, restricted access to the patient, non-availability of some equipments, unfamiliar working environment(as the anesthesiologist only occasionally provides services in this area), unpredictable working hours, and lack of trained and experienced personnel.

3.2 Transfers

Neuro-endovascular procedures entail frequent shifting of patients to and from the INR suite to theradiology services area for imaging (Computed Tomography [CT] or Magnetic Resonance Imaging [MRI]), Emergency Room (ER) from where patient is received, OR for surgical intervention and Intensive Care Unit (ICU)for post-procedure care. Most of these patients are critically ill and unstable requiring intensive monitoring and management during transport.

3.3 Risks and Misconceptions

Many patients undergoing neuro-endovascular procedures are critically ill, elderly, belong to poor clinical grades of neurological conditions, are determined to be surgically difficult, and have significant co-morbidities which enhance peri-procedural risks. As these procedures are minimally invasive in nature, several misconceptions are prevalent among patients, their family and even health care providers (HCPs). These include not a surgical procedure, hence, less risky and require less monitoring and vigilance, which are incorrect.

3.4 Neurological Injury and Systemic Manifestations

Systemic involvement of acute brain injury includes manifestations affecting respiratory (pulmonary aspiration, pulmonary edema), cardiac (myocardial dysfunction, arrhythmia, Haemodynamic instability), and renal (acute kidney injury) systems which can affect clinical outcomes despite optimal management of neurological condition. These factors should be

considered during peri-procedural management of these patients.

3.5 Anaesthesia-related

Adequate preparation is needed for providing anaesthesia for neuro-endovascular procedures which include arranging long breathing circuitsof sufficient slack,lengthy monitoring cables and extended tubings of invasive catheters and linesto avoid entanglement during movement of biplane fluoroscopy, and remote (slave) monitor. Other considerations includeavoidance of patient movement, anti-coagulation monitoring and titration, careful adjustments in fluid administration (taking into account fluids administered by interventional neuroradiologist), peri-procedural contrast-related complications, need for manipulating Haemodynamics based on clinical needs, and management of sudden severe complications. Anesthesiologist should anticipate and prepare for likely manifestations of endovascular interventions such as system hypotension with intra-arterial nimodipine administration for managing cerebral vasospasm[1].

4. Specific Considerations

4.1 Radiation Issues

HCPs working in INR suites are vulnerable for radiation-related issues necessitating safety education and training, and taking certain precautions during the procedures. Sources of radiation in INR suite are 1] direct radiation from X-ray tube, 2] leakage radiation through collimators and protective shielding and 3] scatter radiation reflected from patient and surrounding areas. Radiation exposure is more for digital subtraction angiography (DSA) than fluoroscopy, and decreases proportionally to the square of the distance from the source. The recommended exposure limit for total body dose is 20 mSv/ year. Protection from radiation can be achieved by using lead aprons (0.5mm), thyroid collars, eyewear, glass lead screens, communication between team members and maintaining atleast 4 feet distance from radiation source. Thermo-luminescent dosimetry (TLD) badges help in monitoring the radiation exposure levels.

4.2 Anaesthetic Management

4.2.1 Pre-anaesthetic Assessment (4 Ps)

Pre-anaesthetic assessment of the patient should include evaluation of fasting status, time of ictus, current neurological status, and assessment of co-morbidity, pregnancy or allergy. Pre-anaesthetic evaluation should also include understanding of the neurological pathology such as nature of the disease and associated systemic manifestations. The anesthesiologist should also know about the probable procedure, its duration, and type of anaesthesia that may be needed. The pre-anaesthetic assessment also provides an opportunity to assess preparation and paraphernalia required for the procedure and includes laboratory investigations (Hemogram, Coagulation, Renal function, Electrolytes, blood sugar, electrocardiogram, chest X-ray, CT, MRI), machine location, length of circuit/lines, availability of equipment to assess activated clotting time (ACT), routine and emergency drugs and equipments, protective wears, patient monitors, and ICU bed[2].

Goals of anaesthesia: The goals of anaesthesia for neuro-endovascular procedures are

1. Provide immobility
2. Select appropriate anaesthetic technique
3. Smooth induction and early recovery
4. Monitor and Optimize Cerebral and Systemic function
5. Coagulation function monitoring and maintenance
6. Preparation, early detection, prompt management of complications
7. Haemodynamic manipulation
8. Guide management during transport and post-procedure

4.2.2 Anaesthetic Techniques

There is no clear evidence to suggest one anaesthetic technique is better than the other for neuro-endovascular procedures[3]. Anaesthesia should be tailored according to patient condition, procedure requirement and anesthesiologist preference.

