Subarachnoid hemorrhage (SAH) is defined as the presence of blood within the subarachnoid space between the arachnoid membrane and the pia mater. SAH may be categorized as traumatic or nontraumatic. Nontraumatic or spontaneous SAH accounts for 1 to 7% of all strokes; ~80 to 90% of the time they can be attributed to the rupture of a cerebral aneurysm. Approximately 5% of the population harbors an intracranial aneurysm, and 20 to 30% of this population will have multiple aneurysms. However, the vast majority of aneurysms never rupture. The annual incidence of spontaneous SAH is 2 to 25 per 100,000 people, and ~30,000 spontaneous SAHs occur in the United States per year. The peak age range for aneurysmal SAH is 50 to 60 years, and it is more common in women and blacks. Although it is unclear why, aneurysmal SAH occurs more commonly in the winter and spring (Table 1.1).

Previous SAH is one of the strongest predictors of SAH. Patients with previously ruptured aneurysms should undergo repair of additional unruptured aneurysms. The International Study of Unruptured Intracranial Aneurysms (ISUIA) addressed treatment of unruptured aneurysms detected in patients with and without previous SAH. In patients without a history of SAH, patients >50 years of age with large posterior circulation aneurysms are at the greatest risk for both rupture and repair complications (Table 1.2).

The decision whether to treat an unruptured aneurysm should involve a discussion of the risks of rupture and the risks and benefits associated with treatment. Considerations include aneurysm size and location, as well as the patient’s age and comorbidities. Often, patients without a history of SAH and with aneurysms <7 mm are observed and followed with serial imaging.
Table 1.1  Risk Factors for Aneurysm Formation

<table>
<thead>
<tr>
<th>Modifiable Risk Factors</th>
<th>Nonmodifiable Risk Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cigarette smoking (dose-dependent effect on aneurysm formation; the most important modifiable risk factor)</td>
<td>Previous SAH (new aneurysm formation rate 1–2% per year)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>Polycystic kidney disease</td>
</tr>
<tr>
<td>Moderate to heavy EtOH use</td>
<td>Connective tissue disease (Ehlers–Danlos syndrome, Marfan syndrome)</td>
</tr>
<tr>
<td>Cocaine use</td>
<td>Aortic coarctation</td>
</tr>
<tr>
<td>Endocarditis (mycotic aneurysm)</td>
<td>Pseudoxanthoma elasticum</td>
</tr>
<tr>
<td></td>
<td>Moyamoya disease</td>
</tr>
<tr>
<td></td>
<td>Arteriovenous malformation</td>
</tr>
<tr>
<td></td>
<td>Fibromuscular dysplasia</td>
</tr>
<tr>
<td></td>
<td>Dissection with pseudoaneurysm</td>
</tr>
<tr>
<td></td>
<td>Vasculitis</td>
</tr>
<tr>
<td></td>
<td>Neurofibromatosis 1</td>
</tr>
<tr>
<td></td>
<td>Glucocorticoid remediable</td>
</tr>
<tr>
<td></td>
<td>hyperaldosteronism</td>
</tr>
<tr>
<td></td>
<td>Family history (Japanese and Finnish cohorts. Familial intracranial aneurysm syndrome: Two 1st- to 3rd-degree relatives with intracranial aneurysms; 8% risk of having an unruptured aneurysm. These patients tend to have SAH at a younger age and have multiple aneurysms.)</td>
</tr>
</tbody>
</table>

Abbreviations: EtOH, ethyl alcohol; SAH, subarachnoid hemorrhage.

Table 1.2  Five-Year Rupture Risk for Patients with No History of Subarachnoid Hemorrhage Stratified by Aneurysm Location and Size

<table>
<thead>
<tr>
<th>Aneurysm Location</th>
<th>&lt;7 mm %</th>
<th>7–12 mm %</th>
<th>13–24 mm %</th>
<th>≥25 mm %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavernous carotid artery</td>
<td>0</td>
<td>0</td>
<td>3.0</td>
<td>6.4</td>
</tr>
<tr>
<td>ACOMM/MCA/ICA</td>
<td>0</td>
<td>2.6</td>
<td>14.5</td>
<td>40</td>
</tr>
<tr>
<td>PCOMM/posterior circulation</td>
<td>2.5</td>
<td>4.5</td>
<td>18.4</td>
<td>50</td>
</tr>
</tbody>
</table>

Abbreviations: ACOMM, anterior communicating artery; ICA, internal cerebral artery; MCA, middle cerebral artery; PCOMM, posterior communicating artery.

