ANESTHESIOLOGY™2014
OCTOBER 11-15 | NEW ORLEANS, LA

Session: L002
Session: L086

Only a Little Sniff of Cocaine; Now an Aneurysm Coiling Headache!

Jess W. B. Brallier, M.D.
The Mount Sinai School of Medicine, New York, NY

Disclosures: This presenter has no financial relationships with commercial interests

Stem Case and Key Questions Content

A 24-year-old female presents to the emergency department complaining of severe headache and neck pain. The patient states that she and her boyfriend were “snorting a bit of cocaine” shortly before the onset of symptoms. She denies any significant past medical history, has no known drug allergies and takes no prescription medications. The physical exam reveals exquisite neck pain with flexion and the following vital signs: blood pressure (BP) = 172/90 mmHg, heart rate (HR) =103 beats per minute (bpm), and oxygen saturation (SpO_2) = 98% on room air (RA). A 12-lead EKG reveals S-T depressions in all leads. Computed Tomography (CT) of the brain reveals a diffuse thin layer of subarachnoid blood and magnetic resonance angiography (MRA) reveals a small middle-cerebral artery aneurysm. A neurosurgery consult is obtained and the decision is made to treat the aneurysm via endovascular coiling (EVT).

1. Discuss the advantages/disadvantages of aneurysmal endovascular coiling compared with neurosurgical clipping (NST).

2. Discuss how the timing of intervention (early versus late) affects morbidity and mortality.

3. How are subarachnoid hemorrhages (SAH) graded clinically?

4. How does knowledge of the clinical grade of the SAH affect anesthetic management?

5. Discuss the potential cerebral pathophysiological changes present following SAH.

6. Discuss additional preoperative testing that would be useful in optimizing the patient prior to this procedure.

7. Outline an appropriate anesthetic plan for this patient?

8. How might the patient’s recent cocaine use relate to the SAH?

9. Describe potential anesthetic concerns related to recent cocaine use.

10. Discuss the challenges of performing neurointerventions in the interventional radiology (IR) suite.

The patient is transported to (IR) with a 22-gauge intravenous catheter (IV) in place. Visibly

anxious, she is transferred to the procedure table and demands “to be given something to calm my nerves.” Standard ASA monitors are applied and vital signs read: BP=150/85 mmHg, HR=92 bpm, SpO_2=98% on RA. The neurointerventionalist requests general anesthesia for the procedure.

1. Discuss the desired hemodynamic goals during anesthesia induction and endotracheal intubation in a patient with an unsecured aneurysm and any potential concerns.

2. Which anesthetic agents should be employed to accomplish these goals?

3. Discuss additional monitoring (in addition to ASA standard modalities) and/or IV access needs.

4. What are the risks/benefits of pre-medicating this nervous patient with an anxiolytic and/or opioid agonist?

Anesthesia induction and intubation proceed without incident and the procedure begins. The patient’s blood pressure is stable at 125/70 mmHg. The interventionalist accesses the cerebral circulation via the femoral artery and with stent assistance begins deploying platinum coils into the aneurysmal sac. This is repeated several times. Placement of the 4th endovascular coil becomes difficult and the interventionalist suddenly notices extravasation of contrast dye outside the cerebral vasculature. Moments later the patient becomes hypertensive (BP=202/95) and bradycardic (HR=42).

1. What is the most likely explanation for the sudden change in the patient’s clinical condition?

2. Discuss appropriate management options for treating bleeding catastrophes in the IR suite.

3. How does management of a ruptured aneurysm in IR differ from that in the operating room?

After an hour, the aneurysm is successfully coiled with obliteration of the aneurysmal sac. Due to a complicated intraprocedural course, the decision is made to emerge the patient from anesthesia and perform a “wake-up test” but to keep her intubated. The patient is able to move the left side of her body but is notably weak on the right. Sedation is administered with the endotracheal tube in place and she is transferred to the neurosurgical intensive care unit (NSICU).

