

# Spontaneous Spinal Cerebrospinal Fluid Leaks and Intracranial Hypotension

Wouter I. Schievink, MD

**A** PATIENT PRESENTS WITH A new headache that occurs shortly after assuming an upright position and is relieved by lying down. Although such a positional headache pattern is well-known following a diagnostic lumbar puncture, the spontaneous onset of an orthostatic headache is not well recognized and the patient may be diagnosed with migraine, tension headache, viral meningitis, or malingering. This has been a typical scenario for many patients experiencing spontaneous intracranial hypotension.<sup>1</sup> The spontaneous form of intracranial hypotension was first described in 1938,<sup>2</sup> and much has been learned about this syndrome, particularly since the early 1990s,<sup>3-15</sup> but an initial misdiagnosis remains the norm. Unfamiliarity with spontaneous intracranial hypotension among physicians in general and the unusually varied spectrum of clinical and radiographic manifestations may all contribute to a delay in diagnosis that often is measured in months or even years and decades.<sup>1</sup>

## EVIDENCE ACQUISITION

The material covered in this review is based on a systematic review of journal articles in MEDLINE (1966-2005) and OLDMEDLINE (1950-1965) using the terms *intracranial hypotension*, *CSF leak*, *low pressure headache*, and *CSF hypovolemia*. Reference lists of these articles and ongoing investigations in this area

See also Patient Page.

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**Context** Spontaneous intracranial hypotension is caused by spontaneous spinal cerebrospinal fluid (CSF) leaks and is known for causing orthostatic headaches. It is an important cause of new headaches in young and middle-aged individuals, but initial misdiagnosis is common.

**Objective** To summarize existing evidence regarding the epidemiology, pathophysiology, diagnosis, and management of spontaneous spinal CSF leaks and intracranial hypotension.

**Evidence Acquisition** MEDLINE (1966-2005) and OLDMEDLINE (1950-1965) were searched using the terms *intracranial hypotension*, *CSF leak*, *low pressure headache*, and *CSF hypovolemia*. Reference lists of these articles and ongoing investigations in this area were used as well.

**Evidence Synthesis** Spontaneous intracranial hypotension is caused by single or multiple spinal CSF leaks. The incidence has been estimated at 5 per 100 000 per year, with a peak around age 40 years. Women are affected more commonly than men. Mechanical factors combine with an underlying connective tissue disorder to cause the CSF leaks. An orthostatic headache is the prototypical manifestation but other headache patterns occur as well, and associated symptoms are common. Typical magnetic resonance imaging findings include subdural fluid collections, enhancement of the pachymeninges, engorgement of venous structures, pituitary hyperemia, and sagging of the brain (mnemonic: SEEPS). Myelography is the study of choice to identify the spinal CSF leak. Treatments include bed rest, epidural blood patching, percutaneous placement of fibrin sealant, and surgical CSF leak repair, but outcomes have been poorly studied and no management strategies have been studied in properly controlled randomized trials.

**Conclusions** Spontaneous intracranial hypotension is not rare but it remains underdiagnosed. The spectrum of clinical and radiographic manifestations is varied, with diagnosis largely based on clinical suspicion, cranial magnetic resonance imaging, and myelography. Numerous treatment options are available, but much remains to be learned about this disorder.

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also were used. Clinical trials were not available, and prospective studies were selected over retrospective studies. Selected articles were largely those published within the past 10 years and having adequate documentation and relevant clinical information, but older articles were also included if they were commonly referenced and highly regarded.

## EVIDENCE SYNTHESIS

### Epidemiology

Once considered an exceedingly rare disorder, recent evidence suggests that

spontaneous intracranial hypotension is not that rare and has to be considered an important cause of new daily persistent headaches, particularly among young and middle-aged individuals. In the past, our knowledge re-

**Author Affiliation:** Maxine Dunitz Neurosurgical Institute, Cedars-Sinai Medical Center, Los Angeles, Calif. **Corresponding Author:** Wouter I. Schievink, MD, Maxine Dunitz Neurosurgical Institute, Cedars-Sinai Medical Center, 8631 W Third St, Suite 800E, Los Angeles, CA 90048 ([schievinkw@cshs.org](mailto:schievinkw@cshs.org)). **Clinical Review Section Editor:** Michael S. Lauer, MD. We encourage authors to submit papers for consideration as a Clinical Review. Please contact Michael S. Lauer, MD, at [lauer@ccf.org](mailto:lauer@ccf.org).

garding spontaneous intracranial hypotension was derived from case reports only, and no epidemiologic data were available. In a community-based study conducted in 1994, the prevalence of spontaneous intracranial hypotension was estimated at 1 per 50 000.<sup>16</sup> In a more recent emergency department-based study (2003-2004),<sup>17</sup> spontaneous intracranial hypotension was half as common as spontaneous subarachnoid hemorrhage, for an estimated annual incidence of 5 per 100 000.

Comprehensive population-based epidemiologic studies, however, are not yet available. In the past, spontaneous intracranial hypotension was probably more frequently underdiagnosed than it is now, and it is unlikely that there has been an actual increase in its incidence, although that possibility cannot be entirely excluded.

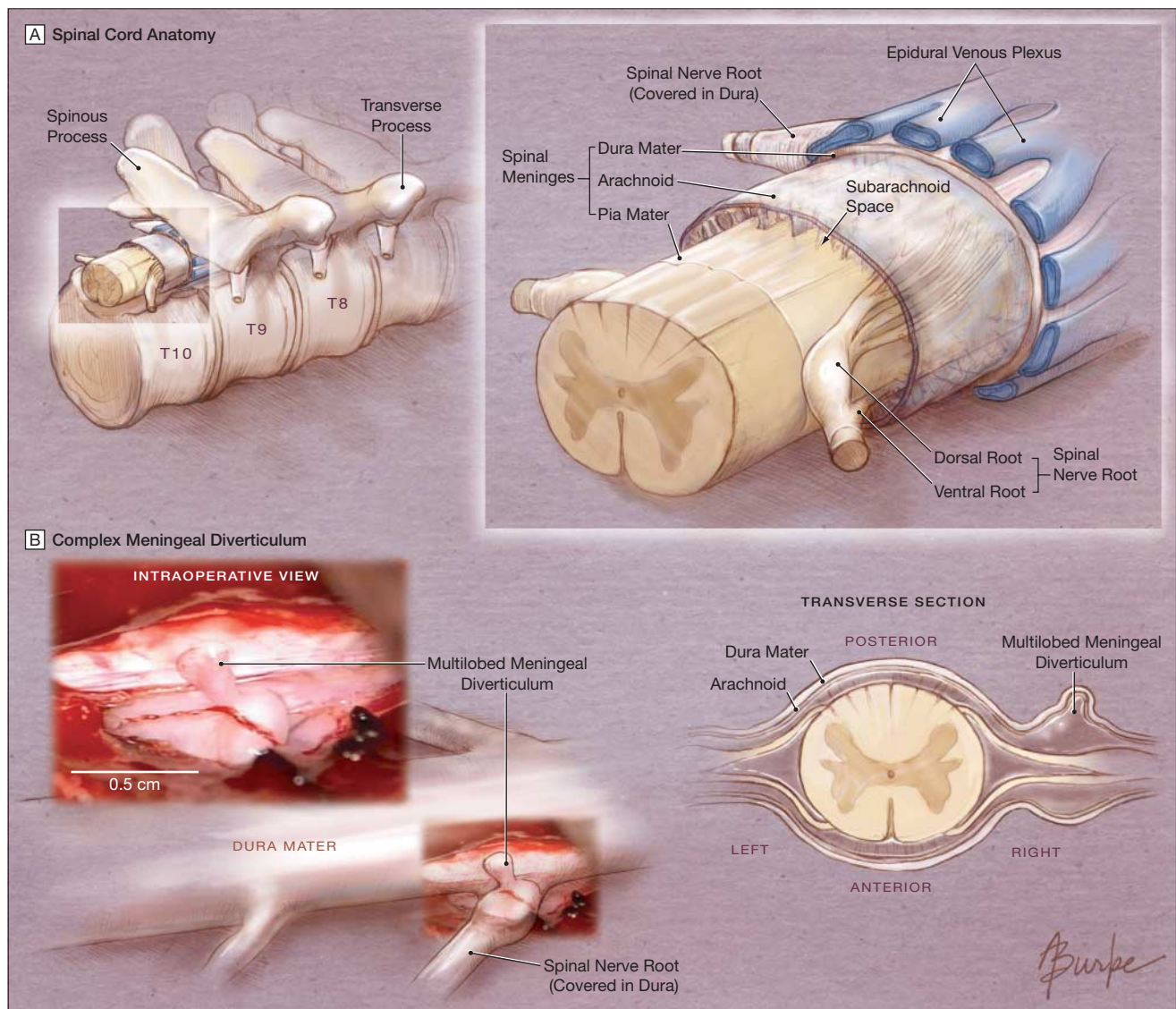
Spontaneous intracranial hypotension affects women more frequently than men, with a female-male ratio of approximately 2:1.<sup>1-16</sup> Onset of

symptoms typically is in the fourth or fifth decade of life, with a peak incidence around age 40 years, but children and elderly persons also may be affected.<sup>1-16</sup>