Case Example

A 56-year-old woman had a sudden onset of “the worst headache of my life and neck stiffness.” She had no known past medical history.

Questions

• What is the patient’s level of consciousness?
• Are there any focal deficits?
• When was the time of onset or when was the patient last seen at her baseline?
• Were there any sentinel headaches?
• Did the patient have a seizure at ictus?
• Is the patient taking any antiplatelet or anticoagulant medications?

Urgent Orders

• Check ABCs (airway, breathing, circulation—always address airway issues, particularly in the context of decompensated mental status)
• Order noncontrast head computed tomography (CT) scan
• Maintain blood pressure control (use nimodipine, and nicardipine or labetalol infusion if needed)
• Confirm infusion of anticonvulsant medication
• Consider antifibrinolytic therapy to prevent rebleeding if the time from SAH onset is <72 hours
• Reverse a coagulopathy, if present. (See chapter 4)

History and Examination

History

The most common presenting complaint is that of a severe headache. Often patients present with a warning or “sentinel” headache that precedes the “thunderclap” headache. Some patients complain of pain radiating down the legs; this is due to pooling of blood in the lumbar cistern and the irritation of nerve roots. Neck stiffness, photophobia, and meningeal symptoms occur. Diplopia (due to cranial nerve palsy) is also common. Loss of consciousness at ictus can occur due to a sudden rise in intracranial pressure (ICP) with a consequent
drop in cerebral perfusion pressure (CPP). This should be distinguished from seizure.

Twelve percent of those with SAH die before reaching medical attention. The misdiagnosis of SAH is thought to be as high as 12% (particularly in patients with mild symptoms). Because treatment is urgent and the consequences of misdiagnosis are severe, a high index of suspicion for SAH should be maintained.

**Physical Examination**

Kernig’s or Brudzinski’s sign may signify meningismus from SAH. Assess for external signs of trauma to evaluate for traumatic versus spontaneous SAH.

**Neurologic Examination**

- A full neurologic examination, including assessment of mental status, cranial nerves, motor skills, and reflexes, as well as a sensory and cerebellar examination, should be performed on all patients.
- Cranial nerve III compression classically occurs from an aneurysm of the posterior communicating artery, but it can also occur with posterior cerebral artery or superior cerebellar artery aneurysms. Uncal herniation causing pupillary dilatation, third nerve palsy, and deteriorating mental status is an ominous sign. Lateral rectus (6th nerve) palsy may signify an increased ICP, but it is generally nonlocalizing.
- Retinal examination: subhyaloid hemorrhages occur in 13% of SAH patients (Terson syndrome).
- The Hunt and Hess\(^6\) and the World Federation of Neurological Surgeons (WFNS) clinical grading scales for SAH are commonly employed. ([Table 1.3](#), [Table 1.4](#)).

### Differential Diagnosis

1. *Ruptured saccular cerebral aneurysm.* Ninety percent of aneurysms develop in the anterior circulation, most commonly the anterior communicating artery (ACOMM, 30%), the posterior communicating artery (PCOMM, 25%), the middle cerebral artery (MCA) bifurcation (20%), the internal carotid artery (ICA) bifurcation (8%), and 7% from other locations. Ten percent of aneurysms arise from the posterior circulation.
Table 1.3 Hunt and Hess Grading Scale for Subarachnoid Hemorrhage

<table>
<thead>
<tr>
<th>Grade</th>
<th>Clinical Examination</th>
<th>Associated Mortality %</th>
<th>Mean Glasgow Outcome Score†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Asymptomatic, mild headache, slight nuchal rigidity</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Cranial nerve palsy, moderate to severe headache, severe nuchal rigidity</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Mild focal deficit, lethargy, confusion</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Stupor, moderate to severe hemiparesis, early decerebrate rigidity</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Deep coma, decerebrate rigidity, moribund appearance</td>
<td>77</td>
<td>2</td>
</tr>
</tbody>
</table>

† See table 1.7

Table 1.4 World Federation of Neurological Surgeons Subarachnoid Grade

<table>
<thead>
<tr>
<th>Grade</th>
<th>GCS Score</th>
<th>Major Focal Deficit (Aphasia, Hemiparesis)</th>
<th>Associated Mortality %</th>
<th>Mean Glasgow Outcome Score†</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>–</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>13–14</td>
<td>–</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>13–14</td>
<td>+</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>7–12</td>
<td>+</td>
<td>33</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>3–6</td>
<td>±</td>
<td>77</td>
<td>2</td>
</tr>
</tbody>
</table>

Abbreviation: GCS, Glasgow Coma Scale.
† See table 1.7
2. Traumatic SAH. Typically convexity SAH, often accompanied by a clear history of trauma and other signs of injury such as orbital frontal contusions, skull fracture, or external scalp trauma.

