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Anaesthetic Management of Cerebral Aneurysm Surgery

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Management of cerebral aneurysm is always a challenge for a neurosurgeon and anaesthesiologist. Proper knowledge, experience, timely intervention and goal directed therapy will definitely save a lot of lives. The leading causes of death and disability were, in descending order, vasospasm, the direct effects of the initial bleed (massive subarachnoid, subdural, or intracerebral hematoma, permanent ischemic effects of increased intracranial pressure, rebleeding, and surgical complications. This article revises the anaesthetic challenges during managing the cerebral aneusysms.

Key words: aneurysm, anesthesia, intraoperative challenge

Management of cerebral aneurysm is always a challenge for a neurosurgeon and anaesthesiologist. Proper knowledge, experience, timely intervention and goal directed therapy will definitely save a lot of lives. The leading causes of death and disability were, in descending order, vasospasm, the direct effects of the initial bleed (massive subarachnoid, subdural, or intracerebral hematoma, permanent ischemic effects of increased intracranial pressure [ICP]), rebleeding, and surgical complications.[1] Successful anesthetic management of patients with cerebral aneurysms requires a thorough understanding of the natural history, pathophysiology, and surgical requirements of the procedures.

Preoperative considerations:

The main steps in preoperative evaluation are as follows:

1. Assessment of the patient's neurologic condition and clinical grading of the subarachnoid hemorrhage (SAH)

2. A review of the patient's intracranial pathologic condition, including the performing of computed tomography (CT) and angiograms

3. Monitoring of ICP and transcranial Doppler ultrasonography (TCD) if available

4. Evaluation of other systemic functions, premorbid as well as current condition, with emphasis on systems affected by SAH

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5. Communication with the neurosurgeon regarding positioning, anticipated difficulty/technique to clip and special monitoring requirements

6. Optimization of the patient's condition by correcting any existing biochemical and physiologic disturbances.

The preoperative assessment allows appropriate planning of an anesthetic regimen with consideration of the pathophysiology of all organ systems as well as the surgical and monitoring requirements. This approach facilitates the goals of smooth anesthesia for an uncomplicated aneurysm and ensures a heightened level of preparedness for a complicated one. [2]

Although the surgical mortality and morbidity vary with different institutions, patients in good preoperative condition (assigned to clinical grades I and II) can be expected to do well; patients with grade V status have a high mortality and morbidity, but aggressive management has resulted in substantial improvement (Table 1).[3]The clinical grade also indicates the severity of associated cerebral pathophysiology. The higher the clinical grade, the more likely the occurrence of vasospasm, elevated ICP[4,5]impairment of cerebral auto- regulation[6,7]and a disordered cerebrovascular response to hypocapnia.[5] A worse clinical grade is also associated with a higher incidence of cardiac arrhythmia and myocardial dysfunction.[8,9]

Patients with worse clinical grades have a tendency to become hypovolemic and hyponatremic.[10,11]Thus, understanding the grading scale allows the anesthesiologist to communicate effectively with other physicians and facilitates assessment of pathophysiologic derangements and the planning of perioperative anesthetic management.

Table1: Modified Hunt and Hess Clinical Grades for Patients with Subarachnoid Hemorrhage*

Grades	Criteria
0	Unruptured aneurysm
I	Asymptomatic or minimal headache and slight nuchal rigidity
II	Moderate to severe headache, nuchal rigidity, but no neurological deficit other than cranial nerve palsy
III	Drowsiness, confusion, or mild focal deficit
IV	Stupor, mild or severe hemiparesis, possible early decerebrate rigidity, vegetative disturbance
V	Deep coma, decerebrate rigidity, moribund appearance

*Serious systemic disease such as hypertension, diabetes, severe arteriosclerosis, chronic pulmonary disease, and severe vasospasm seen on arteriography result in assignment of the patient to the next less favorable category.