**Etiology and Pathogenesis**

Spontaneous intracranial hypotension is caused by spontaneous spinal cerebrospinal fluid (CSF) leaks. Because spinal CSF leaks generally do not cause any local symptoms, they remain undetected unless actively

**Figure 1.** Spinal Cord Anatomy and Intraoperative Photograph With Corresponding Line Drawing of a Complex Meningeal Diverticulum Arising From a Thoracic Nerve Root Sleeve in a 27-Year-Old Woman



**Box 1. Connective Tissue Disorders Associated With Spontaneous Spinal Cerebrospinal Fluid Leaks and Intracranial Hypotension**

**Named Syndromes**

Marfan syndrome  
Ehlers-Danlos syndrome type II  
Autosomal dominant polycystic kidney disease

**Unnamed Syndromes/Associations**

Isolated skeletal features of Marfan syndrome  
Isolated joint hypermobility  
Joint hypermobility with fascial thinning  
Spontaneous retinal detachment

looked for in a patient suspected of spontaneous intracranial hypotension. Also, unlike CSF rhinorrhea or otorrhea, there is no risk of meningitis because the CSF is directly absorbed into the sterile spinal epidural venous plexus or paraspinal soft tissues and is therefore not exposed to the external milieu.

The precise cause of spontaneous spinal CSF leaks remains largely unknown, but an underlying structural weakness of the spinal meninges generally is suspected.<sup>11</sup> A history of a more or less trivial traumatic event preceding the onset of symptoms can be elicited in about one third of patients, suggesting a role for mechanical factors as well.<sup>4,18,19</sup> The dural weakness predisposes to the formation of dural defects that allow CSF to leak into the epidural space. A wide variety of dural defects may be observed at the time of surgery, ranging from simple dural holes or rents to complex fragile meningeal diverticula or even complete absence of the dura that normally covers the spinal nerve root (FIGURE 1).<sup>11,16,20,21</sup> The volume of the CSF leak is quite variable as well, ranging from a minimal amount of seeping CSF only detectable when applying a Valsalva maneu-

ver to large amounts of CSF spontaneously pouring out into the paraspinal soft tissues.

There is good evidence to suggest that a generalized connective tissue disorder plays a crucial role in the development of spontaneous spinal CSF leaks. First reported in 1994,<sup>20</sup> this association has been confirmed by numerous subsequent studies.<sup>11,22-25</sup> Based on physical examination alone, evidence for an underlying generalized connective tissue disorder is found in about two thirds of patients.<sup>25</sup> This group of disorders is heterogeneous, possibly affecting different components of the dural extracellular matrix (BOX 1). Isolated joint hypermobility is found in approximately two fifths of patients with spontaneous intracranial hypotension and may be associated with attenuation of the dorsal muscular fascia, complicating surgical wound closure.<sup>25</sup> Approximately one fifth of patients with spontaneous intracranial hypotension have subtle skeletal manifestations of Marfan syndrome, such as tall stature, arachnodactyly, highly arched palate, and joint hypermobility, but none of the other stigmata of the syndrome.<sup>20,22,23,25</sup> These patients do not harbor mutations in the Marfan syndrome gene (*FBNI*) encoding fibrillin 1, but a defect of microfibrils, important components of the extracellular matrix associated with fibrillin, has been demonstrated.<sup>22,23</sup> Less frequently, spontaneous intracranial hypotension occurs in well-characterized, generalized connective tissue disorders such as Marfan syndrome,<sup>26-29</sup> Ehlers-Danlos syndrome type II,<sup>25</sup> and autosomal dominant polycystic kidney disease.<sup>30</sup> Spinal meningeal diverticula also have been described in neurofibromatosis type 1<sup>31,32</sup> and Lehman syndrome.<sup>33,34</sup> Finally, some patients with spontaneous intracranial hypotension have a personal or family history of spontaneous retinal detachment at an early age, suggesting the presence of a generalized connective tissue disorder affecting both dura and retina.<sup>11</sup>

A distinct and uncommon cause of spontaneous intracranial hypotension not associated with a primary dural defect is the presence of osseous spinal pathology. A congenital osseous spur,<sup>35</sup> as well as acquired degenerative disk disease<sup>36-39</sup> piercing the dura, has been described.

Before precise imaging was able to detect the underlying spinal CSF leak, some authors speculated that spontaneous intracranial hypotension resulted from decreased CSF secretion or generalized CSF hyperabsorption, but there are no data to support such alternate mechanisms. It has been postulated that a decrease in CSF volume, rather than in CSF pressure, may be the final common pathway in the pathophysiology of spontaneous intracranial hypotension.<sup>40</sup> Therefore, "spontaneous CSF hypovolemia" has been introduced as an alternative term.<sup>40</sup> However, this is an oversimplification. For example, loss of CSF volume also occurs with spontaneous CSF rhinorrhea or otorrhea, but the typical imaging and clinical features of spontaneous intracranial hypotension rarely, if ever, occur under those circumstances. The final common pathway is probably not CSF hypovolemia but rather an altered distribution of craniospinal elasticity due to spinal loss of CSF,<sup>41</sup> and "spontaneous spinal CSF leak" is the preferred descriptive term.

**Clinical Presentation**

**Positional Headache.** The prototypical manifestation of spontaneous intracranial hypotension is an orthostatic headache. Such a headache generally occurs or worsens within 15 minutes of assuming the upright position, as reflected by the revised International Classification of Headache Disorders criteria (BOX 2),<sup>42</sup> but in some patients this lag period may be as long as several hours. Improvement of the headache after lying down is less variable and occurs within 15 to 30 minutes. The headache may be diffuse or localized to the frontal, temporal, or—most commonly—the occipital or sub-

occipital regions. The headache may be throbbing or nonthrobbing and is rarely unilateral. Some patients use descriptive terms for their headaches, such as the feeling of “an ice cube in an empty glass” or a “pulling sensation from my head down to my neck,” offering a clue to the diagnosis. Additional clues may be the patient’s recumbent position in the physician’s office or a pillow they carry along to allow them to lie down comfortably. The initial onset of headache generally is gradual or subacute, reaching maximal intensity in several minutes to hours, but it may be instantaneous.<sup>43</sup> Patients with such a “thunderclap” headache often will be suspected of having a subarachnoid hemorrhage and may undergo invasive testing, such as cerebral angiography. The severity of the headache varies widely; many mild cases probably remain undiagnosed, whereas other patients are incapacitated and unable to engage in any useful activity while upright.

The headache is a direct result of the downward displacement of the brain due to loss of CSF buoyancy, causing traction on pain-sensitive structures, particularly the dura. An alternative mechanism involves compensatory dilation of the pain-sensitive intracranial venous structures.