1. What major post-procedural complications is this patient at risk for developing?

2. Evaluate the role of induced hypothermia in this patient.

3. Discuss modalities used to diagnose cerebral vasospasm.

4. When is a patient most vulnerable to experiencing cerebral vasospasm?

5. How is cerebral vasospasm treated?

Model Discussion Content
Despite improvements in the treatment of intracranial aneurysms, the morbidity and mortality associated with aneurysmal rupture remains high. The incidence of intracranial aneurysms (IAs) varies between countries but has been reported to be present on autopsy in 0.2% to 9.9% of the general population. Subarachnoid hemorrhage (SAH) due to rupture of an aneurysm affects 30,000 Americans per year and is responsible for approximately 5% of all strokes (1, 2). Furthermore, an estimated 6700 in-hospital deaths occur each year as a result of aneurysmal SAH in the United States, and this is associated with a 30-day mortality rate of 45% (1). A large proportion of patients with a ruptured aneurysm suffers from additional morbidity in the form of rebleeding or vasospasm. Although the clinical prognosis remains disappointing after a ruptured aneurysm, careful anesthetic management during surgical clipping or endovascular coiling is paramount to good outcomes.

Endovascular coiling:
Treatment of intracranial aneurysms consists of either surgical clipping (NST) or endovascular coiling (EVT). Traditionally these lesions have been treated neurosurgically via a craniotomy. The surgeon exposes the lesion and ultimately places a metal clip across the aneurysmal neck thus eliminating it from the cerebral circulation. These cases generally require several hours of surgery and anesthesia and are associated with longer recovery times. By the end of the 20th century, many aneurysms were being treated endovascularly. These procedures are most often performed in the interventional radiology (IR) suite, take an hour or two, and involve significantly shorter recovery times. The procedure is performed by a neurointerventionalist who gains access to the cerebral circulation via the femoral artery and with the aid of a microguidewire, deploys a series of platinum coils into the aneurysm. An electric current is then applied to the coil which promotes formation of a thrombus. The coil essentially becomes a dense mesh holding the thrombus within the aneurysm. Additional coils are then deployed to fill the entire neck and sac. Since the publication of the International Subarachnoid Aneurysm Trial (ISAT) in 2002, coil embolization has become the preferred choice for treating many lesions with a growing trend towards EVT. Findings from this study demonstrated that patients who underwent EVT were more likely to enjoy independent survival at one year compared to individuals treated neurosurgically with this survival benefit continuing for at least 7 years (3). However, long-term follow-up of ISAT patients revealed that a coiled aneurysm had an increased risk of recurrent bleeding compared with those that were clipped surgically and required closer angiographic surveillance. They also had a higher incidence of repeat treatment (4). Despite this data, the net benefit in functional outcome argues in favor of EVT even in the long-term (5). Other advantages include shorter hospital stays and lower long-term financial costs (6). Finally, patients who are poor surgical candidates (i.e. the elderly or individuals with multiple medical comorbidities) show lower morbidity and mortality when treated endovascularly (7). The study design for ISAT II is currently under development and will involve at least 50 international centers and 1,896 patients. It will include patients who were excluded in the original trial as well as treatment devices not available at the time ISAT was published (8). Although the growing trend is toward EVT, each patient and aneurysm needs to be considered individually when deciding on a treatment plan. Certain individuals may not be appropriate surgical candidates due to their comorbidities and might better tolerate EVT.

Conversely, certain aneurysms due to size or anatomy may be better suited for surgical clipping. This is particularly true for middle cerebral artery aneurysms (9 and 10).

Preoperative management:
The anesthetic considerations for patients undergoing clipping or coiling are often the same and are partially based upon the preoperative condition of the patient. Assessing the severity of the patient's subarachnoid hemorrhage is an important part of the preoperative evaluation of these patients. Although many methods of objectively grading the clinical findings associated with aneurysmal bleeding have been proposed, the most commonly used scoring systems are the modified Hunt and Hess grading scale and Glasgow Coma Scale. The Hunt and Hess score correlates not only with surgical risk and prognosis, but also with the degree of associated cerebral pathophysiology and likelihood of vasospasm (11). Patients with lower Hunt and Hess scores are likely to have relatively normal ICP and intact cerebral blood flow autoregulation. Those with a higher score will probably have more aberrant pathophysiology, including intracranial hypertension, impaired autoregulation, and cerebral edema. Other classifications, such as the Fisher grading scale, are used to predict the risk and severity of cerebral vasospasm after SAH (12). It is also important to assess the patient's neurological status with particular attention to the presence of preoperative focal deficits. Patients with lower Hunt and Hess clinical grades are less likely to present with cerebral pathophysiology (*e.g.*, intracranial hypertension, impairment of cerebral autoregulation) than patients with higher grade pathology (13-15). The presence of vasospasm has important prognostic implications and will influence intraoperative hemodynamic management as well.