3. Vascular malformation

- Arteriovenous malformation (AVM). AVMs are congenital malformations comprised of direct fistulas from arteries to veins without any intervening capillary bed. The interposed brain tissue is nonfunctional. Patients may present with SAH, intracerebral hemorrhage, intraventricular hemorrhage, seizures, headache, or neurologic deficits. The bleeding rate of an AVM is 2 to 4% per year, and the recurrent bleeding rate is 6 to 18% per year (highest during the first year after an initial bleed).\(^7\),\(^8\),\(^9\) The lifetime risk of hemorrhage is 105 minus the patient’s age (in years).\(^10\) Risk factors for rupture include previous rupture, high pressure over the malformation, small nidus, deep brain location, intranidal or feeding artery aneurysms, deep venous drainage, and venous occlusions. Patients with no risk factors have a bleeding rate as low as 0.9% annually.\(^11\) Repair options include embolization with subsequent resection or gamma knife obliteration (for lesions <3 cm). The Spetzler–Martin AVM grading scale assesses surgical risk.\(^12\) Grading is based on size, location, and venous drainage pattern: <3 cm = 1 point, 3 to 6 cm = 2 points, >6 cm = 3 points; eloquent location = 1 point, noneloquent location = 0 point; deep venous drainage = 1 point, superficial venous drainage = 0 point. Increasing points correlate with a higher surgical risk for resection.

- Cavernous malformations are vascular lesions with closely spaced sinusoidal vessels lacking a smooth muscle layer and without interspaced neural tissue. They appear as “popcorn-like” lesions on gradient echo magnetic resonance imaging (MRI) with differing ages of blood products. The annual bleeding rate is 0.25 to 1.1% in the anterior circulation with a rebleed rate of 4.5% per year.\(^13\) The annual bleeding rate for posterior fossa cavernous malformations is 2 to 3% with a 17 to 21% rebleed rate.\(^14\) The high rate of rebleeding for posterior fossa lesions may be related to a higher likelihood of symptoms from small bleeds in very eloquent tissue. Cavernous malformations are angiographically occult, but they may be associated with developmental venous anomalies.
4. Intracranial dissection with pseudoaneurysm rupture

5. Vasculopathy-related SAH. Vasculopathy may present with multiple strokes, cognitive changes, psychiatric symptoms, seizure, headache, and rarely SAH. Etiologies include primary central nervous system (CNS) angiitis, polyarteritis nodosa, Churg–Strauss syndrome, Wegener’s granulomatosis, lupus, cryoglobulinemia, Kawasaki disease, bacterial meningitis, viral infections (hepatitis B and C, cytomegalovirus [CMV], Epstein–Barr virus [EBV], parvovirus B19, varicella, and human immunodeficiency virus [HIV]), syphilis, CNS tuberculosis, drug-induced vasculopathy (e.g. SSRI), and cocaine- and methamphetamine-induced vasculopathy.

6. Oncotic aneurysm rupture

7. Endocarditis with mycotic aneurysm rupture (typically distal fusiform artery aneurysms; may be accompanied by vasculitis).

8. Meningitis/encephalitis. Can be mistaken for SAH with symptoms of headache and meningeal findings. Look for fever, lumbar puncture results.