It should be noted that not all orthostatic headaches are caused by spontaneous spinal CSF leaks, and other diagnoses should be considered.<sup>44,45</sup>

**Other Headache Patterns.** Although a postural headache is the clinical hallmark of spontaneous intracranial hypotension, it is well known that the posture-related component often, but not invariably, becomes less prominent or even disappears over time when the underlying spinal CSF leak remains untreated.<sup>11</sup> Rarely, the reverse occurs with a nonpositional headache preceding a typical orthostatic headache. Some patients have no posture-related component to their headache from the onset,<sup>46,47</sup> while others report exertional headaches,<sup>48</sup> headaches that mainly occur at the end of the day, or even paradoxical headaches that worsen

**Box 2. Diagnostic Criteria for Headache Due to Spontaneous Spinal CSF Leak and Intracranial Hypotension According to the International Classification of Headache Disorders, 2nd Ed<sup>42</sup>**

- A. Diffuse and/or dull headache that worsens within 15 minutes after sitting or standing, fulfilling criterion D and with  $\geq 1$  of the following:
  1. Neck stiffness
  2. Tinnitus
  3. Hypacusia
  4. Photophobia
  5. Nausea
- B. At least 1 of the following:
  1. Evidence of low CSF pressure on MRI (eg, pachymeningeal enhancement)
  2. Evidence of CSF leakage on conventional myelography, CT myelography, or cisternography
  3. CSF opening pressure  $< 60$  mm H<sub>2</sub>O in sitting position
- C. No history of dural puncture or other cause of CSF fistula
- D. Headache resolves within 72 hours after epidural blood patching

Abbreviations: CSF, cerebrospinal fluid; CT, computed tomography; MRI, magnetic resonance imaging.

when lying down.<sup>49,50</sup> Intermittent headaches, presumably caused by intermittent spinal CSF leaks, may occur at intervals of weeks, months, or even years. Finally, some patients deny having any headache, usually when other symptoms of spontaneous intracranial hypotension predominate the clinical picture.

Because of the wide variety of headache patterns, magnetic resonance imaging (MRI) should be considered for all patients with unexplained headache to evaluate for spontaneous intracranial hypotension. A differential diagnosis of headache due to spontaneous intracranial hypotension is provided in the TABLE.

**Miscellaneous Symptoms.** In addition to headaches, a wide variety of other symptoms have been reported in spontaneous intracranial hypotension. Posterior neck pain or stiffness, nausea, and vomiting are the most common, being reported by approximately 50% of patients, and suggest meningeal irritation, particularly when photophobia or phonophobia also is present.<sup>1,11,12</sup> The next most common symptom is a change in hearing, which may be described as “echoing” or as “being underwater” and may be

associated with tinnitus or a disturbed sense of balance. These symptoms may be explained by direct transmission of the abnormal CSF pressure to that in the perilymph.<sup>51</sup> Alternatively, downward displacement of the brain may cause stretching of the eighth nerve complex (cochlear and vestibular nerves). This latter mechanism may also explain other manifestations of spontaneous intracranial hypotension, such as visual blurring or visual field defects (optic nerve or chiasm), diplopia (abducens or, rarely, trochlear and oculomotor nerves), facial numbness or pain (trigeminal nerve), facial weakness or spasm (facial nerve), and dysgeusia (chorda tympani or glossopharyngeal nerve).<sup>11,12,52-55</sup> Distortion of the pituitary stalk has been implicated as a cause of hyperprolactinemia and galactorrhea associated with spontaneous intracranial hypotension.<sup>56</sup> Severe displacement of the brain may even result in a decreased level of consciousness due to diencephalic herniation. Although uncommon, numerous well-documented cases have now been reported from around the world, and spontaneous intracranial hypotension should be considered in the differential diagnosis of stupor and coma, par-

ticularly in otherwise healthy young and middle-aged adults.<sup>57-62</sup> Other rare manifestations of spontaneous intracranial hypotension include parkinsonism, ataxia, and cerebellar hemorrhage.<sup>50,63</sup> Dementia is a rare complication of spontaneous intracranial hypotension,<sup>64</sup> but subtle cognitive deficits are not rare and often are not recognized until cognition improves following successful treatment of the spinal CSF leak. Spinal manifestations include interscapular pain or, rarely, local back pain at the site of the CSF leak; quadriplegia; and radicular symptoms due to stretching of cervical spinal nerve roots or dilation of the epidural venous plexus.

**Diagnosis**

**Cranial MRI.** Magnetic resonance imaging has revolutionized the under-

standing of spontaneous intracranial hypotension and has greatly facilitated the ability to arrive at the diagnosis with confidence without having to resort to invasive procedures, such as spinal puncture or intracranial pressure monitoring. Recognition of the MRI features probably is the most important factor responsible for the ever-increasing number of patients diagnosed with spontaneous intracranial hypotension since the early 1990s. On the other hand, an incomplete understanding of the variability of MRI findings has resulted in the diagnosis of spontaneous intracranial hypotension being erroneously excluded in patients with normal findings.

The 5 characteristic imaging features of spontaneous intracranial hypotension visible on MRI are (1)

subdural fluid collections, (2) enhancement of the pachymeninges, (3) engorgement of venous structures, (4) pituitary hyperemia, and (5) sagging of the brain (mnemonic: SEEPS) (FIGURE 2).

A relationship between subdural hematomas and intracranial hypotension has long been debated in the literature, and accumulation of subdural fluid was the first recognized imaging feature of spontaneous intracranial hypotension.<sup>65-71</sup> Subdural fluid collections are common in spontaneous intracranial hypotension, occurring in approximately 50% of patients.<sup>71</sup> Most of these subdural fluid collections represent hygromas and are thin, bilateral, located over the cerebral convexities, and do not cause any appreciable mass effect. They may also be seen in the posterior fossa, particularly over

**Table.** Differential Diagnosis of Headache Due to Spontaneous Spinal Cerebrospinal Fluid Leak and Intracranial Hypotension\*

Headache Disorder	Typical Age at Onset, y	Female-Male Ratio	Connective Tissue Disorders†	Headache Features	Thunderclap Headache	Associated Features	Confirmatory Testing
Primary New daily persistent headache	15-50 (Mean, 35)	2:1	No	Bilateral more common than unilateral Migraine or tension-type dominant	No	Nausea, fatigue, preceding viral illness	None
Secondary Spontaneous intracranial hypotension	20-60 (Mean, 40)	2:1	Yes	Bilateral much more common than unilateral Improved with recumbancy, but variable	Yes	Visual/aural changes, meningismus, cranial nerve dysfunction	MRI, LP, myelogram
Subarachnoid hemorrhage	>20 (Mean, 50)	1.5:1	Yes	Bilateral more common than unilateral Onset instantaneous in most, but may be gradual	Yes	Meningismus, cranial nerve dysfunction, seizure	CT, LP
Carotid/vertebral artery dissection	20-70 (Mean, 45)	1:1	Yes	Unilateral much more common than bilateral Often with neck pain	Yes	Horner syndrome, cranial nerve dysfunction, pulsatile tinnitus	Angiography
Cerebral venous sinus thrombosis	Any age	3:1	No	Bilateral more common than unilateral (but unilateral when headache is only sign)	Yes	Seizure, papilledema, visual changes, cranial nerve dysfunction	MRI/MRV, angiography
Benign intracranial hypertension	20-40 (Mean, 30)	8:1	No	Bilateral much more common than unilateral Worse in recumbancy	No	Papilledema, visual changes, abducens nerve palsy	LP
Posttraumatic headache	Any age	1.5:1	No	Bilateral much more common than unilateral Tension-type, often after mild head injury	No	Dizziness, neuropsychological symptoms	None
Meningitis	Any age	1:1	No	Bilateral	Yes	Fever, meningismus, systemic illness	LP

Abbreviations: CT, computed tomography; LP, lumbar puncture; MRI, magnetic resonance imaging; MRV, magnetic resonance venography.

\*The headache of spontaneous spinal cerebrospinal fluid leak and intracranial hypotension is best considered under the category of new daily persistent headache. Such headaches have an abrupt onset, often within minutes or hours but by definition within 3 days, and are present on most if not all days thereafter, typically in individuals without a prior history of headache.

