Anesthesia and the cerebral aneurysm patient: An overview

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The author provides a review of anesthetic techniques for use with the patient undergoing surgical treatment following a hemorrhage of a cerebral aneurysm.

Over the last thirty years there has been continual development in the treatment of patients with cerebral aneurysms. The development has included advancement in the areas of preoperative, operative, and postoperative treatment. While this increased knowledge has greatly reduced the mortality and morbidity rates associated with cerebral aneurysm patients, there remain areas where further development and knowledge are needed.

Patient evaluation

Upon the arrival of a patient with a suspected hemorrhage of a cerebral aneurysm, there is a need for a careful evaluation. This will include an assessment of the presenting patient, history taking, and appropriate diagnostic studies. The evaluation is essential in that it allows for an accurate diagnosis from which a plan of care can be developed.

During the initial assessment, the patient may present with a series of common symptoms. These symptoms may include sudden headache, nuchal rigidity, nausea and vomiting, clouding or temporary loss of consciousness and/or temporary neurological losses. The number and severity of the symptoms will be indicative of the severity of the hemorrhage. With this in mind, many institutions use a grading system to designate the condition of the patient. There exists a variety of different grading systems, with each emphasizing different concerns. The areas emphasized, either singly or in various combinations, include level of consciousness, headache and nuchal rigidity, neurological deficit and other major systemic disease states. Various grading systems are commonly used today. Some examples are shown in Table I.

In conjunction with the assessment, a diagnosis and plan of care are made through the use of such diagnostic procedures as computerized tomography (CT) scan, lumbar puncture, and angiography. The use of the CT scan constitutes an attempt to determine the presence of a hematoma and/or midline shift of the ventricles. In a case where a hematoma cannot be discerned by a CT scan, it may be desirable to perform a lumbar puncture to detect the presence of blood in the cerebrospinal fluid (CSF). A third very important test that is used for both the diagnosis and determination of treatment is cerebral angiography. This procedure allows for visualization of the aneurysm to note its size, location, and the status of the surrounding circulation. This information is essential in the planning of surgical treatment.

These procedures are usually performed as soon as possible during the patient's hospitalization. In the case where there is further deterioration, it may be necessary to repeat the CT scan.
and/or cerebral angiography to determine the cause of the deterioration. Possible findings from further tests could show repeated bleeding, increased intracranial pressure (ICP), or vasospasm.  

Preoperative care

Care during the preoperative period is given with three main goals in mind: (1) to allow the brain to recover and prevent ischemic complications; 2) to reduce the risk of a recurrence of the bleeding; and (3) to maintain the patient at a homeostatic state.

The overall care of the patient is determined by the patient's condition, but there are some general guidelines that should be followed. The patient should be maintained on absolute bedrest, in a quiet darkened environment, with minimal disturbances. If necessary, the patient should be sedated with barbiturates and/or minor tranquilizers to facilitate this quiet state. Prophylactic prevention of seizures should be undertaken with the use of appropriate agents such as phenytoin.  

Further attention should be directed toward the patient's diet, which should consist of 1,000 to 1,500 calories per day with careful monitoring of intake and output. Drinks containing caffeine and all smoking should be eliminated. To prevent gastric hemorrhage, especially when steroids are employed to reduce ICP, a prophylactic cimetidine regime should be used. It is also best to use stool softening agents and suppositories to prevent straining and to promote regular bowel movements.

Monitoring of the patient will also be highly variable, but may include any of the following: arterial blood pressure, CVP, rectal temperature probe, ICP, ECG, Swan-Ganz™ catheter and arterial gases. In the comatose patient a more rigorous regime may be necessary. This would include the addition of passive range of motion, log rolling every two hours, use of a cooling blanket, hyperalimentation and/or placement of a feeding tube.

Certain major areas of concern exist during the preoperative period. The first of these is the possibility of repeated bleeding at the aneurysm site. This is very serious because it carries with it a higher rate of morbidity and mortality. The risk of repeated bleeding is increased with patients who exhibit an elevated blood pressure (BP). The goal in this case is to achieve a gradual and stable reduction in BP.

The first approach taken to control BP is fluid restriction. When this is combined with general maintenance measures of sedation, analgesia and bedrest, the desired decrease in BP may often be achieved.

When the necessary reduction in BP cannot be achieved in this manner, there may be a need to use a diuretic such as furosemide in conjunction with gradually increasing doses of propranolol. This allows for a reduction in BP resulting from both a decrease in circulating fluid volume and a decrease in rate and force of cardiac contraction.

