Dural sinus stent placement for idiopathic intracranial hypertension

Clinical article

DAVID A. KUMPE, M.D.,1,2 JEFFREY L. BENNETT, M.D., PH.D.,3,4 JOSHUA SEINFELD, M.D.,1,2 VICTORIA S. PELAK, M.D.,3,4 ASHISH CHAWLA, M.D.,1 AND MARY TIERNEY, N.P.1

Departments of 1Radiology, 2Neurosurgery, 3Neurology, and 4Ophthalmology, University of Colorado Anschutz Medical Campus, Aurora, Colorado

Object. The use of unilateral dural sinus stent placement in patients with idiopathic intracranial hypertension (IIH) has been described by multiple investigators. To date there is a paucity of information on the angiographic and hemodynamic outcome of these procedures. The object of this study was to define the clinical, angiographic, and hemodynamic outcome of placement of unilateral dural sinus stents to treat intracranial venous hypertension in a subgroup of patients meeting the diagnostic criteria for IIH.

Methods. Eighteen consecutive patients with a clinical diagnosis of IIH were treated with unilateral stent placement in the transverse-sigmoid junction region. All patients had papilledema. All 12 female patients had headaches; 1 of 6 males had headaches previously that disappeared after weight loss. Seventeen patients had elevated opening pressures at lumbar puncture. Twelve patients had opening pressures of 33–55 cm H2O. All patients underwent diagnostic cerebral arteriography that showed venous outflow compromise by filling defects in the transverse-sigmoid junction region. All patients underwent intracranial selective venous pressure measurements across the filling defects. Follow-up arteriography was performed in 16 patients and follow-up venography/venous pressure measurements were performed in 15 patients.

Results. Initial pressure gradients across the filling defects ranged from 10.5 to 39 mm Hg. Nineteen stent procedures were performed in 18 patients. One patient underwent repeat stent placement for hemodynamic failure. Pressure gradients were reduced in every instance and ranged from 0 to 7 mm Hg after stenting. Fifteen of 16 patients in whom ophthalmological follow-up was performed experienced disappearance of papilledema. Follow-up arteriography in 16 patients at 5–99 months (mean 25.3 months, median 18.5 months) showed patency of all stents without in-stent restenosis. Two patients had filling defects immediately above the stent. Four other patients developed transverse sinus narrowing above the stent without filling defects. One of these patients underwent repeat stent placement because of hemodynamic deterioration. Two of the other 3 patients had hemodynamic deterioration with recurrent pressure gradients of 10.5 and 18 mm Hg.

Conclusions. All stents remained patent without restenosis. Stent placement is durable and successfully eliminates papilledema in appropriately selected patients. Continuing hemodynamic success in this series was 80%, and was 87% with repeat stent placement in 1 patient. (DOI: 10.3171/2011.10.JNS101410)

Key Words • idiopathic intracranial hypertension • pseudotumor cerebri • stent • dural sinus • venous sinus • hydrocephalus

Idiopathic intracranial hypertension, or pseudotumor cerebri, is an uncommon condition that most commonly affects young obese females. Typical symptoms of IIH include daily headache, pulse-synchronous tinnitus, and transient visual obscurations. In more advanced cases papilledema can develop, which can be associated with vision loss and diplopia. Idiopathic intracranial hypertension is a chronic condition that may worsen after a period of stability, warranting long-term follow-up.

Treatment of IIH is directed toward relief of symptoms and preservation of vision. Traditional treatment of IIH consists of weight loss, diuretics, and headache prophylaxis. Surgical procedures such as lumbarperitoneal, ventriculoperitoneal, or ventriculoatrial shunting and ONSF are reserved for those patients who experience unsuccessful medical management. None of these procedures, however, treat the underlying cause of the increased ICP.

Focal stenoses in the dural sinus outflow have been demonstrated in 30%–93% of patients with IIH. These stenoses characteristically occur in the lateral transverse sinuses and upper sigmoid sinuses, and are likely due to hypertrophied pachionian granulations in most instances. There is increasing evidence that in some patients with IIH, increased ICP is caused by ve-
Dural sinus stents for idiopathic intracranial hypertension

ous outflow obstruction due to these lesions. Recent reports have focused on treatment of these outflow stenoses with stent placement.1,3,5,11,15,24–27,29,31,33,40 Currently, there are 42 cases of stent placement for IIH in the literature. Stenting has shown a 100% technical success rate, and intracranial sinus pressures were invariably reduced by stenting among the reported cases. While short-term clinical follow-up has been favorable, there are very limited follow-up data on the hemodynamic performance of the stented dural sinus system.5,10,32

Since 1999, we have treated 18 patients with IIH with 19 stenting procedures of the dural sinuses. Clinical follow-up is available in all of these patients. Follow-up angiographic studies are available in 16 patients, and follow-up venous manometry in 15. These patients are the basis of this report.