†Including autosomal dominant polycystic kidney disease, Ehlers-Danlos syndrome, and Marfan syndrome.

the cerebellar convexities or in the retroclival space. Subdural hematomas with varying degrees of mass effect also are not uncommon in spontaneous intracranial hypotension and are about half as frequent as subdural hygromas (FIGURE 3).<sup>71</sup> Fortunately, most of these subdural hematomas can be managed with treatment directed at the underlying spinal CSF leak without the need for craniotomy.<sup>71</sup> Only rarely do the subdural hematomas require evacuation, and if the underlying CSF leak is left untreated, the risk of a recurrent subdural hematoma is high.<sup>68,69,71</sup>

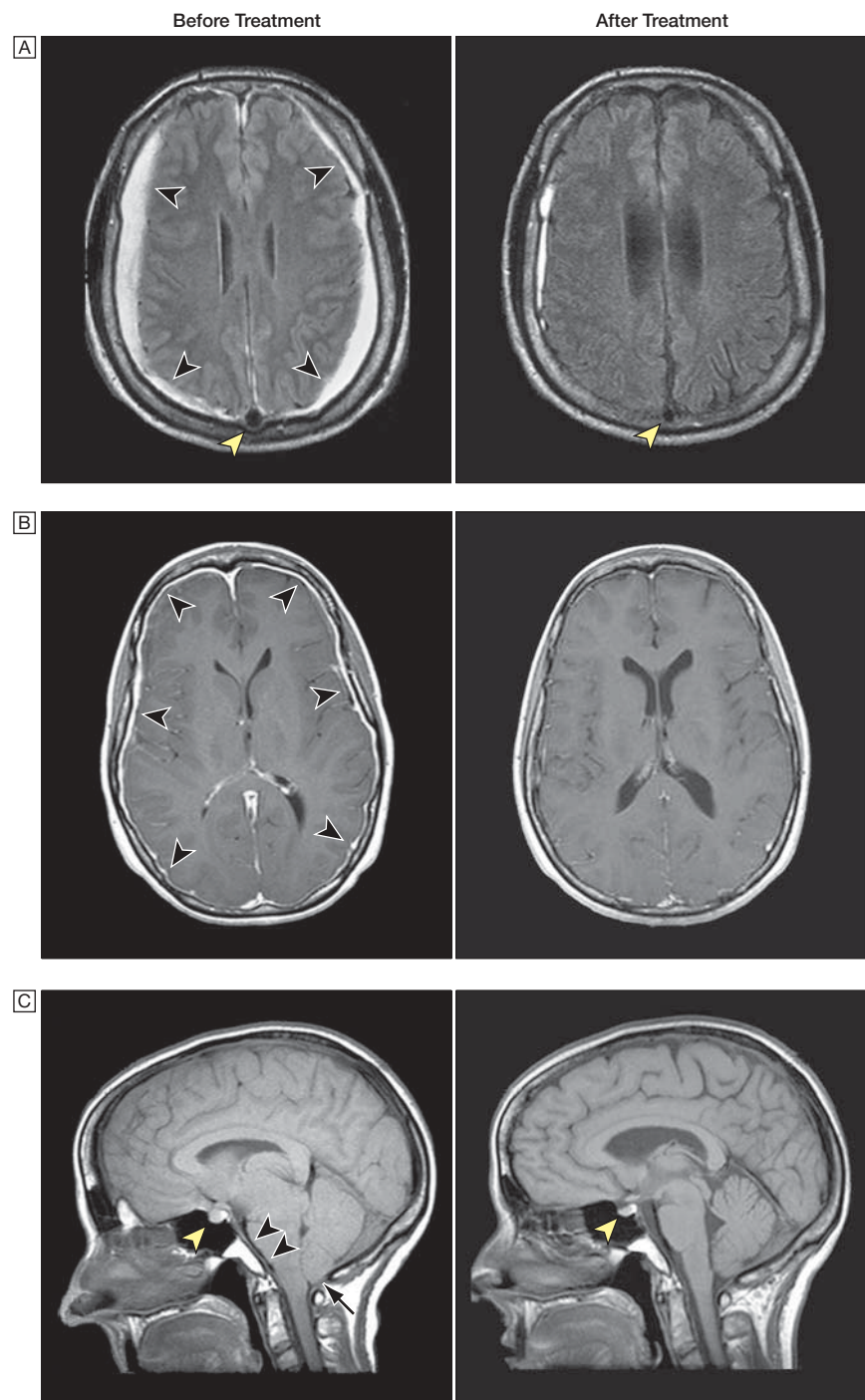
Enhancement of the pachymeninges has become the most well-known imaging abnormality of spontaneous intracranial hypotension. The enhancement is diffuse, nonnodular, involves both supratentorial and infratentorial compartments, and spares the leptomeninges.<sup>72,73</sup> Small, thin-walled dilated blood vessels in the subdural zone are the pathological substrate for the enhancement.<sup>12</sup> The relation between the enhancement and spontaneous intracranial hypotension has been believed to be so close that the term “syndrome of orthostatic headache and diffuse pachymeningeal gadolinium enhancement” was coined.<sup>12</sup> However, up to 20% of patients with spontaneous intracranial hypotension never develop enhancement, or any of the other abnormalities, on MRI.<sup>40,74,75</sup>

Engorgement of venous structures is most readily detected when it affects the dural venous sinuses or large cerebral veins.<sup>76-78</sup> It is rarely the only or the most striking imaging feature of spontaneous hypotension and often is only detectable when pretreatment and post-treatment images are compared.

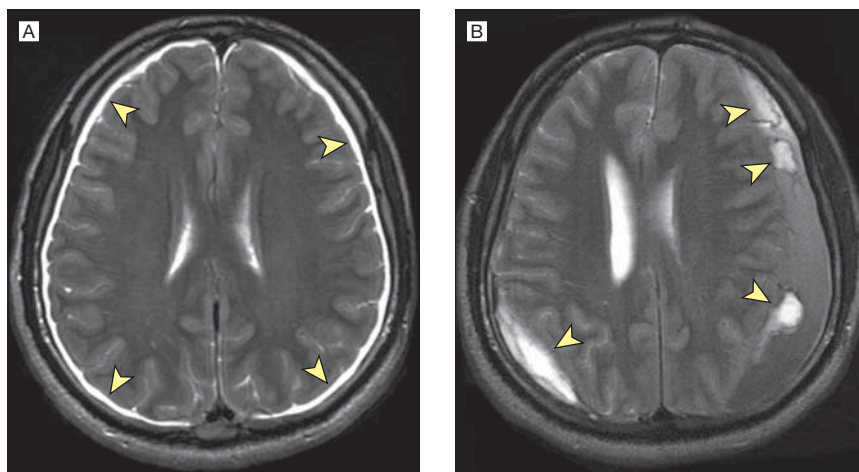
Pituitary hyperemia is a recently described imaging feature of spontaneous intracranial hypotension.<sup>79-82</sup> The pituitary hyperemia may become quite striking and mimic a pituitary tumor or hyperplasia.

Sagging or downward displacement of the brain is a very specific imaging finding of spontaneous intracranial

**Figure 2.** Pretreatment and Posttreatment Magnetic Resonance Imaging



A, Axial fluid-attenuated inversion recovery views showing resolution of bilateral subdural hematomas (black arrowheads) and engorgement of the superior sagittal sinus (yellow arrowhead) in a 35-year-old man. B, Axial T1-weighted views after intravenous administration of gadolinium showing resolution of enhancement of the pachymeninges (arrowheads) in a 39-year-old woman. C, Sagittal T1-weighted views showing resolution of sagging of the brain (flattening of the pons with obliteration of the prepontine cistern [black arrowheads] and downward displacement of the cerebellar tonsils mimicking a Chiari malformation [arrow]) and hyperemia/enlargement of the pituitary gland (yellow arrowheads) in a 41-year-old woman. Also note restoration of ventricular size following treatment in all panels.

**Figure 3.** Axial T2-Weighted Magnetic Resonance Image in a 39-Year-Old Man

A, Imaging shows subdural hygromas (arrowheads). B, The patient's spinal cerebrospinal fluid leaks were left untreated and bilateral subdural hematomas developed (arrowheads).

hypotension and may be accompanied by ventricular collapse.<sup>8,73</sup> Several features can be identified, such as effacement of perichiasmatic cisterns with bowing of the optic chiasm over the pituitary fossa; effacement of the prepontine cistern with flattening of the pons against the clivus; and descent of the cerebellar tonsils, which may mimic a Chiari type 1 malformation. Sagging of the brain in spontaneous intracranial hypotension may be attributed to coexisting subdural fluid collections, but the degree of sagging generally is out of proportion to any mass effect from the subdural fluid collections.