In patients with essential hypertension, it may

<table>
<thead>
<tr>
<th>Grade</th>
<th>Botterrell</th>
<th>Hunt</th>
<th>Alvord</th>
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<tbody>
<tr>
<td>I</td>
<td>Conscious</td>
<td>Asymptomatic or minimal headache and nuchal rigidity</td>
<td>Asymptomatic</td>
</tr>
<tr>
<td></td>
<td>+ meningismus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Drowsy with deficit</td>
<td>Moderate to severe headache, nuchal rigidity, no deficit other than cranial nerve</td>
<td>Minor symptoms, headache, meningismus, diplopia</td>
</tr>
<tr>
<td>III</td>
<td>Drowsy with deficit, probably a clot</td>
<td>Drowsy, confused, mild focal deficit</td>
<td>Poorly responsive but responds appropriately to pain</td>
</tr>
<tr>
<td>IV</td>
<td>Major neurological deficit or deteriorating with clot or pre-existing cerebrovascular disease</td>
<td>Stuporose, moderate to severe hemiparesis, possibly early decerebrate rigidity</td>
<td>Very ill but not likely to die within 24 hours</td>
</tr>
<tr>
<td>V</td>
<td>Moribund, failing vital center, extensor rigidity</td>
<td>Deep coma, decerebrate, rigidity, moribund</td>
<td>Unstable vital signs, likely to die within 24 hours</td>
</tr>
</tbody>
</table>

Table 1
Grading systems for evaluation of the neurologically impaired patient
be necessary to utilize primary antihypertensive agents such as hydralazine and methyldopa. If the patient is in a severe hypertensive crisis, initial therapy may be undertaken with sodium nitroprusside until primary antihypertensive agents can control the BP.\(^2\) If it is determined that the increase in BP is due to an increased ICP, osmotic diuretics, corticosteroids and/or controlled ventilation to produce hypocarbia may be instituted.\(^2\)

Whatever course of treatment is chosen for the reduction of an elevated BP, the goal is to achieve that reduction in a smooth, deliberate manner. This is especially important in the patient with a cerebral hemorrhage because cerebral auto-regulation may be impaired during this time. An increasing ICP and decreasing arterial pressure can result in severe cerebral ischemia.

A second precaution that may be used to prevent a repeated bleeding is therapy with antifibrinolytic agents. Following a subarachnoid hemorrhage there is an increase in fibrinolytic activity in the cerebrospinal fluid (CSF). Since the clot formation is usually the only factor preventing further bleeding at the aneurysm site, it is important to prevent lysis of this clot. Two antifibrinolytic agents that readily cross the blood brain barrier are \(\varepsilon\)-aminocaproic acid and tranexamic acid. Care should be taken in the administration of \(\varepsilon\)-aminocaproic acid since rapid infusion can result in a decreased BP, bradycardia, and/or arrhythmias. Some sources suggest giving high doses of these drugs to insure that an effective dose is being administered. It is further pointed out that the high dosage can be beneficial to the patient because of its suggested diuretic effect, which is apparently the result of a high percentage of the drug being excreted unmetabolized by the kidney.\(^2\)

The last area of major concern regarding the cerebral aneurysm patient is cerebral vasospasm. This vascular narrowing and resultant ischemia usually occurs one to two weeks post-hemorrhage. At present there appears to be no definitive treatment. One suggested approach is to increase fluid volume and BP. This is best accomplished with whole blood and/or volume expanders, but, in the deteriorating patient, a pharmacological approach may be necessary to bring about the desired increase in BP. Since this treatment seems to contradict the initial goals of fluid and BP reduction, there must be a careful evaluation of all consequences before instituting this treatment in the patient with an unclipped aneurysm.\(^1,2\)

### Timing of surgery

The timing of surgery for cerebral aneurysms is still open to debate. In dealing with grade I and II patients, surgery may either be performed immediately or delayed for one to two weeks. The argument for immediate surgery is based partly on studies that have shown that up to 11% of patients have repeated bleeding during the one to two week delay, and that almost a 50% mortality rate is associated with this repeated bleeding.\(^2,3\)

Those who suggest delaying surgery do so partly in the hope of first getting the patient past the period of localized vasospasm. They also point to their belief that patients undergoing early surgery fare worse due to postoperative vasospasm. The fear of repeated bleeding is countered by the encouraging success of the use of antifibrinolytic agents in preventing repeated bleeding during the waiting period.\(^2\)