Table 2 Surgical Mortality and Major morbidity of Subarachnoid hemorrhage according to Clinical Grades

Grade (Hunt and Hess)	Mortality (%)	Morbidity (%)
0	0-2	0-2
I	2-5	0-2
II	5-10	7
III	5-10	25
IV	20-30	25
V	30-40	35-40

Intraoperative considerations:

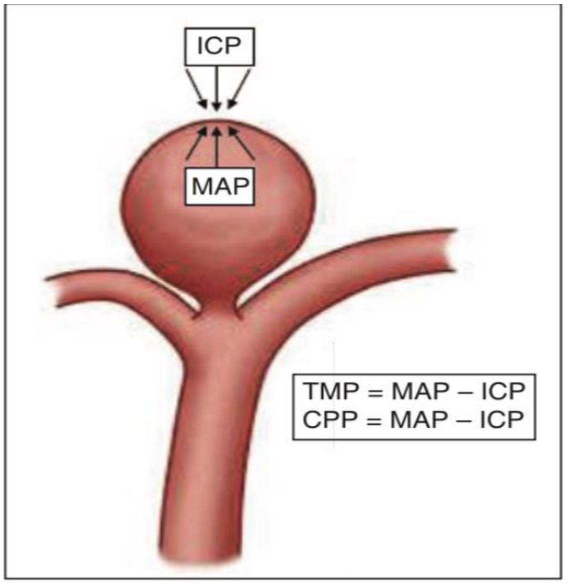

Figure 1 Transmural pressure = Mean arterial blood pressure (MAP) — intracranial pressure (ICP); cerebral perfusion pressure = MAP — ICP

Any sudden rise in blood pressure during tracheal intubation can result in rupture of aneurysm. Therefore, the goal during induction of anesthesia is to reduce the risk of aneurysm rupture by minimizing the transmural pressure (TMP) while simultaneously maintaining an adequate cerebral perfusion pressure (CPP). As illustrated in Figure 1, both TMP and CPP are determined by the same equation, mean arterial blood pressure (MAP) minus ICP (MAP — ICP). Thus these goals represent opposite objectives.[12]

Blood pressure management should be done taking into account patient's clinical grade and baseline blood pressure values. Patients who have been normotensive or those with SAH Grades 0, I, and II generally have normal ICP and are not experiencing acute ischemia.[13]These patients, therefore, tolerate a bigger transient decrease in blood pressure (30-35%). In contrast, patients with poor clinical grades frequently have increased ICP, low CPP, and ischemia.[14]The elevated ICP decreases the TMP and partially protects the aneurysm from re-rupture. These patients may not tolerate transient hypotension as well, and the duration and magnitude of blood pressure decrease should be moderated. As a general principle, the patient's blood pressure should be reduced to 20-25% below the baseline value, and prophylaxis to blunt the hypertensive response to laryngoscopy and intubation should be instituted before tracheal intubation is attempted.

Similarly, discretion should be used whether hyperventilation will be beneficial or harmful. Patients with a good clinical grade should not be hyperventilated, because the reduction in CBF will lead to a reduction in ICP and consequently, an increase in TMP. Conversely, patients with poor clinical grades should be managed with moderate hyperventilation to improve cerebral perfusion. Sudden changes in MAP should be avoided to reduce the risk of aneurysm rupture and ischemia.[15]

Monitoring

Standard monitoring usually includes 5-lead electrocardiogram, continuous intra-arterial pressure, pulse oximetry, capnography, urinary output, body temperature, and neuromuscular block. It is preferable to initiate invasive blood pressure monitoring prior to induction. Many neuroanesthetists routinely insert a central venous catheter for guidance of intravascular volume, for the injection of potent cardiovascular drugs in the case of severe cardiovascular instability, and for the administration of mannitol (which may cause local inflammation when administered through a smaller peripheral vein.[16]

Neurophysiologic monitoring

Although no randomized controlled trials have documented improved outcomes with neurophysiologic monitoring for surgical aneurysm clipping, it is widely used in many institutions. Most commonly used modalities are electroencephalography and evoked potentials (somatosensory evoked potentials, motor evoked potentials, brainstem auditory evoked potentials).[17, 18] Anesthetic agents should be selected to facilitate reliable recordings. One of the key elements is to keep anesthetic depth stable. Volatile anesthetics should remain below 0.5 minimum alveolar concentration when somatosensory evoked potentials and motor evoked potentials are recorded. Muscle relaxants should be avoided after induction when motor evoked potentials are monitored. However, it is mandatory to maintain adequate anesthetic depth to insure immobility. A propofol and opioid infusion should be titrated appropriately. Change in neurophysiologic recordings should prompt the surgical team to re-evaluate clip placement and the anesthesiologist to ensure that blood pressure, pharmacology and oxygenation are optimal.