Most of the MRI features of spontaneous intracranial hypotension can be explained as compensatory changes related to the loss of CSF volume. According to the Monroe-Kellie hypothesis, the sum of the volumes of intracranial blood, CSF, and cerebral tissue must remain constant in an intact cranium.<sup>73</sup> Thus, the loss of CSF from the spine can be compensated for by an increase of the vascular component, accounting for the pachymeningeal enhancement, engorgement of venous structures, and pituitary hyperemia; or by an increase in the intracranial CSF component, accounting for the subdural hygro-

mas. Subdural hematomas may be caused by tearing of bridging veins or rupture of the dilated thin-walled blood vessels in the subdural zone. Sagging of the brain is caused by the loss of CSF buoyancy.

Improvement of abnormalities on MRI can be expected within days to weeks of successful treatment of the CSF leak. Clinical improvement generally precedes that demonstrated on MRI, and in some patients—particularly those who have not received specific treatment for their CSF leak—considerable clinical improvement is shown over time, whereas the MRI abnormalities persist. Small subdural hygromas resolve within days or weeks, but large subdural hematomas may require up to 3 months to resolve.

**Cranial Computed Tomography.** Although not as conclusive as MRI, computed tomography may suggest the diagnosis by showing subdural fluid collections or obliteration of subarachnoid cisterns and ventricular collapse.<sup>66,83,84</sup> Computed tomography can thus be of important diagnostic value, particularly in the emergency department setting.

**Myelography.** Myelography with iodinated contrast followed by thin-cut computed tomography of the entire spine (or with gadolinium fol-

lowed by MRI) has been shown to be the study of choice to accurately define the location and extent of a CSF leak (FIGURE 4).<sup>11</sup> The leak may vary from a small amount of contrast tracking along a single nerve root to extensive bilateral collections of contrast within the paraspinal soft tissues. Single or multiple meningeal diverticula may be demonstrated, but they are frequently below the level of detection of myelography and not uncovered until the time of surgery. The majority of CSF leaks are found at the cervicothoracic junction or along the thoracic spine. Frequently, multiple simultaneous CSF leaks are demonstrated. Retrosplinal collections of contrast at C1-C2 should not be mistaken for the actual site of the CSF leak.<sup>85</sup> Delayed imaging may be required to visualize slow or intermittent leaks, and ultra-early (ie, immediately following injection of contrast) computed tomography may be required to identify the site of rapid high-volume leaks.

The fear of cerebral herniation caused by performing a myelogram is entirely theoretical and has never been documented. Not only is the dural hole made by the lumbar puncture relatively small, but CSF pressure is already low. Aggravation of symptoms is reported by only approximately 5% of patients and is generally mild.

**Radionuclide Cisternography.** Radionuclide cisternography has been used extensively in the evaluation of spontaneous intracranial hypotension but is of relatively limited usefulness.<sup>11,86,87</sup> Typical findings include early accumulation of tracer in the kidneys and bladder, slow ascent along the spinal axis, and a paucity of activity over the cerebral convexities. However, the exact site of the CSF leak remains obscure in as many as one third of patients.<sup>11</sup> Radionuclide cisternography remains useful when the diagnosis of intracranial hypotension is in doubt and myelography results are normal.

**Spinal MRI.** In the past, relatively scant attention was given to spinal MRI in the diagnosis of spontaneous

intracranial hypotension, mainly because it is not particularly effective in localizing the CSF leak. However, numerous spinal manifestations of spontaneous intracranial hypotension have now been described, such as dilated epidural or intradural veins, dural enhancement, meningeal diverticula, extrathecal CSF collections, syringomyelia, and retrospinal C1-C2 fluid collections.<sup>88-94</sup>

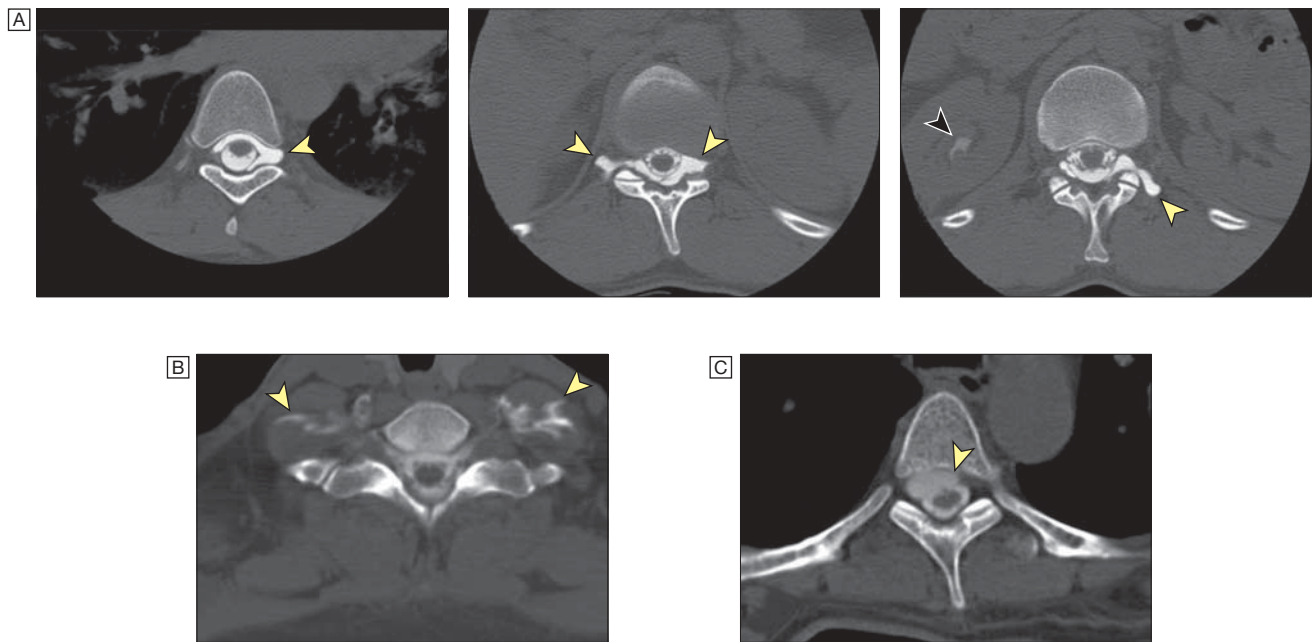
**Lumbar Puncture.** Typically, CSF opening pressure is less than 60 mm H<sub>2</sub>O (reference range, 65-195 mm H<sub>2</sub>O) and can be unmeasurable or even negative.<sup>9</sup> However, some patients have consistently normal CSF opening pressures.<sup>11</sup> Examination of CSF often demonstrates abnormal results, showing a primarily lymphocytic pleocytosis (up to 200 cells/mm<sup>3</sup>), an elevated protein content (up to 1000 mg/dL), or xanthochro-

mia that is probably due to increased permeability of dilated meningeal blood vessels and a decrease of CSF flow in the lumbar subarachnoid space.

