Case example: woman aged 60 yr with history of hypertension reported worst headache of her life; symptom indicated subarachnoid hemorrhage, likely because of aneurysm; patient neurologically intact; areas of hyperintensity on noncontrast computed tomography (CT) demonstrated subarachnoid hemorrhage; CT angiography sometimes identifies aneurysm; anterior communicating artery most common location for aneurysmal rupture; distal middle cerebral artery (MCA) also common; posterior circulation aneurysms less common.

Examinations: high Hunt and Hess grade corresponds with poor neurologic examination (ie, indicating poor prognosis); higher grade on Fisher scale corresponds with radiographic scan indicating poor prognosis; higher incidence of morbidity and mortality in patients with poorer neurologic examination; higher incidence of vasospasm in patients with more blood in brain, particularly clots and intraventricular hemorrhage; irritation causes spasm of vasculature that can lead to ischemic stroke; presence of xanthochromia on lumbar puncture indicates need for vascular imaging; CT angiography and magnetic resonance angiography essentially equivalent; angiography gold standard.

Outcomes: better outcomes in patients with subarachnoid hemorrhage compared with intracranial hemorrhage; CT angiography sensitive; perform endovascular coiling or surgical intervention early to minimize risk of rebleeding; rebleeding leads to poorer outcomes; rebleeding occurs in 14% of cases; risk factors include larger bleed and poor neurologic grade; risk of rebleeding highest in first 24 hr.

Prevention of rebleeding: mean arterial pressure (MAP) good monitor for perfusion pressure; systolic pressure better indicator for shear stress on vessel; maintaining low systolic pressure decreases incidence of rebleeding; guidelines recommend pressure ≤160 mm Hg; patients immediately given antihypertensive medication at speaker’s institution.

Antifibrinolytic therapy: not currently favored, primarily because of increased rate of cerebral infarction; can be useful if significant amount of blood present.

Cardiac manifestations: any arrhythmia possible; Takotsubo cardiomyopathy common; echocardiography potentially important for guiding management of hemodynamics.

Endovascular management: increasingly favored; wide neck aneurysm or large aneurysm >1 cm diameter taken to operating room (OR), but endovascular coiling used whenever possible; coiling improves outcomes in centers familiar with procedure; guidelines call for 25 procedures per year; coil obliterates area of aneurysm and allows blood to pass without causing additional bleeding; vasospasm of greater concern after coiling than rebleeding.

Risks: data indicate benefits outweigh risks in high-volume centers; small incidence of rebleeding in ruptured aneurysms after coiling and “reasonable” rate of recurrence; more likely in posterior circulation compared with anterior; incidence of rebleeding increases with increasing length of time patient left unmanaged; intervention should occur within first 24 hr.

Vasospasm: delayed phenomenon with peak incidence between 3 days and 14 days; may occur ≤4 wk; patients with neurologic changes require close monitoring; patients with new neurologic deficit at high risk for stroke and require management ≤1 hr of new deficit; transcranial Doppler used to assess mean velocities; Lindegaard ratio equals mean velocity in MCA divided by mean velocity in ipsilateral extracranial internal carotid; higher ratio indicates higher velocity in MCA, which could indicate narrowed vessel.

Treatment: triple-H therapy comprises hypertension, hypervolemia, and hemodilution; Lindegaard ratio ≥3 indicates risk for vasospasm; consider increasing blood pressure (BP); attempt to increase perfusion, increase oxygen supply, and decrease oxygen demand; maintain BP; decrease metabolic demand for oxygen; manage intracranial pressure (ICP).

Hypervolemia: hypervolemia detrimental, so first H of triple-H should be avoidance of hypovolemia; hypervolemia can cause pulmonary edema; consider noninvasive monitoring of cardiac output; ensure adequate volume status.

Hypertension: no strong data to indicate benefit, but anecdotal evidence of benefit; hypertensive combined with hypervolemia can cause acute respiratory distress syndrome; elevated central venous pressure can decrease perfusion pressure in patients with compromised intracranial compliance or high ICP.