Monitored Anaesthesia Care(MAC) may be appropriate for treatment ofacute stroke, sinus stenosis, DSA and where awake neurological assessment is needed. Ability to lie still for prolonged periods and communicate is essential for MAC.

Procedural sedation should include measures for alleviation of pain, anxiety and discomfort, provide patient immobility, allow rapid recovery and neurological assessment, prevent airway compromise

and minimize discomfort associated with contrast (burning, headache) and prolonged positioning in supine position. Sedation or MAC may not be feasible option in patients with pulmonary disease, arthritis, obstructive sleep apnea, dementia, and poor neurological grades. It is mostly used for procedures such as intra-arterial nimodipine administration or DSA.Choices of drugs include Midazolam, Ketamine, Fentanyl, Propofol, Dexmedetomidine, or a combination of above, though propofol and dexmedetomidine as continuous infusion are the preferred agents[4].

General Anaesthesia (GA) is most suitable for therapeutic interventions such as coiling and embolization. Though endotracheal tube is mostly preferred, supraglottic airway devices may be used in select patients and procedures. Induction of anaesthesia may be performed with thiopentone or propofol. Both intravenous and inhalational anaesthetics may be used. However sevoflurane based technique was associated with better Haemodynamic stability, faster recovery and less patient movement compared to propofol based technique of anaesthesia maintenance[5]. There is limited role of analgesics so their use should be limited and nitrous oxide may be avoided. Neuromuscular blockade is titrated by monitoring neuromuscular function to avoid under or over dosing and consequent harms. If raised Intracranial Pressure(ICP) is suspected, mild to moderate hyperventilation may be desirable. Monitoring should be based on procedure and patient condition. Smooth and early recovery should be attempted. The advantages and disadvantages of different anaesthesia techniques are described in Table 3.

Table 3. Advantages and disadvantages of different anaesthesia techniques

General Anaesthesia	*MAC/Procedural Sedation*
Advantages 1. Immobile patient 2. Optimal imaging quality 3. Patient comfort 4. Better cardio-respiratory and ICP control **Disadvantages** 1. No clinical testing 2. Time delay 3. Delayed recovery 4. Consequences of GA	**Advantages** 1. No time delay 2. Neurological testing, rapid 3. No cardio-respiratory and ICP changes during anaesthesia Rapid recovery **Disadvantages** 1. Delayed emergency management 2. Movement, image quality 3. Unprotected airway 4. No control on PO2/PCO2

4.2.3 Anaesthetic Techniques

Standard monitoring should be performed regardless of anaesthesia and interventional technique. Electrocardiography, invasive BloodPressure (BP) for therapeutic interventions, fluid intake and urine output oxygen saturation, and end-tidal carbon dioxide are commonly used monitoring parameters during neuro-endovascular procedures. The Depth of Anaesthesia(DOA) assessment is performed with minimum alveolar concentration of anaesthetic agents or BispectralIndex (BIS) or entropy and neuromuscular function is monitored using train-of-four to titrate anaesthetic and neuromuscular blocking drugs, respectively.Cerebral vasospasm during endovascular procedures can result in acute decrease in BIS or entropy and their monitoring helps in early institution of treatment such as nimodipine. Abrupt drop in BIS can also occur during alcohol embolization. Thus, DOA monitor can additionally serve the purpose of monitoring the brain during endovascular procedures[6-8].

Brain function assessment can be performed with cerebral oximeter using near infra-red spectroscopy, angiography and dynamic CT imaging. Temperature monitoring is required as the ambient temperature is set low and large volumes of fluids are administered which can result in hypothermia. Additionally, ACT should be monitored as anticoagulation with heparin is performed and for interventions, ACT should be maintained > 300 s. The reversal of anticoagulation should be performed with protamine guided by ACT values. Drug labelling and a separate intravenous access may be warranted to avoid errors and drug interaction between anaesthetic agents and drugs used for Haemodynamic and coagulation manipulation and contrast agents.

5. Specific Considerations for Few Common Pathologies/ Procedures

5.1 Cerebral Aneurysm

Patients with ruptured aneurysm presenting for endovascular coiling may manifest with intracranial and systemic effects of Subarachnoid Hemorrhage (aSAH) while those with unruptured aneurysm will not have clinical features other than pressure effect. The anaesthetic management and peri-procedural course may vary between these patients. These patients require anaesthesia for DSA, cerebral vasospasm treatment, and coiling and undergo interventions as an emergency procedure. Most often, patients undergoing endovascular treatment for aneurysm are older with significant co-morbidities and the vascular anatomy is considered to be surgically difficult. Patients with aSAH often have full brain with raised ICP, requiring monitoring for ischemia and cerebral protection. Haemodynamic manipulation may be necessary which includes achieving normal to low BP to prevent rebleed before and during the intervention and higher BP after coiling to maintain cerebral perfusion. These patients also need smooth induction and intubation (to prevent aneurysmal rupture) and early recovery (for neurological assessment). Detection and management of complications is important as these can occur suddenly without warning[9].