**Treatment and Outcome**

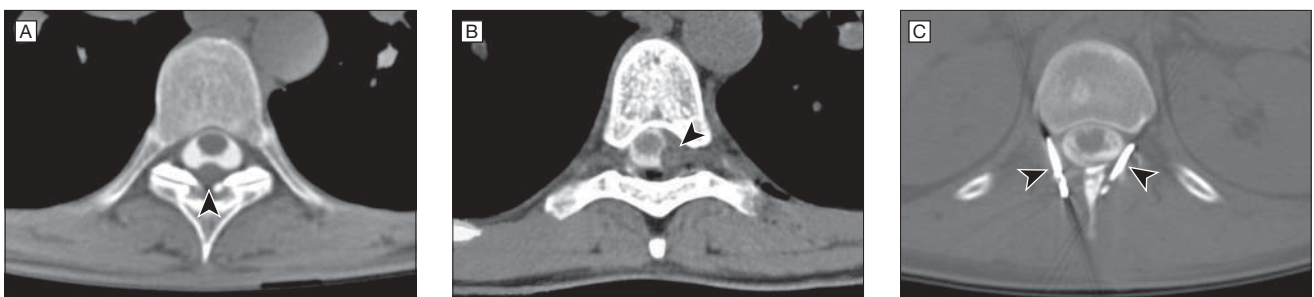
Although data are lacking, it is often stated that many cases of spontaneous intracranial hypotension resolve spontaneously without any specific therapy. Fortunately, several options are avail-

**Figure 4.** Postmyelography Computed Tomography Scans—Demonstration of Spinal Cerebrospinal Fluid (CSF) Leaks



A, Multiple thoracic CSF leaks associated with meningeal diverticula in a 23-year-old woman (arrowheads). Also note contrast within the right kidney (black arrowhead). Images taken at T6-7, T10-11, and T11-12. B, Bilateral CSF leaks at the cervicothoracic junction extending into the paraspinal soft tissues in a 54-year-old woman (arrowheads). Image taken at C7-T1. C, Contained CSF collection anterolateral to the thoracic spinal cord in a 58-year-old man (arrowhead). Image taken at T3-4.

**Figure 5.** Postmyelography Computed Tomography Scans—Results of Treatment



A, Results of an epidural blood patch in a 46-year-old woman. Note posterior midline location of epidural blood patch (arrowhead). Image taken at T7-8. B, Percutaneous placement of a fibrin sealant in a 48-year-old woman. Note lateral location of fibrin sealant (arrowhead). Image taken at T6-7. C, Surgical clipping (arrowheads) of bilateral meningeal diverticula in a 23-year-old woman. Image taken at T12-L1.



able to treat patients with spontaneous intracranial hypotension who seek medical attention (FIGURE 5). However, none of the treatments have been evaluated by randomized clinical trials. A purely conservative approach consists of bed rest, oral hydration, a generous caffeine intake, and use of an abdominal binder. Given enough time, this treatment is probably effective in many patients. However, symptoms may be debilitating, and more timely results may be desired. Administration of steroids, intravenous caffeine, or theophylline all have been advocated as specific treatments for spontaneous intracranial hypotension, but their effectiveness is limited.

The mainstay of treatment is the injection of autologous blood into the spinal epidural space, the so-called epidural blood patch.<sup>95,96</sup> Relief of symptoms often is instantaneous, thereby also serving a diagnostic purpose, and this is likely due to replacement of lost CSF volume with blood volume within the spinal canal. Initially, about 10 to 20 mL of blood is used, and this is effective in relieving symptoms in about one third of patients, presumably by forming a dural tamponade, thereby sealing the leak. Another mechanism of action may be restriction of CSF flow within the spinal epidural space, thereby interfering with CSF absorption. If the epidural blood patch is unsuccessful it can be repeated, and consideration should be given to a large-volume (20-100 mL) epidural blood patch. Given the potentially high volume of injected blood, a minimum of 5 days between blood patches is advised. The volume of blood that can be injected is mainly limited by local back pain or the development of radiculopathy. I prefer to place the blood patch at 2 separate sites, first at the thoracolumbar junction and then in the lower lumbar area, after which the patient is placed in the Trendelenburg position, either supine, prone, and/or lateral for 30 to 60 minutes, depending on the location of the CSF leak. This allows blood to travel over many spinal segments toward the site of the leak.

If epidural blood patches fail to provide relief, a directed epidural blood patch or percutaneous placement of fibrin sealant is recommended. These therapies require that the exact site of the CSF leak be known, and placement of fibrin sealant probably provides the best chance of alleviating symptoms. In my experience, about one third of patients for whom epidural blood patching has not been effective experience relief with the percutaneous placement of fibrin sealant, thereby avoiding surgery.<sup>97</sup>

Surgical treatment is reserved for those patients in whom these nonsurgical measures have failed. Surgical repair of CSF leak is safe and often succeeds in providing relief for those patients in whom a structural abnormality or focal CSF leak is identified.<sup>16,20,21</sup> Leaking meningeal diverticula can be ligated with suture or a metal aneurysm clip, while dural rents, holes, or other defects are repaired either directly with suture or, more commonly, by placement of a muscle pledget along with gelfoam and fibrin sealant. Rarely, intradural exploration may be required.

Intrathecal infusion of saline or artificial CSF should not be expected to seal a CSF leak but may be required as an effective temporizing measure to restore CSF volume until the leak can be permanently repaired in patients who require urgent treatment, such as those with a decreased level of consciousness.<sup>59,62</sup>

A recurrence of headache following successful treatment of spontaneous intracranial hypotension may indicate a recurrent CSF leak,<sup>98</sup> but if the pattern of headache has changed, rebound transient intracranial hypertension<sup>11</sup> or dural venous sinus thrombosis<sup>99</sup> should be considered.

Data on long-term outcomes are scarce, but in my experience, recurrence of a spinal CSF leak is seen in approximately 10% of patients, regardless of treatment. Outcome studies have shown that patients with abnormal brain MRI findings and a focal spinal CSF leak have an excellent prognosis,

while those with normal initial MRI findings and a diffuse multilevel spinal CSF leak have a poor prognosis.<sup>100</sup> Some patients have persistent symptoms following treatment, in spite of documented resolution of CSF leakage. Such patients may have residual altered CSF dynamics or small residual CSF leaks below the level of detection of current imaging techniques.

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**Study concept and design; acquisition of data; analysis and interpretation of data; drafting of the manuscript; critical revision of the manuscript for important intellectual content; administrative, technical, or material support; study supervision:** Schievink.

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## REFERENCES

- Schievink WI. Misdiagnosis of spontaneous intracranial hypotension. *Arch Neurol*. 2003;60:1713-1718.
- Schaltenbrand G. Neuere Anschauungen zur Pathophysiologie der Liquorzirkulation. *Zentralbl Neurochir*. 1938;3:290-300.
- Lindquist T, Moberg E. Spontaneous hypoliquorrea. *Acta Med Scand*. 1949;132:556-561.
- Nosik WA. Intracranial hypotension secondary to lumbar nerve sleeve tear. *JAMA*. 1955;157:1110-1111.
- Bell WE, Joynt RJ, Sahs AL. Low spinal fluid pressure syndromes. *Neurology*. 1960;10:512-521.
- Teng P, Papatheodorou C. Primary cerebrospinal fluid hypotension. *Bull Los Angeles Neuro Soc*. 1968;33:121-128.
- Lasater GM. Primary intracranial hypotension: the low spinal fluid pressure syndrome. *Headache*. 1970;10:63-66.
- Billings JJ, Gilford EJ, Henderson JK. The low intracranial pressure syndrome. *Proc Aust Assoc Neurol*. 1975;12:31-34.
- Rando TA, Fishman RA. Spontaneous intracranial hypotension: report of two cases and review of the literature. *Neurology*. 1992;42:481-487.
- Renowden SA, Gregory R, Hyman N, et al. Spontaneous intracranial hypotension. *J Neurol Neurosurg Psychiatry*. 1995;59:511-515.
- Schievink WI, Meyer FB, Atkinson JLD, et al. Spontaneous spinal cerebrospinal fluid leaks and intracranial hypotension. *J Neurosurg*. 1996;84:598-605.
- Mokri B, Piepgras DG, Miller GM. Syndrome of orthostatic headaches and diffuse pachymeningeal gadolinium enhancement. *Mayo Clin Proc*. 1997;72:400-413.
- Dillon WP, Fishman RA. Some lessons learned about the diagnosis and treatment of spontaneous intracranial hypotension. *AJNR Am J Neuroradiol*. 1998;19:1001-1002.
- Chung SJ, Kim JS, Lee MC. Syndrome of cerebral spinal fluid hypovolemia: clinical and imaging features and outcome. *Neurology*. 2000;55:1321-1327.
- Miyazawa K, Shiga Y, Hasegawa T, et al. CSF hypovolemia vs intracranial hypotension in "spontaneous intracranial hypotension syndrome." *Neurology*. 2003;60:941-947.
- Schievink WI, Morreale VM, Atkinson JLD, et al. Surgical treatment of spontaneous spinal cerebrospinal fluid leaks. *J Neurosurg*. 1998;88:243-246.
- Schievink WI, Roiter V. Epidemiology of cervical artery dissection. In: Baumgartner RW, Bogouss-