9. Thunderclap headache and benign coital headache

Life-Threatening Diagnoses Not to Miss

- Aneurysmal SAH
- Dissection with pseudoaneurysm rupture
- Endocarditis with mycotic aneurysm rupture
- Meningitis/encephalitis

Diagnostic Evaluation

- Imaging studies.
  - Noncontrast CT scan. SAH is radiographically visible in 90% of patients within 24 hours of ictus, but the sensitivity of CT drops to 60% 5 days after ictus.\(^\text{15}\) The thickness of SAH clot and the presence of intraventricular hemorrhage (IVH) both predict the risk of vasospasm. The modified Fisher scale
incorporates the risk of vasospasm due to both SAH and IVH into its grading system (Table 1.5, Fig. 1.1).16,17,18

- **Cerebral angiogram.** Gold standard for ruling out a ruptured cerebral aneurysm, for defining the relevant neuroanatomy, and possibly providing immediate endovascular treatment. Fifteen to 20% of SAH patients have negative angiograms. Repeat angiography detects an abnormality in 1 to 2%.19
- **CT angiography (CTA).** >5 mm aneurysm = 95 to 100% sensitive, <5 mm aneurysm = 64 to 83% sensitive.20,21
- **Magnetic resonance angiography (MRA).** >5 mm aneurysm = 85 to 100% sensitive, <5 mm aneurysm = 56% sensitive.22
- **Lumbar puncture.** A lumbar puncture must be performed if the history is suspicious for SAH and the head CT is negative. Always check an opening pressure. Look for clearing of blood between

**Table 1.5 Modified Fisher and Fisher Grading Scale for Subarachnoid Hemorrhage**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Modified Fisher</th>
<th>% with Vasospasm</th>
<th>Fisher</th>
<th>% with Vasospasm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No SAH or IVH</td>
<td>—</td>
<td>No SAH or IVH</td>
<td>21</td>
</tr>
<tr>
<td>1</td>
<td>Thin SAH, no IVH</td>
<td>24</td>
<td>Focal or diffuse, thin SAH</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>Thin SAH with IVH</td>
<td>33</td>
<td>Diffuse thick or localized clot +/− ICH or IVH</td>
<td>37</td>
</tr>
<tr>
<td>3</td>
<td>Thick SAH, no IVH</td>
<td>40</td>
<td>No or diffuse thin SAH + ICH or IVH</td>
<td>31</td>
</tr>
</tbody>
</table>

**Note:** ~1 mm vertical thickness as the cutoff between thin and thick.

**Abbreviations:** ICH, intracranial hemorrhage; IVH, intraventricular hemorrhage; SAH, subarachnoid hemorrhage.

Fig. 1.1  (A) Fisher\textsuperscript{18} and modified (B)\textsuperscript{15,16} Fisher computed tomography (CT) rating scales. The percentage of patients who developed symptomatic vasospasm is listed next to each grade. ICH, intracerebral hemorrhage; IVH, intraventricular hemorrhage; SAH, subarachnoid hemorrhage.
tubes 1 and 4 and spin for xanthochromia (may not be present within 12 hours of ictus, but it remains for ~2 weeks).

- **Laboratory studies.** Perform toxicology screen in at-risk populations.

### Treatment

#### Secure the Aneurysm

- **Open microsurgical or endovascular methods.** The optimal method for each patient should be individualized based on several factors, including: (1) aneurysm morphology, (2) patient characteristics, and (3) the experience of the treating facility. Early treatment is recommended to decrease the 67% mortality rate that is associated with rebleeding.23

- **The International Subarachnoid Aneurysm Trial (ISAT)** randomized 2143 spontaneous SAH patients to clipping versus coiling within 28 days of SAH onset. The majority of patients were World Federation of Neurological Surgeons (WFNS) grade 1–2; 97% had anterior circulation aneurysms, and most aneurysms were <10 mm. At 1 year, 24% of endovascular treated patients had disability or death (modified Rankin Scale 3–6) compared with 31% of surgically treated patients \((p = .0019)\). At 7-year follow-up, the mortality was significantly higher in the surgical group \((p = .03)\), and seizure rates were higher in the surgical group. The early rebleeding risk (up to 30 days after the initial procedure) was higher with endovascular repair, but at 7 years the rebleeding rates between the two groups was similar.24,25

#### Manage Complications of SAH

- **Rebleeding.** There is a 3–4% risk of rebleeding during the first 24 hours, 2% risk the second day, and 0.3% risk each subsequent day, or a 15 to 20% rebleeding risk within the first 2 weeks and up to 50% risk during the first 6 months if the aneurysm is not repaired.26 Rebleeding is the most treatable cause of poor outcome after SAH. Risk factors for rebleeding include aneurysm size, the severity of the initial bleed, elevated blood pressure (which may
be causative or secondary to the rebleeding), seizure, loss of consciousness at ictus, sentinel bleed, and the presence of intracranial hemorrhage (ICH) or IVH. Although placement of an external ventricular drain (EVD) may change the pressure dynamics of an aneurysm leading to rebleeding, this is a rare complication, and an EVD should nonetheless be placed if it is indicated.