Hemodilution: ideal hemoglobin level debatable; data indicate associations between hemoglobin level 10 g/dL to 11 g/dL and better neurologic outcomes; speaker tends toward higher hemoglobin in comatose patients, but follows neurologic examination when possible.

Magnesium: no demonstrated benefit for administration of magnesium for treatment of vasospasm; can be beneficial for...

Educational Objectives

The goal of this program is to improve the management of acute subarachnoid and nontraumatic intracranial hemorrhages. After hearing and assimilating this program, the clinician will be better able to:

1. Recognize the signs and symptoms of acute subarachnoid hemorrhage.
2. Optimize medical and surgical treatment of patients with subarachnoid hemorrhage.
4. Recognize and treat seizures after subarachnoid and intracranial hemorrhage.
5. Optimize the management of intracranial pressure in patients at risk for herniation.

Faculty Disclosure

In adherence to ACCME Standards for Commercial Support, Audio Digest requires all faculty and members of the planning committee to disclose relevant financial relationships within the past 12 months that might create any personal conflicts of interest. Any identified conflicts were resolved to ensure that this educational activity promotes quality in health care and not a proprietary business or commercial interest. For this program, members of the faculty and planning committee reported nothing to disclose.
shivering; shivering can increase cerebral metabolic rate of oxygen (CMRO₂) and oxygen demand. Medications: nicardipine has angiographic evidence for assistance with vasospasm; nimodipine does not alter vasospasm but improves neurologic outcome in setting of aneurysmal subarachnoid hemorrhage; verapamil treats vasospasm and increases blood flow distally. Angioplasty: effective for treating vasospasm.

**Hydrocephalus:** inflammation because of intraventricular hemorrhage can impede reabsorption of cerebrospinal fluid (CSF); blood clots can cause obstructive hydrocephalus.

**Intraventricular hemorrhage:** patients with intraventricular hemorrhage at higher risk for hydrocephalus and vasospasm; external ventricular drains used for drainage of blood; tissue plasminogen activator can clear blood and decrease incidence of ventriculoperitoneal shunt, but with some risk of chemical ventriculitis causing transient neurologic problems; ventriculostomy helpful; chronic ventriculomegaly may require shunt; aggressive treatment improves outcomes.

**Seizures:** common in patients with hemorrhage; frequently nonconvulsive; seizures occur in 19% of patients with subarachnoid hemorrhage (>66% nonconvulsive); antiepileptic medications indicated for patients at high risk for seizures, but prophylactic use not yet substantiated and some evidence indicates phenytoin (eg, Cerebyx, Dilantin, Phenytoin) detrimental if given without evidence of seizures; speaker tends not to use prophylactic phenytoin and uses continuous electroencephalography (EEG) for patients with neurologic examination inconsistent with CT.

**Temperature control:** increase in temperature 1°C above normal increases CMRO₂ 7%; important to maintain normothermia; normothermia decreases ICP and metabolic demand for oxygen, which theoretically decreases incidence of stroke.

**Intracranial hemorrhage case example:** woman aged 60 yr with history of hypertension taking multiple medications; responsive to external stimuli; reactive pupils; systolic BP 240 mm Hg; with history of hypertension taking multiple medications; rapidly increasing neurologic status; immediately administer coagulopathy reversal; experienced doctor dose of fresh frozen plasma between 10 mL/kg and 20 mL/kg; large volumes can cause or exacerbate congestive heart failure; prothrombin complex concentrate (Kcentra) with vitamin K can reverse coagulopathy within 1 hr if dosed appropriately; rivaroxaban (Xarelto), dabigatran (Pradaxa), and some others not as easily reversed; new reversal agents in development; reversal less effective in patients with liver failure; maintain platelets >1000 X 10⁹/L; factor VII detrimental; factor VIII effective for expansion of hematoma but significantly increases incidence of thrombotic events.