It is generally agreed that grade III patients are delayed to allow for some improvement in their condition before surgery. It is also felt that grade IV and V patients should be dealt with in a supportive manner to allow for stabilization and, it is hoped, improvement so as to decrease an exceedingly high risk of morbidity and mortality. It is pointed out, though, that decompression surgery should readily be undertaken when an increased ICP does not readily respond to medical treatment with osmotic diuretics, corticosteroids, and hyperventilation.\(^2,3\)

### Anesthesia

After it has been determined when the surgery is to be performed, it is necessary for the anesthetist to tailor the anesthesia to the highly individual needs of the patient. It is extremely important that the anesthesia care plan be developed in direct consultation with the surgeon. In this type of case, consultation will not only make matters more convenient for the surgeon, but also may be the determining factor in a successful procedure.

**Premedication.** As discussed earlier, it is suggested that the patient be kept in a well-sedated state. During the 24 hours preceding surgery it may be necessary to increase the level of sedation to prevent undue anxiety. This can best be done by utilizing the benzodiazepines and/or barbiturates. Because of the possibility of respiratory depression, narcotics should be avoided as there can be a resultant increase in ICP from hypercarbia. The level of consciousness will determine the exact need for premedication; in some cases, all that will be needed is an anticholinergic agent such as atropine.
Monitoring. In cases where patient condition or special procedures are involved further monitoring may be necessary.

All patients undergoing this type of procedure should have at least one large bore IV that will allow for rapid fluid administration and/or blood replacement in the event of an uncontrolled bleed. The IV will also be useful in fluid replacement after the aneurysm is dealt with so the patient can be returned to a normal state of hydration.

The ECG monitor is used in this case as it is in most every type of case today. It allows for rapid detection of rate changes and accurate assessment of dysrhythmias. The esophageal stethoscope is used for further monitoring of the heart and also for auscultatory monitoring of breath sounds. The monitoring of breath sounds is an essential safeguard against disconnection of the breathing circuit, since visualization of many of the connections will not be possible. Blood pressure monitoring can be accomplished with just the use of a sphygmomanometer.

In the case of anesthesia for cerebral aneurysm surgery, where it is very likely that some sort of hypotensive technique will be used, it would be wise to use an arterial catheter. Its usage would allow for continuous monitoring of BP and a faster response to change. An added advantage of the arterial catheter is that it provides a means of monitoring frequent blood gases, since a hypocarbic state (PaCO₂ 25-35 torr) is usually desired. It may also be wise to monitor central venous pressure (CVP) with aneurysm patients because these patients are often maintained in a relatively hypovolemic state. In the patient who runs an increased risk of developing air emboli, the monitoring of CVP becomes mandatory along with the addition of a Doppler® monitor placed over the right atrium. This allows for both early detection and rapid evacuation of an air embolus.³⁶

Monitoring of urinary output is useful in assessing the adequacy of renal perfusion. A rate of 60 ml/hr is considered adequate in the average adult patient. The relative effectiveness of osmotic diuretics can also be evaluated through the monitoring of urinary output. The use of diuretics makes output monitoring an inaccurate tool for assessing renal perfusion.³⁶

Temperature monitoring is also an important consideration. Changes in body temperature, such as hypothermia, can result in prolongation of muscle relaxants, and postoperatively may result in an increased oxygen demand in the shivering patient. Thus, in addition to monitoring the patient’s temperature, it is useful to have available a blanket that can heat and cool the patient so a desired body temperature can be maintained.³⁶

Because it is very important that the patient not move during surgery but still be receptive to reversal, it is useful to use a peripheral nerve stimulator. This allows for careful titration of muscle relaxants to meet the individual patient’s needs.

Induction. In choosing an induction technique for the cerebral aneurysm patient, the main goal is a smooth transition of the patient from an awake state to one ready for surgical stimulation. This must be accomplished with minimal change in the cardiovascular state, ICP and cerebral blood flow (CBF).