Methods

From February 1999 to November 2009, 18 patients were treated with 19 stenting procedures (Table 1). All patients had a clinical diagnosis of IIH. All patients had papilledema and 17 of 18 had visual disturbance. All patients had undergone unsuccessful medical management.

Patient Demographics

There were 6 men and 12 women in the study sample (Table 1). Ages ranged from 16 to 62 years. All 12 female patients had headaches: 10 chronic, 1 intermittent, and 1 subacute (3 weeks). One of 6 male patients had headaches that disappeared after he lost weight. All patients had papilledema at some time in their clinical course, and 17 had papilledema at the time of the procedure. One of these patients had papilledema with acute retinal hemorrhages. Symptom duration ranged from 3 weeks to 20 years (median 28.5 months). Four patients were referred for urgent stent placement because of rapidly deteriorating vision in the form of central field loss associated with an afferent pupillary defect.

Seventeen patients were reported to have elevated opening pressures (≥ 25 cm H2O) on lumbar puncture. Two patients had opening pressures of 25 and 26 cm H2O, and 12 patients had opening pressures between 33 and 55 cm H2O. Three patients had elevated opening pressures reported, but the values were not available. One patient had no lumbar puncture opening pressure reported.

Prior Surgical Procedures

Prior to stent placement, 3 patients had ventriculoperitoneal shunts placed (Cases 1, 6, and 8) and 7 had undergone 8 total ONSFs, 1 bilateral (Case 9) and 6 unilateral (Cases 1, 5, 8, 11, 12, and 15).

Five of 7 patients undergoing ONSF had deterioration of vision in the operated eye after ONSF. There was immediate worsening of visual acuity in 2 cases. Case 5 noted initial improvement but then deterioration in visual acuity in the operated eye within 1 month. Another 2 patients (Cases 9 and 12) suffered catastrophic vision loss in the operated eye within 1 and 2 months of the operation, respectively. The patients who had deterioration of vision after ONSF had further deterioration of central visual acuity. Deterioration of vision after ONSF was believed to be due to ongoing injury to the optic nerve of uncertain origin. Three of these patients underwent emergency stent placement within 1, 1, and 2 months of failed ONSF to prevent vision loss in the remaining eye. Five patients’ eyes had optic nerve atrophy at presentation; all had undergone ONSF. Three eyes developed nerve atrophy following ONSF and 2 had atrophy prior to ONSF.

Body Mass Index

Body mass indices ranged from 22.6 to 38 kg/m2 (Table 1). Sixteen (88%) of 18 of patients were overweight or obese. Twelve patients (67%) had BMIs ≥ 30 kg/m2 (obese), and 4 had BMIs of 26–30 kg/m2 (overweight).

Neuroimaging Studies

Interpretations were available for 17 scans performed on 15 patients. Five patients had 6 CT venograms, 8 had MR venograms, and 2 had MR venograms and CT venograms. All scans showed filling defects in the transverse-sigmoid junction regions. However, in 7 patients (11 scans) studies were interpreted as normal with no mention of the filling defects. The defects were specifically described in 3 scans on 3 patients.

Dural Sinus Anatomy

Eight patients had right dominant transverse/sigmoid sinuses, while 4 had left dominant systems. Six had right and left transverse/sigmoid sinuses of equal size. Filling defects were present at the transverse-sigmoid junction in all patent dural sinuses. There was asymmetrical superficial versus deep venous drainage, in which the deep system drained into the nondominant side, and the superficial system drained into the dominant side, in 9 of 12 patients with a dominant sinus.

Operative Procedures

Nineteen stent procedures were performed. One patient had 2 separate stent placements after a hemodynamic failure of the first stenting procedure.

All patients underwent diagnostic cerebral arteriography, venous manometry, and selective intracranial dural sinus venography. The dural sinuses were depicted in a minimum of 4 angiographic projections to visualize their entire length, particularly in the transverse-sigmoid junction region.