Maintenance of anesthesia

The goals during maintenance of anesthesia are to: [19]

1. Provide a relaxed or "slack" brain that will allow minimal retraction pressure.
2. Maintain perfusion to the brain.
3. Reduce TMP if necessary during dissection of the aneurysm and final clipping and
4. Allow prompt awakening and assessment of patients with good SAH grades.

The choice of anesthetic agents should take into account the brain condition based on preoperative radiologic investigations and Hunt and Hess grading. Either an I.V. or inhalation anesthetic or a combination of both can be used to provide such conditions. Propofol has cerebral vasoconstrictive actions, thus it causes decrease in CBF, cerebral metabolic rate and thus decreases ICP.[20,21] Isoflurane, sevoflurane and desflurane may also be used in concentrations <1 minimum alveolar concentration (MAC) beyond which these cause increase in ICP.

Intraoperative analgesia is provided either by intermittent boluses or infusions of opioids. Periods of intense stimulation like pin insertion, skin incision or elevation of periosteum and incision of duramater should be covered by administering additional doses of opioids and deepening the planes of anesthesia to prevent hypertension.[19]

Brain relaxation

Optimal brain relaxation and reduction in brain bulk helps surgical exposure, reduce the forces required for brain retraction, and facilitates clipping of the aneurysm. Following agents/maneuvers have been used in combination:[22,23]

1. Positioning

15-30° head up position is the optimal position which decreases ICP yet maintains CPP. Excessive neck flexion or rotation should be avoided. Endotracheal tube should be taped instead of tying it around the neck. If it has to be tied across the neck, it should be ensured that the tie is not too tight and there is no pressure on neck veins.

2. Mannitol

Mannitol is usually the drug of choice to decrease brain water content. 20% mannitol (0.5-2 g/kg) is usually given over 30 min. The usual dose is 1 g/kg; an additional dose is given when indicated by the brain conditions. A total dose of 2 g/kg is frequently given when temporary artery occlusion is planned.

3. Frusemide

Frusemide reduces CSF formation and water and ion movement across the blood–brain barrier. The prolonged diuresis after the administration of frusemide can potentiate the effect of mannitol by sustaining elevated serum osmolality.[24] Frusemide is used in a dose of 0.25-1 g/kg.

4. Hypertonic saline

Hypertonic saline (3%) is a equiefficacious to 20% mannitol in the extent of brain relaxation.[25] However, mannitol continues to remains the drug of choice for intraoperative brain relaxation.

5. Cerebrospinal fluid drainage

Decreasing the volume of CSF using a lumbar subarachnoid or ventriculostomy catheter is an effective means of reducing brain bulk and may become necessary to achieve satisfactory brain relaxation. Extreme caution should however, be exercised during insertion of the drain to minimize CSF loss and a sudden decrease in ICP, so as to avoid an abrupt increase in TMP and a re-bleed. Due to the risk of brainstem herniation, lumbar drainage of CSF is contraindicated in patients with intracerebral hematoma. In theory, free drainage should be allowed only after the dura is open to minimize the risk of rebleeding; in practice; however, 20-30 mL of CSF is usually drained just before dural opening to facilitate dural incision. The drain is usually left open during the procedure, until the aneurysm is clipped or until the beginning of dural closure.