- **Prevention of rebleeding.** The only definitive method to prevent rebleeding is to secure the aneurysm by excluding it from the intracranial circulation by neurosurgical clipping or endovascular obliteration. Antifibrinolytics (epsilon-aminocaproic acid: 4 mg intravenous (IV) load, then 1 g/hour continuous infusion or tranexamic acid: 1 g IV loading dose then 1 g every 6 hours until aneurysm occlusion) have been used to reduce the incidence of early rebleeding when early definitive treatment is not available. In some studies, these medications have reduced rebleeding from 10 to 2%.27 Because antifibrinolytics can cause vasospasm, their use should be limited to within 72 hours of ictus (prior to typical vasospasm onset period) and should not be used in patients with coagulopathies, history of myocardial infarction (MI), ischemic stroke, pulmonary embolism (PE), or deep vein thrombosis (DVT). Blood pressure lowering to a systolic blood pressure (SBP) of 140 to 160 mm Hg is reasonable prior to securing the aneurysm and is usually done with a titratable drip such as nicardipine or labetalol. Seizure prophylaxis prior to aneurysm repair is reasonable since seizures have been associated with rebleeding in unsecured aneurysms.

- **Hydrocephalus** is associated with worse clinical grade and increased blood on CT. It occurs in 15% of patients radiographically, 40% of whom are symptomatic. Temporary cerebrospinal fluid (CSF) diversion is achieved by external ventricular drainage (EVD). Typical indications for EVD include ventriculomegaly on CT with symptoms of hydrocephalus, a noncommand following exam, and suspicion of elevated ICP. Most EVDs are set to drain at 15 to 20 cm H2O initially with a goal ICP of <20 mm Hg. Forty to 80% of patients have some improvement in exam with EVD placement. Patients who undergo surgical clipping of their aneurysm may also be treated with a third ventriculostomy, which may ameliorate hydrocephalus. A ventriculoperitoneal shunt is needed in roughly 30%.28,29

- **Elevated ICP** can be treated initially with CSF diversion, mannitol 20% 1 g/kg IV bolus or 23% saline IV push (30 cc over 10 to 20 minutes via a central line; see Chapter 15).
• **Seizures** occur in 10% of patients at ictus, 4% during hospital stay, and another 7% have late seizures. Risk factors include ICH, MCA aneurysm, hypertension (HTN), and infarct. All patients who have seizures should receive anticonvulsants. Prior to securing an aneurysm, antiepileptic prophylaxis is reasonable because seizures can lead to aneurysm rebleeding. Many practitioners treat patients who have not seized for a period of 7 days to prevent early seizure. Some data have shown that patients exposed to phenytoin have worse cognitive outcomes at 3 months, although eventually these patients slowly recover to the level of those not exposed once anticonvulsants are discontinued.\(^{30}\) Phenytoin has been the anticonvulsant traditionally used; however, newer generations of anticonvulsants are undergoing evaluation.

• **Hyponatremia** is commonly seen in SAH patients; it was originally thought to be secondary to the syndrome of inappropriate antidiuretic hormone (SIADH), but is most often due to cerebral salt wasting (CSW). CSW has been postulated to be related to neural humoral control of atrial natriuretic factor (ANF) and brain natriuretic peptide (BNP). SIADH results from excess release of antidiuretic hormone (ADH), which acts at the distal collecting duct of the nephron. Differentiation between SIADH and CSW can be determined by volume status because SIADH is associated with normovolemia/hypervolemia, whereas CSW results in volume depletion. Urine output that exceeds input in SAH patients should alert physicians to the possibility of CSW. Sodium should be monitored every 6 to 12 hours and urine output replaced such that “ins” and “outs” are matched.