For intracranial dural sinus pressure measurements, a guiding catheter was placed in the internal jugular vein on the side that appeared to be most appropriate anatomically for stenting, according to arteriography and scanning studies. A large-bore microcatheter (0.025-inch inner lumen) was advanced through the guiding catheter to its tip, where venous pressure is measured through the microcatheter. Under subtraction fluoroscopy, the microcatheter was then advanced into the posterior superior sagittal sinus. Pressure was measured in the lower superior sagittal sinus, the torcular, transverse, and sigmoid sinuses, and internal jugular vein. In some patients, we have also measured pressures on either side of the filling.
defects in both transverse/sigmoid sinuses. After pressure measurements, intracranial sinus venography was performed. When a significant pressure gradient existed across the filling defect, the patient was brought back on a separate occasion for elective stent placement. In 4 patients (Cases 2, 7, 9, and 12), 3 of whom were referred for urgent or emergency stenting, we performed stent placement at the time of the first examination. The patient was placed under general anesthesia for all stent procedures. A 6 Fr guide sheath (Shuttle, Cook Inc.) was advanced over a glide wire (Terumo Medical Corporation) into the sigmoid sinus. A 0.018-inch system self-expanding stent (Precise, Codman Neurovascular; Acculink, Guidant-Boston Scientific; or Zilver, Cook Inc.) was then deployed across the stenosis under roadmap imaging. Postdilation of the stent has not been necessary in our experience. Pressure measurements were repeated from the torcular herophili through the internal jugular vein to document that the gradient had decreased.

Patients were placed on 75 mg per day of clopidogrel and 325 mg per day of aspirin for at least 5 days preceding the stent placement and for 6 months after stent placement. After 6 months, the clopidogrel was discontinued and the patients were continued on aspirin. Follow-up angiography with venous pressure measurements was performed with the patient awake using the technique described above (Fig. 1).

**Stent Procedures**

Of the 19 stenting procedures, stents were placed in the right transverse-sigmoid junction region on 12 occasions and on the left side on 7 occasions. Two balloon-expandable stents were placed on 1 occasion, while single self-expanding stents were used in all other cases except 1 in which 2 self-expanding stents were required to cover the narrowed segment. Stent diameters ranged from 6 to 10 mm, and stent lengths ranged from 24 to 80 mm. Sixteen stents were 8–10 mm in diameter. The most common stent lengths were 40 mm (8 cases) and 30 mm (6 cases). Stents were placed in the dominant sinus in 17 patients and in the nondominant sinus in 1 patient.

**Results**

**Pressure Gradients**

All stent placement procedures were successful. Presten venous pressure gradients were recorded for 16 patients when awake. Gradients between the torcular herophili and the internal jugular vein ranged from 10.5 to 39 mm Hg (Table 2). The median gradient was 21.1 mm