The induction agents most commonly suggested are thiopental (Pentothal®), diazepam, and droperidol with or without fentanyl. These agents are given in a slow manner to minimize change in cerebrovascular status, but in sufficient quantity to prevent coughing or bucking. Before the induction is started, the patient should be adequately preoxygenated. As the induction progresses, the patient should be encouraged to take deep breaths and, at cessation of respiration, controlled hyperventilation should be instituted. With the assurance of an adequate airway, the muscle relaxant of choice for intubation should be administered. The muscle relaxant for intubation should be chosen with its specific limitations in mind. We will deal here with the two more widely used relaxants: succinylcholine and pancuronium.³⁴⁶

Succinylcholine, a very rapid depolarizing agent, allows for complete relaxation and thus intubation in the shortest period of time. For this reason, it is sometimes recommended. The main drawback of its use in cerebral aneurysm surgery is an associated increase in ICP. The increase in ICP can be associated with the muscle fasciculations resulting from the use of succinylcholine. These can be greatly diminished with adequate pretreatment by a nondepolarizing agent. The avoidance of this agent must be given consideration in light of any muscle wasting from prolonged bedrest. This is particularly applicable in grade III, IV, and V patients. The resultant K⁺ shift could produce serious cardiac disturbances.³⁴⁶

Pancuronium is an alternate choice for muscle relaxation for intubation. When given in a sufficient dose (0.1 mg/kg), it will allow for a sufficiently relaxed patient in an acceptable time span. Most sources agree that this can be accomplished with minimal change in CBF and ICP. A major concern when using this agent is maintaining an adequate airway to allow for positive pres-
sure ventilation until relaxation is sufficient for intubation.\textsuperscript{3,4,5,6}

During laryngoscopy it is suggested that the vocal cords and larynx be sprayed with a topical anesthetic, such as lidocaine 4\%, in order to minimize swings in BP and pulse from endotracheal tube stimulation while the patient is being brought to a surgical level of anesthesia.\textsuperscript{5}

Regardless of which muscle relaxant is used for intubation, it is suggested that a nondepolarizing muscle relaxant be used for maintenance throughout the procedure. The reasoning behind this technique is as follows: (1) the cerebral aneurysm patient will not tolerate bucking or coughing due to the resultant increase in ICP; (2) during the delicate dissection of the aneurysm, any sudden movement could not only make dissection difficult but also bring about a sudden rupture of the aneurysm; and (3) cerebral aneurysm surgery is relatively nonstimulating, other than during opening and closing of the wound and possibly during dissection around cranial nerves. This makes accurate assessment of patient depth difficult and increases the risk that movement will occur.\textsuperscript{3,4,5}

Maintenance of anesthesia. After hyperventilation has been instituted, maintenance of anesthesia can be accomplished with a volatile agent and N\textsubscript{2}O or a narcotic and N\textsubscript{2}O combination. When making the decision of which agents to use, it is important to consider how each will affect CBF and ICP (see Table II).

While it is noted that inhalational agents increase CBF and ICP, it is generally agreed that hyperventilation preceding the introduction of these agents minimizes the rise. It is further noted that inhalational agents may prove beneficial in the reduction of BP during desired periods of hypotension. If the choice of agent is to be based on the two parameters of CBF and ICP, neurolept anesthesia is clearly more advantageous.

There are also strong indications from animal studies that high doses of barbiturates protect the brain from ischemia and resultant hypoxic damage. Though the protective mechanism is not known, many sources believe it is the result of a decrease in cerebral metabolic requirements for O\textsubscript{2}. This suggests that the use of thiopental in conjunction with the other agents throughout surgery may help protect the brain from ischemic insult. This also suggests its possible preoperative use for the same protection. Since no technique has been proven absolutely superior in actual clinical practice, the choice must be made according to what works best in the individual anesthetist's hands.\textsuperscript{3,4,5}

Adjuncts to anesthesia. Further steps can be taken to both provide for a safer course of anesthesia and facilitate the surgeon. These can be utilized singularly or in any combination.

Hypotensive anesthesia is widely used in cerebral aneurysm surgery. A hypotensive state may be deliberately induced to diminish the risk of a sudden rupture of the aneurysm during clipping, and in the event of rupture, to minimize the severity of the blood loss. It is generally accepted that a reduction of mean arterial pressure to 50 torr is safe, and reduction to the 25-40 torr range has been noted without untoward side effects.

The risk of this type of pressure reduction is increased significantly in the presence of preexisting cerebrovascular disease and/or arterial hypertension. Resultant cerebral ischemia can occur at