Ideally, medical comorbidities should be optimized prior to intervention with close attention paid to the cardiovascular system. Electrocardiographic abnormalities, elevation of cardiac biomarkers (i.e. troponins) and wall motion abnormalities are common in patients who have had a SAH (16, 17). The majority of patients with these findings have normal coronary artery anatomy; the cardiac dysfunction seen after SAH is neurogenic in origin. Although the exact mechanism of these changes is unknown, it is generally accepted that sympathetic stimulation induces catecholamine release in the myocardium which leads to impaired systolic and diastolic function, repolarization abnormalities and myocardial damage (18). In most cases, surgical intervention need not be delayed for further cardiac workup in patients without a known cardiac history, but patients who have an established cardiac history and in whom concomitant ischemic heart disease is suspected, briefly postponing the surgery or intervention may be necessary in order to obtain additional information or suggestions from a cardiologist about optimizing the patient's cardiac status.

Cocaine use and cerebral aneurysms:
Cocaine abuse continues to increase and is a risk factor for cerebral aneurysm rupture in young people (19). One report found the incidence of ruptured intracranial aneurysms in patients with cocaine-induced subarachnoid hemorrhage to be 84.9% with a mean age of 31.1 and overall mortality of 60.5% while another found 40% of patients to have a pre-existing lesion. This has led to the recommendation that cerebral angiography be performed in cases of cocaine-related intracerebral hemorrhage (19, 20). Cocaine is a potent central nervous system stimulant that prevents the reuptake of serotonin, norepinephrine and dopamine into presynaptic neurons. The precise mechanism of cocaine-induced hemorrhagic stroke remains unclear but is likely due to hypertensive surges associated with altered cerebral autoregulation (19). Additionally, there is evidence that cocaine use increases both the occurrence and influence of cerebral vasospasm (21).

Interventional Radiology:
Many interventional radiology suites are located in remote, outlying regions of the hospital far from the main operating room facilities and support personnel. Therefore, careful planning prior to the start of any procedure is imperative. All routinely used anesthetizing equipment should be checked and readily available. This includes anesthesia machines and workstations, wall and tank oxygen supply sources, emergency airway equipment and resuscitation drugs. Finally, access to a telephone and back-up anesthesia personnel are important should an emergency occur. Furthermore, many special procedure and interventional suites are configured so that gaining immediate access to the patient is challenging. Ensuring that IV and oxygen source extensions are available and in place are essential to pre-procedural preparation.

Intraoperative management
Choice of Anesthetic Technique and monitoring considerations:
General anesthesia is the technique most often utilized for endovascular aneurysm treatment. It is generally preferred over monitored anesthesia care (MAC) or sedation in order to minimize motion artifact and improve fluoroscopic images. Additionally, patient movement during coil deployment can result in failed placement or even rupture. A multitude of anesthetic agents have been used successfully for such procedures and selection of a specific drug is less important than vigilant use. Anesthesia induction is usually accomplished with propofol or etomidate (particularly for patients with compromised left ventricular function). Maintenance is most often achieved with a balanced technique consisting of a volatile agent and short-acting opioid such as fentanyl or remifentanil. An intermediate acting non-depolarizing agent is appropriate to maintain muscle relaxation. Finally, careful titration and reliance on shorter-acting anesthetics is conducive to rapid emergence and neurological evaluation at the conclusion of the procedure.

In addition to monitors recommended by the ASA basic monitoring standards, additional modalities should include an intra-arterial catheter to monitor blood pressure on a beat-to-beat basis. This should be inserted prior to induction so that untoward fluctuations in blood pressure can be rapidly treated. Although, projected blood loss for endovascular coiling procedures are less than for a craniotomy, care should be taken to ensure the patient has adequate IV access in case of bleeding or aneurysmal rupture. Induction can be accomplished with a small, in-situ IV but a larger bore catheter should be placed after induction and prior to the start of the procedure. A urinary catheter should be inserted after induction to measure output and core temperature

should be monitored. Evoked potential monitoring, while frequently for cases involving surgical clipping, is rarely used for coiling procedures.