---

**TABLE 1: Patient demographics**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age at Stent Placement (yrs), Sex</th>
<th>Headache</th>
<th>Vision Disturbance</th>
<th>Duration of Symptoms (mos)</th>
<th>BMI (kg/m²)</th>
<th>Lumbar Puncture Opening Pressure (cm H₂O)</th>
<th>Shunt Placed</th>
<th>ONSF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>41, F</td>
<td>yes</td>
<td>yes</td>
<td>240</td>
<td>38</td>
<td>36 (multiple shunts w/ infection pre- and post-stent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>16, F</td>
<td>yes</td>
<td>yes</td>
<td>0.75</td>
<td>22.6</td>
<td>&gt;50 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>58, M</td>
<td>no</td>
<td>yes</td>
<td>27</td>
<td>28.2</td>
<td>elevated (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>30, M</td>
<td>no</td>
<td>yes</td>
<td>12</td>
<td>31.9</td>
<td>36 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>52, M</td>
<td>no</td>
<td>yes</td>
<td>4</td>
<td>26</td>
<td>33 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6a</td>
<td>25, F</td>
<td>yes</td>
<td>yes</td>
<td>72</td>
<td>elevated</td>
<td>yes 2001 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6b (stent 2)</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>78</td>
<td>26.2</td>
<td>34 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>59, F</td>
<td>yes</td>
<td>yes</td>
<td>4.5</td>
<td>33.9</td>
<td>43.5 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>28, F</td>
<td>yes</td>
<td>yes</td>
<td>4.5</td>
<td>28.6</td>
<td>33 (multiple)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>28, F</td>
<td>yes</td>
<td>yes</td>
<td>72</td>
<td>24.4</td>
<td>34 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>62, M</td>
<td>no</td>
<td>yes</td>
<td>27</td>
<td>36.4</td>
<td>55 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>22, F</td>
<td>yes</td>
<td>yes</td>
<td>30</td>
<td>35.8</td>
<td>44 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>52, F</td>
<td>yes</td>
<td>yes</td>
<td>10</td>
<td>31.1</td>
<td>25 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>36, F</td>
<td>yes</td>
<td>yes</td>
<td>35</td>
<td>2.5</td>
<td>31.3 (&gt;50)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>23, F</td>
<td>yes</td>
<td>yes</td>
<td>2.5</td>
<td>33.4</td>
<td>elevated (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>44, M</td>
<td>no at present; h/a in 2005 before weight loss</td>
<td>Lt &gt; rt</td>
<td>36</td>
<td>34.4</td>
<td>55 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>23, F</td>
<td>yes</td>
<td>yes</td>
<td>60</td>
<td>37.8</td>
<td>26 (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>53, M</td>
<td>no</td>
<td>no</td>
<td>120</td>
<td>not available</td>
<td>none (none)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>26, F</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>30.9</td>
<td>not available (none)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* All patients had papilledema. Abbreviation: h/a = headache.
Hg and the average gradient was 21.5 mm Hg. Fifteen patients had 16 pressure gradients recorded while under anesthesia (1 patient underwent restenting). Gradients while under anesthesia ranged from 4 to 30 mm Hg, with a median of 10 mm Hg and mean of 13.7 mm Hg. Among 13 patients who underwent recordings both while awake and under general anesthesia, the pressure gradient decreased during anesthesia in 11 and increased in 2. Poststent pressure gradients improved immediately in all patients. Pressure gradients immediately after placement were reduced to 0–7 mm Hg (Table 2).

Transit Time

As an angiographic indicator of hemodynamic improvement immediately following stent placement, the transit time on internal carotid arteriography was recorded from the time of first appearance of contrast material at the catheter tip to first appearance of contrast at the
jugular foramen. Among 14 patients in whom this information was available, transit time decreased acutely in 11 (79%) and was unchanged in 3. For example, in Case 7 transit time decreased from 8.42 seconds to 6.33 seconds, a 25% decrease. In 7 patients, transit time decreased by 18%–26%, and in 2 patients by 12%. In another 2 patients, transit time decreased by 1 second, although the specific times were not recorded.

**Complications**

There were 1 major and 2 minor complications. One patient developed a urinary tract infection. This same patient had a brief syncopal episode when transferring from the bed to a chair the morning after stent placement.

One patient had a concomitant small parasagittal brain AVM. She was referred for urgent stent placement after a failed ONSF in which she became functionally blind in the operated eye over the following month. Urgeent transcatheter obliteration of the AVM followed by stent placement, was performed to preserve vision in the remaining eye. The patient had also developed occlusion of the left sigmoid sinus during the month after ONSF. During stent placement, there was transient stasis of flow in the solitary right sigmoid sinus. The patient developed a left subdural hematoma and subarachnoid hemorrhage, managed with placement of a ventriculostomy catheter. The subdural hematoma resolved spontaneously within 24 hours. At 6 months after stent placement the patient was normal except for trace right foot weakness believed to be secondary to curative embolization of the AVM.

**Clinical Follow-Up**

Clinical follow-up was available in all patients and ranged from 11 to 136 months (median 30 months, mean 43.7 months). Sixteen patients have undergone follow-up fundoscopic examinations. The examining ophthalmologist was aware that the patients had undergone dural sinus stent placement. Papilledema resolved in 15 (94%) of 16 patients (Table 3) and has not recurred. Visual acuity information before and after stent placement was available in 15 patients. Visual acuity remained stable or improved in every patient. Visual acuity did not improve from baseline in the eyes that had deteriorated vision either from optic nerve atrophy or following ONSF. Follow-up lumbar punctures were not obtained because of the increased incremental risk of hemorrhage among these patients who were all receiving daily clopidogrel and aspirin.