**External ventricular drains:** primarily for management of ICP; ICP not ideal surrogate for injured brain, but tends to act as global cerebral measure of resuscitation; optimize CPP and decrease ICP; anesthesiologists may not know how to manage ICP; inotropic support less effective in patients with liver failure; maintain platelets >1000 X 10⁹/L; factor VII detrimental; factor VIII effective for expansion of hematoma but significantly increases incidence of thrombotic events.

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**Intracranial hemorrhage case example:** woman aged 60 yr with history of hypertension taking multiple medications; became obtunded within minutes of hearing bad news; unresponsive to external stimuli; reactive pupils; systolic BP 240 mm Hg; classic hypertensive nontraumatic hemorrhage.

**Hemorrhagic strokes:** basilar ganglia most common area; thalamus also common; less frequent in pons, cerebellum, and brainstem, but consequences potentially more severe; obstruction of fourth ventricle or expansion of hematoma in cerebellum could cause herniation of tonsils with arrhythmias and cardiac arrest; obstructive hydrocephalus can cause neurologic decline; compliance of posterior fossa poor; prophylactic suboccipital decompression possibly indicated; pontine hemorrhage not amenable to surgery.

**Management of airway:** patients with declining neurologic status may require intubation; compliance poor in patients with space-occupying lesion; change in ICP can cause herniation; manage airway without increasing BP; optimize oxygenation and ventilation; optimize cerebral perfusion pressure (CPP)

**Brain injury:** hematoma causes tissue dissection and mass effect; underlying brain injured; brain cells die; swallowing applies pressure to living cells; minimize expansion of hematoma and cell death.

**Cerebral edema:** larger hematomas cause more cerebral edema; maximum edema occurs between 2 days and 5 days.

**Volume of hematoma:** important prognostic indicator; determines need for surgery; hematomas >30 mL considered high risk; increased risk for expansion of hematoma in patients with ongoing hypertension; any expansion of hematoma worsens outcome; speaker recommends early and aggressive treatment for patients on anticoagulation therapies; immediately administer coagulopathy reversal; recommended dose of fresh frozen plasma between 10 mL/kg and 20 mL/kg; large volumes can cause or exacerbate congestive heart failure; prothrombin complex concentrate (Kcentra) with vitamin K can reverse coagulopathy within 1 hr if dosed appropriately; rivaroxaban (Xarelto), dabigatran (Pradaxa), and some others not as easily reversed; new reversal agents in development; reversal less effective in patients with liver failure; maintain platelets >1000 X 10⁹/L; factor VII detrimental; factor VIII effective for expansion of hematoma but significantly increases incidence of thrombotic events.

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Intracranial compliance: acute increase in BP does not cause significant increase in ICP in healthy adults; small increases in BP can cause large increases in ICP and herniation in patients with tumor or large hemorrhage; avoid both hypotension and hypertension; CPP equals MAP minus ICP; multiple components of ICP to manage

Venous component of ICP: placing patient in sitting position can significantly reduce ICP; elevating head of bed from 30° to 60° reduces ICP; maintain straight neck; ensure ties placed around neck do not compress jugular veins; in neurologic intensive care unit, avoid placing central venous catheters in internal jugular (IJ) vein; central catheters can cause clots and hematomas; IJ compressed when central catheter removed

Arterial component: with intact autoregulation, maintain MAP, partial pressure of carbon dioxide, and oxygenation within normal range; increasing cerebral blood flow increases CMRO₂ which, in turn, increases ICP; autoregulation impaired in most patients; small changes in parameters may cause large changes in ICP; optimize oxygenation

Cerebrospinal fluid: draining CSF possibly helpful; intraventricular catheter, as opposed to intraparenchymal monitor, can facilitate drainage of CSF; lumbar drain possibly sufficient for removing CSF in subarachnoid hemorrhage