- lavsky J, Caso V, et al, eds. *Handbook of Cerebral Artery Dissection*. Basel, Germany: Karger; 2005: 12-15.
18. Schievink WI, Ebersold MJ, Atkinson JLD. Roller-coaster headache due to spinal cerebrospinal fluid leak. *Lancet*. 1996;347:1409.
  19. Schievink WI. Spontaneous spinal cerebrospinal fluid leaks. *Neurosurg Focus*. 2000;9:1-9.
  20. Schievink WI, Reimer R, Folger WN. Surgical treatment of spontaneous intracranial hypotension associated with a spinal arachnoid diverticulum: case report. *J Neurosurg*. 1994;80:736-739.
  21. Schievink WI, Jacques L. Recurrent spontaneous spinal cerebrospinal fluid leak associated with "nude nerve root" syndrome: case report. *Neurosurgery*. 2003;53:1216-1218.
  22. Schievink WI, Schrijver I, Meyer FB, et al. A syndrome of spontaneous spinal cerebrospinal fluid leaks and skeletal features of Marfan syndrome. *Ann Neurol*. 1998;44:458.
  23. Schrijver I, Schievink WI, Godfrey M, et al. Spontaneous spinal cerebrospinal fluid leaks and minor skeletal features of Marfan syndrome: a microfibrilopathy. *J Neurosurg*. 2002;96:483-489.
  24. Mokri B, Maher CO, Sencakova D. Spontaneous CSF leaks: underlying disorder of connective tissue. *Neurology*. 2002;58:814-816.
  25. Schievink WI, Gordon OK, Tourje J. Connective tissue disorders with spontaneous spinal cerebrospinal fluid leaks and intracranial hypotension: a prospective study. *Neurosurgery*. 2004;54:65-70.
  26. Davenport RJ, Chataway SJ, Warlow CP. Spontaneous intracranial hypotension from a CSF leak in a patient with Marfan's syndrome. *J Neurol Neurosurg Psychiatry*. 1995;59:516-519.
  27. Fukutake T, Sakakibara R, Mori M, et al. Chronic intractable headache in a patient with Marfan's syndrome. *Headache*. 1997;37:291-305.
  28. Rosser T, Finkel J, Vezina G, et al. Postural headache in a child with Marfan syndrome: case report and review of the literature. *J Child Neurol*. 2005;20: 153-155.
  29. Milledge JT, Ades LC, Cooper MG, et al. Severe spontaneous intracranial hypotension and Marfan syndrome in an adolescent. *J Paediatr Child Health*. 2005; 41:68-71.
  30. Schievink WI, Torres VE. Spinal meningeal diverticula in autosomal dominant polycystic kidney disease. *Lancet*. 1997;349:1223-1224.
  31. Miles J, Pennybacker J, Sheldon P. Intrathoracic meningocele: its development and association with neurofibromatosis. *J Neurol Neurosurg Psychiatry*. 1969;32:99-110.
  32. Erkulrawatr S, El Gammal T, Hawkins J, et al. Intrathoracic meningoceles and neurofibromatosis. *Arch Neurol*. 1979;36:557-569.
  33. Lehman RAW, Stears JC, Wesenberg RL, et al. Familial osteosclerosis with abnormalities of the nervous system and meninges. *J Pediatr*. 1977; 90:49-54.
  34. Philip N, Andrac L, Moncla A, et al. Multiple lateral meningoceles, distinctive facies and skeletal anomalies: a new case of Lehman syndrome. *Clin Dysmorphol*. 1995;4:347-351.
  35. Vishteh AG, Schievink WI, Baskin JJ, et al. Cervical bone spur presenting with spontaneous intracranial hypotension: case report. *J Neurosurg*. 1998; 89:483-484.
  36. Winter SC, Maartens NF, Anslow P, et al. Spontaneous intracranial hypotension due to thoracic disc herniation: case report. *J Neurosurg*. 2002;96: 343-345.
  37. Eross EJ, Dodick DW, Nelson KD, et al. Orthostatic headache syndrome with CSF leak secondary to bony pathology of the cervical spine [published correction appears in *Cephalalgia*. 2002;22:769]. *Cephalalgia*. 2002;22:439-443.
  38. Rapport RL, Hillier D, Searce T, et al. Spontaneous intracranial hypotension from intradural thoracic disc herniation: case report. *J Neurosurg*. 2003;98:282-284.
  39. Binder DK, Sarkissian V, Dillon WP, et al. Spontaneous intracranial hypotension associated with transdural thoracic osteophyte reversed by primary dural repair: case report. *J Neurosurg Spine*. 2005; 2:614-618.
  40. Mokri B. Spontaneous cerebrospinal fluid leaks: from intracranial hypotension to cerebrospinal fluid hypovolemia—evolution of a concept. *Mayo Clin Proc*. 1999;74:1113-1123.
  41. Levine DN, Rapalino O. The pathophysiology of lumbar puncture headache. *J Neurol Sci*. 2001; 192:1-8.
  42. Headache Classification Subcommittee of the International Headache Society. The International Classification of Headache Disorders, 2nd ed. *Cephalalgia*. 2004;24(suppl 1):1-160.
  43. Schievink WI, Wijdicks EFM, Meyer FB, et al. Spontaneous intracranial hypotension mimicking aneurysmal subarachnoid hemorrhage. *Neurosurgery*. 2001; 48:513-516.
  44. Mokri B, Low PA. Orthostatic headaches without CSF leak in postural tachycardia syndrome. *Neurology*. 2003;61:980-982.
  45. Schievink WI, Akopov SE. Filum ependymoma mimicking spontaneous intracranial hypotension. *Headache*. 2005;45:607-609.
  46. Case records of the Massachusetts General Hospital: weekly clinicopathological exercises: case 2-1998: a 50-year-old woman with increasing headache and a left abducent-nerve palsy. *N Engl J Med*. 1998;338: 180-188.
  47. Schievink WI, Smith KA. Nonpositional headache caused by spontaneous intracranial hypotension. *Neurology*. 1998;51:1768-1769.
  48. Mokri B. Spontaneous CSF leaks mimicking benign exertional headaches. *Cephalalgia*. 2002;22: 780-783.
  49. Mokri B, Aksamit AJ, Atkinson JLD. Paradoxical postural headaches in cerebrospinal fluid leaks. *Cephalalgia*. 2004;24:883-887.
  50. Schievink WI, Maya MM. Quadriplegia and cerebellar hemorrhage in spontaneous intracranial hypotension. *Neurology*. In press.
  51. Portier F, de Minteguiga C, Racy E, et al. Spontaneous intracranial hypotension: a rare cause of labyrinthine hydrops. *Ann Otol Rhinol Laryngol*. 2002;111: 817-820.
  52. Horton JC, Fishman RA. Neurovisual findings in the syndrome of spontaneous intracranial hypotension from dural cerebrospinal fluid leak. *Ophthalmology*. 1994;101:244-251.
  53. Ferrante E, Savino A, Brioschi A, et al. Transient oculomotor cranial nerves palsy in spontaneous intracranial hypotension. *J Neurosurg Sci*. 1998;42:177-179.
  54. Warner GT. Spontaneous intracranial hypotension causing a partial third cranial nerve palsy: a novel observation. *Cephalalgia*. 2002;22:822-823.
  55. Brady-McCreery KM, Speidel S, Hussein MA, et al. Spontaneous intracranial hypotension with unique strabismus due to third and fourth cranial neuropathies. *Binocul Vis Strabismus Q*. 2002;17:43-48.
  56. Yamamoto M, Suehiro T, Nakata H. Primary low cerebrospinal fluid pressure syndrome associated with galactorrhea. *Intern Med*. 1993;32: 228-231.
  57. Pleasure SJ, Abosch A, Friedman J, et al. Spontaneous intracranial hypotension resulting in stupor caused by diencephalic compression. *Neurology*. 1998; 50:1854-1857.
  58. Beck CE, Rizk NW, Kiger LT, et al. Intracranial hypotension presenting with severe encephalopathy: case report. *J Neurosurg*. 1998;89:470-473.
  59. Binder DK, Dillon WP, Fishman RA. Intrathecal saline infusion in the treatment of obtundation associated with spontaneous intracranial hypotension: technical case report. *Neurosurgery*. 2002;51:830-836.
  60. Whiteley W, Al-Shahi R, Myles L, et al. Spontaneous intracranial hypotension causing confusion and coma: a headache for the neurologist and the neurosurgeon. *Br J Neurosurg*. 2003;17:456-458.
  61. Kashmere JL, Jacka MJ, Emery D, et al. Reversible coma: a rare presentation of spontaneous intracranial hypotension. *Can J Neurol Sci*. 2004;31: 565-568.
  62. Weisfelt M, den Munckhof R, Bouma GJ, et al. Headache and impaired consciousness due to the spontaneous intracranial hypotension syndrome [in Dutch]. *Ned Tijdschr Geneesk*. 2005;149:1001-1006.
  63. Pakiam AS, Lee C, Lang AE. Intracranial hypotension with parkinsonism, ataxia, and bulbar weakness. *Arch Neurol*. 1999;56:869-872.
  64. Hong M, Shah GV, Adams KV, et al. Spontaneous intracranial hypotension causing reversible frontotemporal dementia. *Neurology*. 2002;58:1285-1287.
  65. Holmes JM. Intracranial hypotension associated with subdural haematoma. *BMJ*. 1953;20:1363-1366.
  66. Sipe JC, Zyffro J, Waltz TA. Primary intracranial hypotension and bilateral isodense subdural hematomas. *Neurology*. 1981;31:334-337.
  67. Pannullo SC, Reich JB, Krol G, et al. MRI changes in intracranial hypotension. *Neurology*. 1993;43:919-926.
  68. Sato Y, Honda Y, Maruoka H, et al. Recurrence of spontaneous intracranial hypotension with subdural hematomas. *Cephalalgia*. 1997;17:42-45.
  69. Garcia-Morales I, Porta-Etessam J, Galan L, et al. Recurrent subdural hematomas in a patient with spontaneous intracranial hypotension. *Cephalalgia*. 2001; 21:703-705.
  70. de Noronha RJ, Sharrack B, Hadjivassiliou M, et al. Subdural haematoma: a potentially serious consequence of spontaneous intracranial hypotension. *J Neurol Neurosurg Psychiatry*. 2003;74:752-755.
  71. Schievink WI, Maya MM, Moser FG, et al. Spectrum of subdural fluid collections in spontaneous intracranial hypotension. *J Neurosurg*. 2005;103: 608-613.
  72. Mokri B, Krueger BR, Miller GM, et al. Meningeal gadolinium enhancement in low pressure headaches [abstract]. *Ann Neurol*. 1991;30:294-295.
  73. Fishman RA, Dillon WP. Dural enhancement and cerebral displacement secondary to intracranial hypotension. *Neurology*. 1993;43:609-611.
  74. Schievink WI, Tourje J. Intracranial hypotension without meningeal enhancement on magnetic resonance imaging: case report. *J Neurosurg*. 2000;92: 475-477.
  75. Schoffer KL, Benstead TJ, Grant I. Spontaneous intracranial hypotension in the absence of magnetic resonance imaging abnormalities. *Can J Neurol Sci*. 2002;29:253-257.
  76. Koss SA, Ulmer JL, Hacey-Bey L. Angiographic features of spontaneous intracranial hypotension. *AJNR Am J Neuroradiol*. 2003;24:704-706.
  77. Roll JD, Larson TC III, Soriano MM. Cerebral angiographic findings of spontaneous intracranial hypotension. *AJNR Am J Neuroradiol*. 2003;24:707-708.
  78. Baryshnik DB, Farb RI. Changes in the appearance of venous sinuses after treatment of disordered intracranial pressure. *Neurology*. 2004;62:1445-1446.
  79. Mamelak AN, Fishman RA, Dillon WP, et al. Spontaneous intracranial hypotension. *J Neurosurg*. 1996; 85:192-193.
  80. Shimazu N, Oba H, Aoki S, et al. Pituitary enlargement in spontaneous intracranial hypotension on