6. Hyperventilation

Controlling CO_2 levels can be used therapeutically to lower ICP. However, excessive hyperventilation carries the risk of inducing ischemia especially in poor grade patients. Thus, use of hyperventilation should be individualized according to the operating conditions. A reasonable approach is to institute mild hypocapnia (30-35 mm Hg) before the dura is open, moderate hypocapnia (25-30 mm Hg) after the dura is open, and relative normocapnia during induced hypotension and after the aneurysm is clipped.[19]

Fluid and Electrolyte Balance

Fluid should be administered according to the patient’s need and guided by intraoperative blood loss, urine output, and CVP, if present, or other dynamic index of volume status such as pulse pressure variation.[26]Intravenous fluid should not be withheld if induced hypotension is planned, because hypovolemic hypotension is detrimental to organ perfusion. The aim is to maintain normovolemia before aneurysm clipping and slight hypervolemia after clipping. Electrolytes should be replaced as needed. Glucose-containing solutions should not be given, because evidence exists that hyperglycemia may aggravate both focal and global transient cerebral ischemia.[27,28]Because lactated Ringer’s solution is relatively hypo-osmolar, a more physiologic solution, such as PlasmaLyte, Normosol, or normal saline, is preferred. Some practitioners use 5% albumin after clipping of the aneurysm, but the advantages of this protocol have not been documented. On the other hand, hetastarch probably should not be used or should be used sparingly (less than 500 mL) because of the risk of intracranial bleeding.[29,30]

Temporary arterial occlusion and brain protection

For large aneurysms and those deemed at risk of intraoperative rupture, surgeons may use temporary occlusion of the proximal artery to facilitate dissection and clipping. To minimize the risk of focal brain ischemia, the period of occlusion should be minimized by a skilled surgeon. A 10min occlusion seems to be safe while more than 20min of occlusion is associated with poor outcomes.[31–33]Blood pressure should be kept in the high normal range with pressors (phenylephrine or norepinephrine) to maximize collateral flow. Although many surgeons still request some type of pharmacologic brain protection e.g. thiopental or propofol, there are no human studies demonstrating a benefit in neurosurgery.[34,35]There is no convincing evidence for benefit of mild intraoperative hypothermia, but no clear evidence either for harm.[36,37]Hyperthermia and hyperglycemia should be avoided.

Intraoperative aneurysm rupture

Intraoperative aneurysm rupture carries a high morbidity and mortality. It may occur at any time during the procedure, associated mostly with an abrupt increase in the TMPG of the aneurysm (as a consequence of either a sudden increase in blood pressure or an abrupt decrease in ICP) or with surgical manipulation. It is to be expected that rupture of an aneurysm with an open skull and dura carries a better prognosis than a rupture occurring during induction of anaesthesia.

The incidence of aneurysm rupture varies with size and location of the aneurysm, and with surgical experience. Frank intraoperative rupture occurred in approximately 11% of patients with previously ruptured aneurysm (compared with an incidence of 1.2% in previously unruptured aneurysms).[38]Hemorrhagic shock may develop in 8% of aneurysm ruptures.[39]

The choice of acute interventions will depend on the size of the leak/rupture, the completeness of the dissection of the aneurysm and thus the surgeon's direct access to it, and the feasibility of temporary occlusion of blood vessels proximally and distally to the aneurysm. The primary hemodynamic goal during rupture of an aneurysm is maintenance of normovolaemia. Temporary occlusion of cerebral arteries proximal and distal to the aneurysm is an effective means of gaining control over ruptured aneurysms.

The blood pressure management during rupture of an aneurysm is controversial. On the one hand, a transient decrease in MAP to 40–50 mm Hg decreases wall shear stress, reduces bleeding, and facilitates surgical orientation, exposure, and clipping. On the other hand, in the presence of clinically relevant blood loss, the combination of hypotension and hypovolemia may result in profound cerebral ischaemia. Thus, temporary vessel occlusion is the preferred technique to gain control over a ruptured aneurysm—with the possible exception of when temporary occlusion is not possible.[40]

Postoperative considerations

Consideration of risk factors, continued treatment for stroke-related conditions, and behavior modification are all necessary in the postoperative period and beyond for prevention of recurrence.

In the immediate postoperative period, cerebrovascular imaging may be necessary to identify any remnants or further occurrence of aneurysm. Initiation or continued use of nimodipine for blood pressure control and maintenance of normovolemia is recommended to help prevent Delayed cerebral ischemia.[41,42]

Conclusion

Anesthetic management of cerebral aneurysm surgery patients is a complex team approach. Careful consideration of individual patient status, techniques, and the safest evidence-based methods are required for successful management

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