Among the 12 female patients, all of whom had headache at presentation, headaches resolved in 2 (Cases 6 and 12) and were present but improved (decreased intensity and frequency, with a different pattern) in 8 (Cases 2, 7, 9, 11, 13, 14, 16, and 18; Table 3). Headaches were unchanged in 2 cases. Thus, 10 of 12 patients had persistent headache in some form, even though they improved in 8 of the 10. No male patient had headaches before or after stent placement.

**TABLE 2: Pressure gradients across the stenosis**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Venous Pressure Gradient (mm Hg)</th>
<th>Interval from Stenting to Last Angiogram (mos)</th>
<th>Venous Pressure Gradient (mm Hg) At Last Follow-Up</th>
<th>Change From Immediate Poststent Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before Stent Placement</td>
<td>During Anesthesia</td>
<td>After Stent Placement</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>NA</td>
<td>14</td>
<td>3</td>
<td>72</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>NA</td>
<td>6</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>14</td>
<td>7</td>
<td>21.5</td>
</tr>
<tr>
<td>4</td>
<td>17.5</td>
<td>24</td>
<td>2</td>
<td>41.5</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
<td>8</td>
<td>0</td>
<td>10.5</td>
</tr>
<tr>
<td>6</td>
<td>NA</td>
<td>10</td>
<td>1</td>
<td>10.5</td>
</tr>
</tbody>
</table>

6 (restent) | 10.5 | 7 | 0 | 25.5 | 0 | 0 |

7 | 18 | NA | 3 | 7.3 | 4 | 1 |
| 8 | 16.5 | 9 | 3 | 25 | 5.5 | 2.5 |
| 9 | 20 | 30 | 4 | 29.5 | 5 | 1 |
| 10 | 22 | 7 | 1 | 5 | 2 | 1 |
| 11 | 27 | 10 | 3 | NA | NA | NA |
| 12 | NA | 28 | 5 | 7.5† | 8 | 3 |
| 13 | 16 | 10 | 0 | 24.5 | 2.5 | 2.5 |
| 14 | 39 | 9 | 1 | 6.5 | 4.5 | 3.5 |
| 15 | 16.5 | NA | 3 | 8.5 | 3 | 0 |
| 16 | 23 | 14 | 3 | 6 | 10.5 | 7.5 |
| 17 | 24.5 | 21 | 1.5 | 9 | 2.5 | 1 |
| 18 | 22 | 4 | 1 | 8 | 18 | 17 |

* NA = not available.
† Patient underwent CT angiography at 15.5 months that showed continuing patency of the stent without any restenosis. No venous pressures were available at this time.
Sixteen patients underwent 29 follow-up catheter arteriograms and 1 CT arteriogram between 5 and 99 months (median 18.5 months, mean 25.3 months). All stents were patent with no in-stent restenosis. In 2 patients (Cases 9 and 12) there were intraluminal filling defects immediately adjacent to the upper end of the stent. In retrospect, the filling defects were present at the time of stent placement and were not covered completely by the stent. This was a technical error. In 4 patients (Cases 6, 8, 16, and 18) there was a tapered narrowing of the transverse sinus as it approached the stent, without an intraluminal filling defect. The transverse sinus above the stent was widely patent in the remaining 10 patients.

In 15 patients there were also 28 venous pressure determinations during follow-up. Pressure gradients between the torcular herophili and the internal jugular vein at the last follow-up ranged from 0 to 18 mm Hg. In 12 patients (80%), the change from the gradient immediately after stent placement was less than 4 mm Hg, including the 2 patients who had a filling defect above the stent (Fig. 2). Three of the 4 patients with tapered narrowing of the transverse sinus above the stent had significant hemodynamic failure, with changes from the immediate poststent gradient of 7.5–17 mm Hg. One of these patients (Case 6), who experienced recurrence of the original gradient of 10.5 mm Hg, underwent restenting with elimination of the gradient. Two other patients (Cases 16 and 18) who developed narrowing of the transverse sinus above the stent had pressure gradients of 10.5 and 18 mm Hg at follow-up, compared with preexistent gradients of 23 and 22 mm Hg and immediate poststenting gradients of 3 and 1 mm Hg, respectively (Fig. 3). None of these patients developed recurrent papilledema.