  - Sodium supplementation can be administered by oral salt tablets (3 to 9 g/day), hypertonic saline (2 or 3% saline infusion), or fludrocortisone acetate (2 mg by mouth [PO] or IV twice daily [b.i.d.]). Rapid overcorrection may result in central pontine myelinolysis (CPM), although this is rare in patients with hyponatremia for less than 24 hours. Avoid overcorrection by not exceeding 8 meq/24 hours in patients who are chronically hyponatremic. Fluid restriction of SAH patients should be strictly avoided because this has been shown to exacerbate the development of infarcts related to vasospasm. Avoid \(\frac{1}{2}\) normal saline (NS) or 5% dextrose in water (D5W) IV fluids. Conivaptan, an inhibitor of vasopressin V1a and V2 receptors, can be used to treat SIADH.
• **Vasospasm** typically occurs between days 3 to 14 after ictus, but timing can be variable. Symptomatic vasospasm occurs in 20 to 40% of patients and is defined as a clinical deterioration due to vasospasm when other causes (seizure, hydrocephalus, edema, etc.) have been excluded. Angiographic vasospasm occurs in 30 to 70% of patients, but its significance is unclear. Delayed cerebral ischemia is defined as symptomatic vasospasm or new infarct on CT or MRI due to vasospasm. Risk factors for vasospasm include poor clinical grade, thick blood on CT (SAH and IVH), fever, admission hypertension, sentinel bleed, ultra-early angiographic spasm, volume depletion, low cardiac output, and smoking.

• Diagnosing vasospasm:
  - Cerebral angiography is the gold standard.
  - Transcranial Doppler ultrasound (TCD) shows elevated velocities that may precede clinical symptoms by 24 to 48 hours. An inability to insonate intracranial vessels occurs in ~10% of patients. For angiographic spasm, the positive predictive value of MCA mean flow velocity (MFV) > 200 cm/s is 87%, and the negative predictive value for MCA MFV < 120 cm/s is 94%. However, the predictive value in other territories, such as the ACA, is poor, and the association of TCD velocities and symptomatic vasospasm is limited. The Lindegaard ratio corrects the MFV for hyperemia (due to increased cardiac output, pressor use, or anemia) and is defined as the MCA/ICA velocity (Table 1.6).

<table>
<thead>
<tr>
<th>Lindegaard Ratio</th>
<th>Angiographic Vasospasm</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3</td>
<td>No spasm</td>
</tr>
<tr>
<td>3–4.5</td>
<td>Mild spasm</td>
</tr>
<tr>
<td>4.5–6</td>
<td>Moderate spasm</td>
</tr>
<tr>
<td>&gt;6</td>
<td>Severe spasm</td>
</tr>
</tbody>
</table>

TCD is typically performed on a daily basis and serves to indicate which patients may require closer observation for impending symptomatic vasospasm/ischemia. Treatment for vasospasm should not be initiated based on TCD values: patients should be maintained in a normovolemic state, and if symptoms of vasospasm/ischemia develop, further evaluation and treatment should be initiated. In patients with marginal exams in whom it is difficult to detect symptomatic spasm, additional testing such as digital subtraction angiography, CT or MR angiography may be useful when TCD velocities are elevated or increasing. Hypercalcemia can cause or exacerbate vasospasm and should be avoided or corrected. TCD does have a reasonable negative predictive value for angiographic and symptomatic spasm.

- Alternatively, CT angiography/CT perfusion, MR perfusion, MRA, xenon CT, and single-photon emission computed tomography (SPECT) scan can be used to detect vasospasm/ischemia. These modalities may be particularly useful for detecting small vessel distal spasm.

- **Vasospasm prophylaxis:**
  - Nimodipine is the only medication proven in large trials to improve outcome after SAH. In a meta-analysis of 10 studies, nimodipine reduced death or severe disability, symptomatic vasospasm, and CT-documented infarction from vasospasm. However, nimodipine does not reduce rates of angiographic vasospasm.\(^{33,34}\)

  Nimodipine is given for 21 days and typically dosed as 60 mg every 4 hours for SBP > 140 mm Hg, 30 mg every 4 hours for SBP 120 to 140 mm Hg, and held for an SBP < 120 mm Hg.

  - Fever is associated with the development of symptomatic spasm and should be controlled aggressively.
  - Volume-depleted patients are at increased risk for symptomatic vasospasm, and normovolemia should be maintained.
  - Prophylactic hypervolemic-hypertensive-hemodilution (HHH) therapy (in those *without* symptoms of vasospasm) has not been shown to reduce rates of symptomatic vasospasm or improve outcome and is not recommended.