Induction and endotracheal intubation:
The Induction of anesthesia and management of the airway are critical events in the patient with an unsecured cerebral aneurysm. The objectives are to attain loss of consciousness and prevent further aneurysmal bleeding while preserving adequate cerebral perfusion. Very tight control of systemic blood pressure is therefore critical during this stage of the procedure, and should be guided with continuous invasive monitoring. While the incidence of rupture during induction is rare, it is a devastating complication and is usually avoidable with careful hemodynamic management. In patients with a low grade aneurysm (Hunt/Hess scores of 0-2)

ICP is usually normal and cerebral autoregulation is generally preserved. Lowering the MAP during induction and intubation decreases the transmural pressure (TMP) across the wall of the aneurysm, lowering the risk of subsequent bleeding. A moderate decrease in CPP does not usually produce acute cerebral ischemia in this group of patients. TMP is defined as:
TMP = MAP – ICP

Assuming ICP remains relatively constant, pressure across the aneurysmal wall decreases with the MAP. Thus, lowering the MAP slightly below the patient's baseline and avoiding acute increases in MAP help to prevent aneurysmal rupture. This is the same equation used to represent cerebral perfusion pressure (CPP):
CPP = MAP – ICP

Patients who have a higher grade lesion (i.e., Hunt/Hess 4 or 5) are more likely to have aberrant cerebral pathophysiology and require a different strategy for managing the hemodynamic response to induction of anesthesia and airway management. These patients may have intracranial hypertension and decreased CPP. A large decrease in MAP may therefore compromise cerebral perfusion. Although decreasing MAP decreases TMP, it also decreases CPP, placing these patients at risk for further ischemic insult. Mean arterial pressure should therefore be maintained at or close to the patient's preoperative baseline.

Aneurysmal rupture in the interventional radiology suite:
In the conscious patient, bleeding catastrophes are often accompanied by nausea, vomiting, and sudden headache. In the anesthetized individual, such a diagnosis is usually made via the interventionalist by visualizing the extravasation of contrast material. Additionally, the patient will exhibit the sudden onset of bradycardia and hypertension (Cushing response). Essential to good outcomes in IR is the establishment of a well-prepared plan and effective communication between anesthesia and radiology personnel. The remote location of many IR suites and the potential lack of immediate back-up make these two elements critical. In addition to the geographical and physical challenges inherent to this environment, management of an intraprocedural aneurysm rupture is complicated by other factors. Although intraoperative rupture during surgical clipping carries a high risk of morbidity, a temporary clip (or sometimes even a permanent one) can be placed across the aneurysmal neck or supplying vessel to obtain hemostasis. Furthermore, systemic blood pressure can be temporarily lowered in order to improve surgical field visualization. In the case of EVT, the nearest operating room is often floors away and surgical equipment and personnel are often unavailable making the possibility of performing an emergent craniotomy impossible. Appropriate resuscitation in the IR suite begins with communication between all team members and calling for further assistance. In the case of the conscious patient, the airway should be secured immediately and positive pressure ventilation employed. Prompt reversal of heparin should occur and a low-normal MAP maintained. Further management targeting elevated intracranial pressure (ICP) should include administration of mannitol (1g/kg), a head-up position (15-30 degrees) if possible and ventriculostomy placement. Communication with operating room coordinators and staff should also begin should an emergent craniotomy become necessary.

Fortunately, most instances of vascular rupture can be managed in the IR suite. The interventionalist can attempt to successfully coil the aneurysm or seal the rupture sight (22, 23). Additionally, a ventriculostomy can be placed and in high-risk patients may even be placed prior

to the procedure (24). In all cases, management should be anticipated and efficient as the morbidity and mortality for such an event is high (25).