Retreatment

Two patients required retreatment. One patient (Case 6) underwent placement of a second stent into the narrowed transverse sinus 11 months after the initial stent placement because her gradient of 10 mm Hg had completely recurred. Follow-up venous manometry 15 months after placement of the second stent showed a zero gradient.

At the time of the initial stent placement, one patient (Case 2) had a subacute thrombosis of her right transverse sinus that could not be recanalized using a transcathe-ter technique. The stent was placed in her stenotic left transverse-sigmoid junction with a decrease in her pressure gradient from 22 to 6 mm Hg. A hypercoagulability syndrome that was not characterized was diagnosed in this patient. Seventy months after stent placement, and 1 month after a stillbirth, she developed thrombosis of the left sigmoid sinus downstream from the stent. The thrombus was successfully cleared using transcatheter intracranial thrombolysis and mechanical thrombectomy, with restoration of the original poststenting gradient. There was no stenosis within the stent. At 99 months follow-up, angiography and venous manometry showed a patent stent with a pressure gradient equal to the original poststenting gradient.
**Discussion**

**Anatomical Considerations**

Stenoses in the lateral transverse sinuses are commonly found in patients with IIH. Farb et al. found that more than 90% of patients with IIH undergoing imaging using a specialized MR venography demonstrated evidence of sinovenous stenoses. There is controversy as to whether stenoses in the lateral transverse sinuses are a primary cause of elevated ICP or a result of increased ICP. Disappearance of stenoses in the transverse sinuses and transverse-sigmoid sinus junctions after shunting or lumbar puncture have been documented by several investigators who assert that the phenomenon is secondary to increased ICP. Conversely, Bono et al. followed 14 patients with IIH and transverse sinus stenoses and found no change in the anatomical narrowing despite normalization of CSF pressure in 64% of the patients. The explanation of these contradictory findings may be secondary to the presence of 2 patient populations in IIH, one with truly IIH and one with intracranial hypertension caused by venous outflow obstruction. These distinct populations are apparent in the study by Farb et al., who noted 2 types of dural sinus narrowing in patients with IIH: 1) long, smooth-tapered narrowing secondary to external compression from swollen brain parenchyma; and 2) acutely “marginated” (clearly demarcated with a sharply defined margin) intraluminal filling defects secondary to enlarged, partially obstructing intraluminal arachnoid granulations.

Intraluminal filling defects are common in the lateral sinuses. Leach et al. found discrete filling defects within the dural sinuses on 138 (24%) of 573 contrast-enhanced CT examinations in a nonselect group of patients, and in 13 (13%) of 100 contrast-enhanced MR studies. These defects are focal, well defined, and typically located adjacent to venous entrance sites. Arachnoid granulations were observed in 66% of 29 cadaveric specimens in a similar distribution. They concluded that these are normal structures and should not be confused with a sinus thrombosis or intrasinus tumor. Significant bilateral obstruction of venous outflow may ultimately trigger the onset of IIH.

It is our opinion, shared by others, that patients who have a clinical diagnosis of IIH should undergo noninvasive scanning studies, either MR venography or CT venography, to look for anatomical evidence of dural sinus abnormality, either bilateral filling defects in the transverse-sigmoid junction region or unilateral hypoplasia of the transverse and/or sigmoid sinus with a filling defect in the contralateral patent transverse/sigmoid sinus. The clinician should review the studies because filling defects in the transverse sinus region are commonly present and might not be described in the radiology report. Fifteen patients in this series had filling defects on either CT venography, MR venography, or both, but in 7 of 15 patients the studies were interpreted as normal with no mention of the filling defects. We believe that patients with such filling defects should undergo diagnostic arteriography and venous manometry. The angiographic/manometric diagnostic workup in our experience has been safe and without complications. Patients who will respond to unilateral stenting have intraluminal filling defects with a pressure gradient precisely across the filling defect.

**Clinical Considerations**

All patients in this series had a clinical diagnosis of severe IIH producing papilledema and 17 of 18 had visual disturbance. Four developed unilateral blindness. Three patients had rapidly progressive vision loss shortly following ONSF and were referred for urgent stent place-
ment. Another patient had become blind in 1 eye previously.

Our clinical follow-up ranged from 11 to 136 months. Half of the patients had follow-up of more than 30 months. No patient experienced visual deterioration from baseline after stent placement. Papilledema resolved in 15 (94%) of 16 patients, with no recurrence in follow-up. Two patients did not have fundoscopic examination following stent placement; in both patients visual symptoms improved.