<table>
<thead>
<tr>
<th>Table I\textsuperscript{4,5}</th>
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<td>Effects of anesthesia agents on cerebral blood flow (CBF) and intracranial pressure (ICP)</td>
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<table>
<thead>
<tr>
<th>Agents</th>
<th>CBF change</th>
<th>ICP change</th>
</tr>
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<tbody>
<tr>
<td>Thiopental</td>
<td>decrease</td>
<td>decrease</td>
</tr>
<tr>
<td>Fentanyl (Sublimaze\textsuperscript{®})</td>
<td>decrease</td>
<td>decrease</td>
</tr>
<tr>
<td>Droperidol</td>
<td>decrease</td>
<td>decrease</td>
</tr>
<tr>
<td>Diazepam (Valium\textsuperscript{®})</td>
<td>decrease</td>
<td>decrease</td>
</tr>
<tr>
<td>N\textsubscript{2}O</td>
<td>increase</td>
<td>increase</td>
</tr>
<tr>
<td>Enflurane (Ethrane\textsuperscript{®})</td>
<td>increase</td>
<td>increase</td>
</tr>
<tr>
<td>Halothane</td>
<td>increase</td>
<td>increase</td>
</tr>
<tr>
<td>Isoflurane (Forane\textsuperscript{®})</td>
<td>increase</td>
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a mean arterial pressure of greater than 50 torr in the face of occlusive cerebral vascular disease. In the presence of arterial hypertension, the brain's autoregulatory mechanism may not function at a mean arterial pressure even much greater than 50 torr. The exact degree of hypotension that will be tolerated in the hypertensive patient is not known. The lower limits that will be accepted should be adjusted upward according to the severity of the preexisting hypertension. Further intracranial factors that increase the risk of using a hypotensive technique are the presence of preoperative cerebral vasospasm, brain swelling, and the presence of a cerebral hematoma. Extracranial risk factors include fever because it results in increased oxygen demand, anemia, and hypovolemia.

When working towards a hypotensive state it is best to begin with the least invasive techniques. These include elevation of the head and lowering of the legs to produce venous pooling.

Pharmacologically, the first course of action would be to utilize anesthetic agents that produce a vasodilatory effect, such as droperidol and the inhalational anesthetics. If further reduction in BP is desired, direct vasodilators (such as nitroprusside and nitroglycerin) may be used. These agents may only be necessary during actual approach and clipping of the aneurysm, when the greatest reduction in BP is usually desired. It is important that the lowering of the BP be done slowly over 5-10 minutes. This allows for some autoregulatory compensation and also diminishes the wide pressure swings higher and lower than the desired level. If a tolerance to nitroprusside develops in conjunction with a metabolic acidosis, cyanide toxicity should be considered and appropriate therapy instituted. If the desired reduction in BP is not achieved with a dose of 10 \( \mu g/kg/min \) of nitroprusside, it is best to seek an alternate course of action.

The patient should be returned to a normotensive state (that is, post clipping) by gradually decreasing the dosage to minimize the risk of rebound hypertension.

The anesthetist may be called upon to facilitate the surgeon through the administration of osmotic diuretics. These diuretics work by increasing the intravascular osmotic pressure, thus drawing water from the interstitial space and decreasing brain mass.

The two agents most widely used are urea 1-1.5 gm/kg and mannitol 1-1.5 gm/kg. Urea has been found to cause a rebound increase in ICP 3-7 hours after administration. Thus, in most areas, mannitol is used instead of urea. Mannitol causes little venous thrombosis or tissue damage, which were drawbacks associated with the use of urea. Mannitol is given over 30 minutes and begins action within 20 minutes. Maximum action is achieved in 1-2 hours. Because these agents cause a transitory increase in circulatory fluid volume, care must be exercised in the patient with limited cardiac reserve.

Further improvement in visualization for the surgeon or a greater reduction in ICP can be accomplished by the removal of CSF via a lumbar puncture. It is important to remove the CSF slowly because the presence of increased ICP can result in tonsillar herniation with rapid removal of CSF.

While it has been demonstrated that reduction in temperature does reduce CBF, ICP, and metabolism, it does not do so as expeditiously as pharmacological agents. As a result, this method is not used frequently today. It is generally agreed that it still is useful in specific cases, such as those of giant basilar artery aneurysms where circulatory arrest is necessary.

**Emergence.** The goal at the time of emergence is a smooth transition of the patient from surgical anesthesia to an awake state. This emergence sequence should begin after the dressing has been applied and the anesthetist has gained complete access to the patient. To facilitate a smooth emergence, stimulating activity such as suctioning should be done before reversal is started. Preferably, extubation should take place while the patient is still in a deep enough plane of anesthesia to prevent coughing and straining. If the patient's condition dictates that he remain intubated, sedation and muscle relaxants should be utilized.

**Conclusion**

It is necessary to have a clear understanding of the special needs involved in the care and treatment of the patient with cerebral aneurysm. The anesthetist must understand the need for careful study and communication to provide a smooth, uneventful course of anesthesia.

**REFERENCES**

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