Postoperative management:
The two major postoperative complications experienced by patients after SAH are rebleeding and vasospasm. Rebleeding is most common in an untreated aneurysm (i.e. uncoiled or unclipped) with the highest incidence in the first 24 hours after rupture. Rebleeding rates decrease dramatically when aneurysms are treated within 48 hours of rupture (26).
Cerebral vasospasm, also known as delayed cerebral ischemia (DCI), can lead to ischemia and infarction in those who initially survive a SAH. It is the leading cause of morbidity and mortality following aneurysmal SAH. Angiographic vasospasm is known to occur in up to 70% of patients and is typically observed between 5 and 14 days after the onset of SAH. However, symptomatic vasospasm occurs in a smaller percentage of those afflicted with a reported incidence of about 30%. Delayed ischemic neurologic deficits occur in about 50% of patients with evidence of angiographic vasospasm which may lead to stroke or death despite maximal therapy (27). Diagnosis is often made after the appearance of a new focal sign or a decrease in level of consciousness. Transcranial Doppler (TCDs) can be done at the bedside as a first-line diagnostic tool but should be confirmed via a cerebral angiogram. Treatment modalities for vasospasm include calcium channel blockers (specifically nimodipine which has reduced morbidity by 40-70%) (28), hemodynamic augmentation (previously known as triple-H therapy) and transluminal angioplasty. Administration of vasodilators such as papaverine and nicardipine has also shown favorable results (29, 30). Numerous studies have now been published comparing rates of vasospasm between patients treated with microsurgical clipping and endovascular coiling. Results of these studies show unanimously lower rates of vasospasm in patients treated with coiling (31).

References
1. Rinkel GJ, D.M., Algra A, et al. *Prevalence and risk of rupture of intraranial aneurysms: a systematic review.* Stroke, 1998. 29: p. 251-6.
2. Bederson JB, Connolly ES., Batjer HH, et al. *Guidelines for the Mangement of Aneurysmal Subarachnoid Hemorrhage: A Statement for Healthcare Professionals From a Special Writing Group of the Stroke Council, American Heart Association.* Stroke, 2009. 40: p. 994-1025.
3. Molyneux AJ, Kerr RS, Stratton I, et al. *International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised trial.* Lancet, 2002. 360 (9342):1267-74.
4. Molyneux AJ, Kerr RS, Birks J, et al. *Risk of recurrent subarachnoid haemorrhage, death, or dependence and standardised mortality ratios after clipping or coiling of an intracranial aneurysm in the International Subarachnoid Aneurysm Trial (ISAT): long-term follow-up.* Lancet Neurol. 2009 May;8(5):427-33.
5. Dupont SA, Wijdicks EF, Lanzino G, et al. *Aneurysmal subarachnoid hemorrhage: an overview for the practicing neurologist*. Semin Neurol. 2010 Nov;30(5):545-54.
6. Seibert B, Tummala RP, Chow R, et al. *Intracranial aneurysms: review of current treatment options and outcomes.* Front Neurol. 2011;2:45.
7. Van der Schaaf I, Algra A, Wermer M, et al. *Endovascular coiling versus neurosurgical clipping for patients with aneurysmal subarachnoid haemorrhage.* Cochrane Database Syst Rev. 2005 Oct 19;(4).
8. Darsaut TE, Jack AS, Kerr RS, Raymond J. *International Subarachnoid Aneurysm Trial-ISAT*