- **Treatment of symptomatic vasospasm:**
  - HHH therapy is typically employed by elevating blood pressure with either phentolamine or norepinephrine to at least
20 mm Hg above baseline blood pressure to a maximum pressure of 220/120 mm Hg. Pressor use can be limited by the development of end organ damage (myocardial infarction, congestive heart failure [CHF], renal insufficiency, digital ischemia, etc.). Patients similarly receive volume in the form of normal saline or colloid. Hemodilution using phlebotomy is typically not used. There are no randomized trials proving the efficacy of HHH therapy, and certain studies have questioned the value of hypervolemia.35

Endovascular treatment of vasospasm can reverse symptoms of delayed cerebral ischemia (DCI) in 30 to 70% of patients. Options include intra-arterial vasodilators such as papaverine, verapamil, and nicardipine, or angioplasty. Vasodilators are short-lived, and angioplasty has a more durable effect but also carries the risk of vessel rupture. Endovascular treatment is most successful if performed early, preferably within 2 hours of symptom onset.36

Sample Admission Order Set for SAH

- Prescribe fosphenytoin 20 mg/kg IV load, then phenytoin 100 mg IV every 8 hours.
- Prescribe nimodipine 60 mg PO every 4 hours for SBP ≥140, 30 mg for SBP 120 to 140, hold for SBP ≤120 mm Hg.
- Keep SBP between ≤160 mm Hg with labetalol drip or Cardene (Roche Laboratories, Inc., Nutley, NJ) drip (avoid nitroprusside, as this can raise ICP) and ≥90 mm Hg with norepinephrine or phenylephrine 2 to 10 mg/kg/min as needed.
- Assess need for aminocaproic acid (Wyeth-Ayerst Pharmaceuticals, Radnor, PA) administration if prior to SAH day 3 and aneurysm treatment will be delayed >12 hours and no history of stroke, MI, peripheral vascular disease (PVD), or abnormal electrocardiogram (EKG).
  - Give 4 g IV over first hour, then 1 g IV every hour; hold aminocaproic acid 1 to 3 hours prior to angiogram.
- Order noncontrast head CT; consider CT angio/CT perfusion.
- Assess for hydrocephalus; consider EVD.
- Schedule cerebral angiogram. In patients with renal insufficiency, preangiogram treatment with hydration (NS at 1 mL/kg/h) before and after the angiogram can be nephroprotective. Some advocate acetylcysteine (600 mg PO b.i.d. x 2 days).
Prognosis

Major predictors of outcome include Hunt–Hess grade, age, aneurysm size, and rebleeding. Overall, approximately 10% of patients die before reaching the hospital, and 65% have some cognitive impairment. There are several causes of poor outcome following SAH. These include, in order of decreasing importance: (1) deleterious effects on the brain of the initial bleed; (2) aneurysm rerupture; (3) cerebral vasospasm; (4) hydrocephalus; and (5) hyponatremia, seizures, and other causes. Two commonly used measures of outcome are the Glasgow Outcome Score (Table 1.7) and the Modified Rankin Scale (mRS) (Table 1.8).

Table 1.7 Glasgow Outcome Score

<table>
<thead>
<tr>
<th>Glasgow Outcome Score</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dead</td>
</tr>
<tr>
<td>2</td>
<td>Persistent vegetative state</td>
</tr>
<tr>
<td>3</td>
<td>Severe disability, conscious but limited communication skills, dependent for daily activities of living</td>
</tr>
<tr>
<td>4</td>
<td>Independent but with disabilities; able to work</td>
</tr>
<tr>
<td>5</td>
<td>Resumption of normal life despite minor physical or mental deficits</td>
</tr>
</tbody>
</table>


Table 1.8 Modified Rankin Scale

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No symptoms at all</td>
</tr>
<tr>
<td>1</td>
<td>No significant disability despite symptoms; able to carry out all usual duties and activities</td>
</tr>
<tr>
<td>2</td>
<td>Slight disability; unable to carry out all previous activities, but able to look after own affairs without assistance</td>
</tr>
<tr>
<td>3</td>
<td>Moderate disability; requiring some help, but able to walk without assistance</td>
</tr>
</tbody>
</table>

(Continued)
Pearls and Pitfalls

- All practitioners should maintain a high index of suspicion for subarachnoid hemorrhage, even when the initial CT is negative. A lumbar puncture should be performed to assess for CSF xanthochromia in CT-negative patients.
- Early treatment of a ruptured aneurysm is strongly recommended to prevent the mortality and morbidity associated with rerupture.
- Symptomatic vasospasm is a significant contributor to morbidity and must be treated early and aggressively.

References

1. Stehbens WE. Aneurysms and anatomical variation of cerebral arteries. Arch Pathol 1963;75:45–64