5.2 Arterio-Venous Malformations (AVMs) and Arterio-venous Fistulas (AVFs)

These are complex vascular malformations requiring anaesthesia support for embolization. AVMs with multiple feeding arteries undergo staged treatment thus requiring multiple anaesthetics. Unlike aneurysm treatment, endovascular treatment for AVM is usually an elective procedure allowing optimization of patients. Haemodynamic manipulation during procedure is often needed. Deliberate hypotension or flow arrest during glue injection to slow the blood flow through the feeding artery to prevent systemic embolization is needed. The commonly used drugs include sodium nitroprusside, nitroglycerin, Labetalol, Esmolol, and Adenosine (for flow arrest). If cerebral ischemia is anticipated, deliberate hypertension to improve collateral circulation is required. This can be achieved with vasopressors such as norepinephrine and vasopressin, and inotropes such as dobutamine. After the procedure, BP should be maintained 15-20% below the baseline to prevent Normal Perfusion Pressure Breakthrough (NPPB) which can cause hyperemia, bleeding and cerebral edema. Anesthesiologist should be familiar with embolization agents (glue, onyx) to detect and manage complications associated with them.

The AVFs present with unique anaesthetic challenges. Traumatic carotid-cavernous fistula can present with severe epistaxis, oral bleeding and worsen to desaturation requiring emergent intubation after heparinization for DSA[10]. Care must be taken during mask ventilation to avoid damage to the painful eye swelling[11]. There can be significant bradycardia and cardiac arrest during embolization due to trigemino-cardiac reflex[12].

5.3 Preoperative Tumour Embolization

This is usually done using poly-vinyl alcohol particles as part of preoperative preparation to reduce tumour vascularity and intraoperative blood loss in patients undergoing surgery for meningioma, glomus tumour and juvenile nasopharyngeal angiofibroma.

5.4 Carotid Angioplasty and Stenting

These interventions are performed for treating symptomatic carotid artery stenosis. Patients can have concurrent ischemic heart disease. The anaesthesia technique is mostly MAC and rarely GA. Changes in heart rate and BP are common during the procedure and preparation for detection, prevention and management should be in place. Bradycardia is the most common cardiovascular change and atropine, isoprenaline, pacing should be available to manage an emergency situation. Hypertension can occur and should be managed with labetelol to maintain BP within 80% of the baseline. Monitoring for complications affecting cerebral perfusion and oxygenation should be done. Common complications include carotid dissection, perforation or occlusion, device-induced arterial spasm, occlusion of adjacent vessels, distal thromboembolism leading to transient ischemic episodes and stroke, and cerebral hyperperfusion causing hemorrhage or brain swelling.

5.5 Acute Stroke Intervention

Interventions for acute ischemic stroke include chemical thrombolysis and mechanical thrombectomy. Anaesthetic considerations are elderly patients with co-morbidities, need for care of patients with acute neurological insult, and emergency nature of procedure. GA, procedural sedation or MAC can be used depending

on local practice, patient condition, and time. BP should be maintained upto 120% of baseline to prevent cerebral ischemia. Hemorrhage and thromboembolism are common complications and should be managed appropriately.

5.6 Vein of Galen malformation

These interventions often involve young children and infants and principles governing pediatric neuroanaesthesia should be followed. Difficult cannulation, airway and temperature management, fluid and drug titration are some of the challenges apart from pre-existing issues such as cardiac failure and failure-to-thrive in this population. Monitoring of cerebral oxygen saturation can help detect intracranial complications and also guide completeness of the procedure[13].

6. Complications during Neuro-endovascular Procedures

Neurological, cardiovascular and pulmonary complications are the common problems seen in patients undergoing neuro-endovascular procedures[16]. The approach to neurological complications during the neuro-endovascular procedures is shown in Figure 1[2].