MRI [in Japanese]. *Nippon Igaku Hoshasen Gakkai Zasshi*. 1998;58:349-352.

81. Mokri B, Atkinson JLD. False pituitary tumor in CSF leaks. *Neurology*. 2000;55:573-575.

82. Alvarez-Linera J, Escribano J, Benito-Leon J, et al. Pituitary enlargement in patients with intracranial hypotension syndrome. *Neurology*. 2000;55:1895-1897.

83. Murros K, Fogelholm R. Spontaneous intracranial hypotension with slit ventricles. *J Neurol Neurosurg Psychiatry*. 1983;46:1149-1151.

84. Schievink WI, Maya MM, Tourje J, et al. Pseudo-subarachnoid hemorrhage: a CT-finding in spontaneous intracranial hypotension. *Neurology*. 2005;65:135-137.

85. Schievink WI, Maya MM, Tourje J. False localizing sign of C1-2 cerebrospinal fluid leak in spontaneous intracranial hypotension. *J Neurosurg*. 2004;100:639-644.

86. Weber WE, Heidendal GA, de Krom MC. Primary intracranial hypotension and abnormal radionuclide cisternography: report of a case and review of the literature. *Clin Neurol Neurosurg*. 1991;93:55-60.

87. Moriyama E, Ogawa T, Nishida A, et al. Quan-

titative analysis of radioisotope cisternography in the diagnosis of intracranial hypotension. *J Neurosurg*. 2004;101:421-426.

88. Moayeri NN, Henson JW, Schaefer PW, et al. Spinal dural enhancement on magnetic resonance imaging associated with spontaneous intracranial hypotension: report of three cases and review of the literature. *J Neurosurg*. 1998;88:912-918.

89. Rabin BM, Roychowdhury S, Meyer JR, et al. Spontaneous intracranial hypotension: spinal MR findings. *AJNR Am J Neuroradiol*. 1998;19:1034-1039.

90. Dillon WP. Spinal manifestations of intracranial hypotension. *AJNR Am J Neuroradiol*. 2001;22:1233-1234.

91. Yousry I, Forderreuther S, Moriggl B, et al. Cervical MR imaging in postural headache: MR signs and pathophysiological implications. *AJNR Am J Neuroradiol*. 2001;22:1239-1250.

92. Sharma P, Sharma A, Chacko AG. Syringomyelia in spontaneous intracranial hypotension: case report. *J Neurosurg*. 2001;95:905-908.

93. Chiapparini L, Farina L, D'Incerti L, et al. Spinal radiological findings in nine patients with spontaneous intracranial hypotension. *Neuroradiology*. 2002;44:143-150.

94. Burtis MT, Ulmer JL, Miller GA, et al. Intradural spinal vein enlargement in craniocervical hypotension. *AJNR Am J Neuroradiol*. 2005;26:34-38.

95. Sencakova D, Mokri B, McClelland RL. The efficacy of epidural blood patch in spontaneous CSF leaks. *Neurology*. 2001;57:1921-1923.

96. Berroir S, Loisel B, Ducros A, et al. Early epidural blood patch in spontaneous intracranial hypotension. *Neurology*. 2004;63:1950-1951.

97. Schievink WI, Maya MM, Moser FM. Treatment of spontaneous intracranial hypotension with percutaneous placement of a fibrin sealant: report of four cases. *J Neurosurg*. 2004;100:1098-1100.

98. Schievink WI, Maya MM, Riedinger M. Recurrent spontaneous spinal cerebrospinal fluid leaks and intracranial hypotension: a prospective study. *J Neurosurg*. 2003;99:840-842.

99. Berroir S, Grabli D, Heran F, et al. Cerebral sinus venous thrombosis in two patients with spontaneous intracranial hypotension. *Cerebrovasc Dis*. 2004;17:9-12.

100. Schievink WI, Maya MM, Louy C. Cranial MRI predicts outcome of spontaneous intracranial hypotension. *Neurology*. 2005;64:1282-1284.

The universe is full of magical things patiently waiting for our wits to grow sharper.  
—Eden Phillpots (1862-1960)