Osmotic therapy: evidence indicates hypertonic saline effective; increasing sodium concentration in blood increases osmolarity and creates osmotic gradient between blood and brain; water drawn out of brain, decreasing volume and ICP; effective for both cytotoxic compression injury and vasogenic injury; mannitol also effective

Steroids: effective only for vasogenic edema and for abscesses; not otherwise used for intracranial or subarachnoid hemorrhage

Reflection coefficient (RC): RC close to 1 required to effectively draw water out of brain; highest reflection coefficient with sodium; mannitol second; some beneficial effect of hypertonic saline on inflammatory response; possible to reverse herniation with hypertonic saline

Hemicraniectomy: not well studied in intracranial hemorrhage population; some trials indicate benefit for young patients with large hemispheric strokes; data extrapolated to patients with large-volume hemorrhage at speaker’s institution

Suggested Readings


Acknowledgments

Dr. Minokadeh was recorded at University of California, San Diego, Anesthesiology Update 2016, held January 13-16, 2016, in San Diego, CA, and presented by the University of California, San Diego, School of Medicine, Department of Anesthesiology. For information about upcoming CME opportunities from the University of California, San Diego, School of Medicine, please visit cme.ucsd.edu. The Audio Digest Foundation thanks Dr. Minokadeh and the University of California, San Diego, School of Medicine for their cooperation in the production of this program.
PERIOPERATIVE NEUROLOGIC MANAGEMENT FOR THE CRITICALLY ILL PATIENT

1. Which of the following arteries is the most common location for aneurysmal rupture?
   (A) Anterior communicating artery
   (B) Posterior communicating artery
   (C) Middle cerebral artery
   (D) Posterior cerebral artery

2. A high Hunt and Hess grade corresponds with a neurologic examination that indicates a _______ prognosis, and a higher Fisher scale corresponds with radiography indicating a _______ prognosis.
   (A) Good; good
   (B) Good; poor
   (C) Poor; good
   (D) Poor; poor

3. What percentage of patients with subarachnoid hemorrhage experience rebleeding?
   (A) 6%
   (B) 14%
   (C) 26%
   (D) 42%

4. Which of the following time periods represents the peak incidence of vasospasm after subarachnoid hemorrhage?
   (A) 6 hr to 12 hr
   (B) 24 hr to 48 hr
   (C) 3 days to 14 days
   (D) 4 wk to 6 wk

5. Which of the following is the threshold Lindegaard ratio indicating risk for vasospasm?
   (A) ≥0.5
   (B) ≥1
   (C) ≥3
   (D) ≥5

6. Hemorrhagic strokes most commonly occur in which of the following areas?
   (A) Basal ganglia
   (B) Pons
   (C) Cerebellum
   (D) Brainstem

7. After an intracranial hemorrhage, cerebral edema reaches its maximum during which of the following time periods?
   (A) 12 hr to 24 hr
   (B) 24 hr to 48 hr
   (C) 2 days to 5 days
   (D) 7 days to 14 days

8. Which of the following volumes of hematoma is considered high risk?
   (A) ≥10 mL
   (B) ≥20 mL
   (C) ≥25 mL
   (D) ≥30 mL

9. Seizures occur in about one-third of patients with intracranial hemorrhage. What percentage of these seizures are nonconvulsive?
   (A) ≈10%
   (B) ≈25%
   (C) ≈50%
   (D) ≈66%

10. Which of the following cranial nerves is most affected by uncal herniation?
    (A) Cranial nerve II
    (B) Cranial nerve III
    (C) Cranial nerve IV
    (D) Cranial nerve V

Answers to Audio Digest Anesthesiology Volume 58, Issue 45: 1-B, 2-D, 3-D, 4-D, 5-D, 6-C, 7-D, 8-A, 9-A, 10-C

Attention, CME/CE Participants

The cutoff date for logging 2016 credits is December 31, 2016. Test forms received after that date will be accrued to 2017.