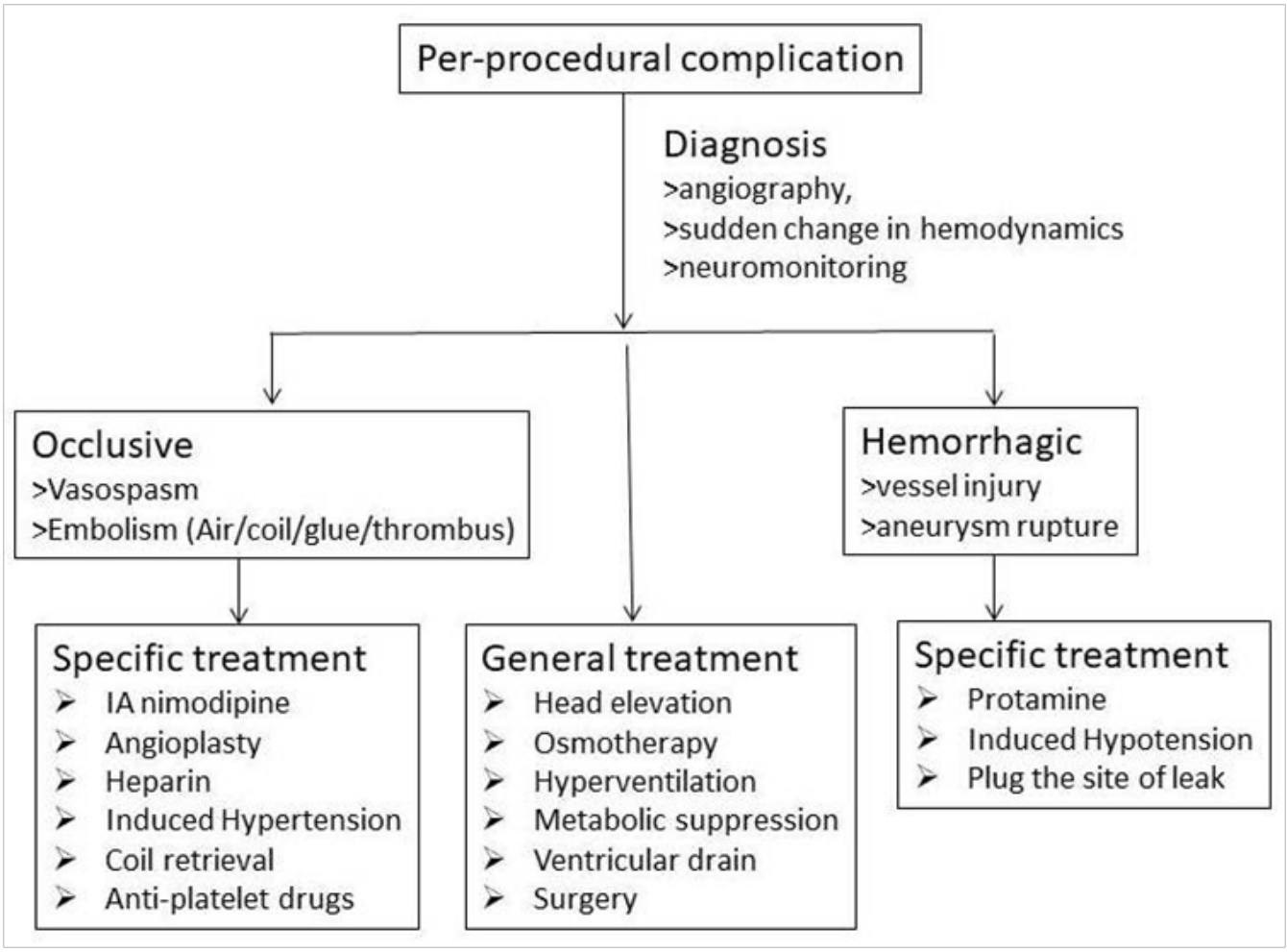

Figure 1. Approach to neurological complications during the neuro-endovascular procedures

7. Post-procedure Considerations

Close Haemodynamic and neurological monitoring is needed after neuro-endovascular procedures. BP manipulation specific to procedure is required to prevent ischemic and haemorrhagic complications. Hydration, temperature management and prevention of nausea and vomiting are needed. Often these patients are transferred

to ICU, imaging and OR and care during transport and imaging should continue at the same level as during the procedure. If complications occur during the procedure, a multi-disciplinary ICU management involving neurosurgeon, neurointensivist and interventional neuroradiologist should be undertaken.

8. Conclusion

Neuroendovascular procedures are increasingly performed over the past few years and present significant challenges to the anesthesiologist. A good knowledge of the pathologies, procedures and anaesthetic considerations are needed to provide optimal peri-procedural care for these patients. The principles governing the neuroanaesthesia practice should guide anaesthetic management. Complications can be abrupt and catastrophic.Hence, good planning, adequate preparation and meticulous management are important for successful outcomes.

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