part II: study protocol for a randomized controlled trial. Trials. 2013 May 29;14.
9. Rodriguez-Hernandez A, Sughrue ME, Akhavan S, et al. *Current management of middle cerebral artery aneurysms: surgical results with a clip first policy.* Neurosurgery. 2013 Mar; 72(3).
10. Abla AA, Jahshan S, Kan P, et al. *Results of endovasuclar treatment of middle cerebral artery aneurysms after first giving consideration to clipping.* Acta Neurochir (Wien). 2013 Apr; 155(4).
11. Rosen DS, MR. *Subarachnoid Hemorrhage Grading Scales. A Systematic Review.* Neurocrit. Care. 2005. 2: p. 110-118.
12. Frontera JA, Claassen J, Schmidt JM, et al. *Prediction of symptomatic vasospasm after subarachnoid hemorrhage: the modified fisher scale.* Neurosurgery. 2006. 59(1): p. 21-7.
13. Heuer GG, Smith MJ, Elliott JP, et al. *Relationship between intracranial pressure and other clinical variables in patients with aneurysmal subarachnoid hemorrhage.* J Neurosurg, 2004. 101: p. 408-416.
14. Zweifel C, Castellani G, Czosnyka M, et al. *Continuous assessment of cerebral autoregulation with near-infrared spectroscopy in adults after subarachnoid hemorrhage.* Stroke, 2010 41(9): p. 1963-8.
15. Urrutia VC, Wityk RJ. *Blood pressure management in acute stroke*. Neurol Clin., 2008 26(2): p. 565-8.
16. Rose JJ, Vanhecke TE, McCullough PA. *Subarachnoid hemorrhage with neurocardiogenic stunning.* Rev Cardiovasc Med, 2010. 11(4): p. 254-63.
17. Hakeem A, Marks AD, Bhatti S, et al. *When the worst headache becomes the worst heartache!* Stroke, 2007. 38(12): p. 3292-5.
18. Van der Bilt IA, Hasan D, Vandertop WP, et al. *Impact of cardiac complications on outcome after aneurysmal subarachnoid hemorrhage: a meta-analysis.* Neurology.2009. 72: p. 635-42.
19. Pozzi M, Roccatagliata D, Sterzi R. *Drug abuse and intracranial hemorrhage*. Neurol Sci. 2008. 29 Suppl 2:S269-70.
20. Oyesiku NM, Colohan AR, Barrow DL, et al. *Cocaine-induced aneurysmal rupture: an emergent negative factor in the natural history of intracranial aneurysms?* Neurosurgery. 1993. 32(4):518-25; discussion 525-6.
21. Howington JU, Kutz SC, Wilding GE, et al. 20. *Cocaine use as a predictor of outcome in aneurysmal subarachnoid hemorrhage.* J Neurosurg. 2003. 99(2):271-5.
22. Li MH, Gao BL, Fang C, et al. *Prevention and management of intraprocedural rupture of intracranial aneurysm with detachable coils during embolization.* Neuroradiology. 2006. 48(12):907-15. Epub 2006 Sep 27.
23. Kwon BJ, Han MH, Oh CW, et al. *Procedure-related haemorrhage in embolisation of intracranial aneurysms with Guglielmi detachable coils.* Neuroradiology. 2003. 45(8):562-9. Epub 2003 Jul 8.
24. Connolly ES Jr, Lavine SD, Meyers PM, et al. *Intensive care unit management of interventional neuroradiology patients.* Neurosurg Clin N Am. 2005.16(3):541-5.
25. Elijovich L, Higashida RT, Lawton MT, et al. Cerebral Aneurysm Rerupture After Treatment (CARAT) Investigators. *Predictors and outcomes of intraprocedural rupture in patients treated for ruptured intracranial aneurysms: the CARAT study.* Stroke. 2008. 39(5):1501-6. Epub 2008 Mar 6.
26. Cong W, Zhongxin Z, Tiangui L, et al. *Risk factors for rebleeding of aneurysmal subarachnoid hemorrhage based on the analysis of on-admission information.* Turk Neurosurg. 2012;22(6):675-81.
27. Velat GJ, Kimball MM, Mocco JD, et al. *Vasospasm after aneurysmal subarachnoid*

hemorrhage: review of randomized controlled trials and meta-analyses in the literature. World Neurosurg. 2011. 76(5):446-54.
28. Dorhout Mees SM, Rinkel GJ, Feigin VL, et al. *Calcium antagonists for aneurysmal subarachnoid haemorrhage.* Cochrane Database Syst Rev. 2007. 18;(3).
29. Lele A, Lyon T, Pollack A, et al. *Intra-arterial nicardipine for the treatment of cerebral vasospasm in postpartum cerebral angiopathy: a case study and review of literature.* Int J Neurosci. 2011. 121(10):537-42. Epub 2011 Aug 4.
30. Hoh BL, Ogilvy CS. *Endovascular treatment of cerebral vasospasm: transluminal balloon angioplasty, intra-arterial papaverine, and intra-arterial nicardipine.* Neurosurg Clin N Am. 2005 Jul;16(3):501-16, vi.
31. Gross BA, Lai PM, Frerichs KU et al. *Treatment Modality and Vasosopasm After Aneurysmal Subarachnoid Hemorrhage.* World Neurosurg. 2013 Aug. [Epub ahead of print].