Headaches persisted in some form in 10 of 12 female patients, although 8 of the 10 had decreased frequency and severity of the headaches, which also had a different pattern from that at presentation. Continued headache in patients with IIH after successful treatment is not uncommon. In 1 series of patients with IIH treated using shunt procedures, 95% had significant improvement in headache immediately after shunt placement. However, 48% of patients with a functioning shunt had recurrence of their headaches at 3 years. Friedman and Rausch noted that, among a series of 82 patients with IIH, 67% had persistent headaches despite successful treatment for increased ICP.

### Angiographic and Hemodynamic Considerations

The minimum pressure gradient at which stenting will produce significant clinical benefit has not been established. In our experience, the maximum normal pressure gradient between the torcular herophili and the internal jugular vein is 4–5 mm Hg, which is compatible with published figures. We set an arbitrary pressure gradient of 10 mm Hg as the lower limit of when stenting was to be performed. All patients in this series had a pressure gradient of at least 10 mm Hg.

This study suggests that stenting is a durable procedure. All stents studied angiographically have remained patent, and the longest study interval was 99 months. No patient has experienced a recurrent stenosis within the stent. The only reocclusion developed as an acute dural sinus thrombosis in the sigmoid sinus below the stent, at 70 months after stent placement. This patient had had a prior episode of dural sinus thrombosis and was believed to have a hypercoagulable state.

Hemodynamic improvement was sustained in 13 of 15 patients studied with venous manometry in follow-up. Twelve patients had no or minimal (< 4 mm Hg) hemodynamic deterioration at 8–96 months after a single stenting procedure, while 1 patient underwent repeat stent placement.

Three patients with hemodynamic deterioration developed narrowing of the transverse sinus above the stent with no intraluminal filling defect. The cause of the narrowing is not clear. These 3 patients may have had primary idiopathic intracranial hypertension rather than venous obstruction as a cause of their increased ICP, despite the findings on diagnostic arteriography and selective intracranial venous pressure measurements. Rohr et al. published a widely quoted single stenting failure similar to our 3 cases, associated with recurrence of symptoms. The stenosis was documented on CT and MR imaging, without follow-up angiographic or hemodynamic studies. The incidence of development of hemodynamic deterioration across a new narrowing above the stent is 20% (3 of 15 patients with hemodynamic follow-up) in this series. In 1 of these 3 patients, who underwent repeat stent placement, there is continued hemodynamic success without new narrowing above the second stent. None of the patients with hemodynamic deterioration has developed recurrent papilledema to date. No other such stenting failures have been reported. At present we do not have a fixed limit of pressure gradient recurrence above which we will perform repeat stent placement. We are following these patients’ clinical status. If they redevelop papilledema or visual changes, we will perform restenting of the narrowed segment above the stent. Of note, the mode of hemodynamic failure in these 3 patients does not involve a problem with the stented segments, which have universally remained patent without restenosis, but with the dural sinus above the stent. More experience with the procedure should refine patient selection criteria. It is an open question whether primary stenting of the transverse sinus as well as the focal narrowing at the transverse-sigmoid junction eliminates this possibility.

### Comparison With Reported Experience With Stenting

Our outcomes of stent placement are comparable with those in the literature, with longer follow-up. There are 42 reported cases of stent placement for IIH. These cases consist of 4 series of 4, 10, 10, and 12 patients and 6 individual case reports. The literature results have been tabulated in 2 recent reports. In this reported experience, technical success has been 100%. Between 10% and 42% of patients have been asymptomatic in follow-up, and 58%–100% of patients either asymptomatic or improved. One patient, cited above, had clinical failure within 1 week associated with a change in Doppler velocities. Clinical follow-up has been reported from 2 to 60 months, with 6 patients followed for longer than 24 months and only 2 patients followed for longer than 36 months. There is almost no information about stent patency or the hemodynamic performance of the stented venous system in follow-up. Our clinical results (100% technical success, 89% with either no or improved headaches, and 94% with resolution of papilledema) are comparable with reported results, and with a longer clinical follow-up of up to 136 months (mean 43.7 months, median 30 months). In addition, we have angiographic follow-up studies for as long as 99 months in 16 patients, and hemodynamic follow-up studies in 15 patients, which indicate that both angiographic patency and the hemodynamic result of stenting are durable. One retreatment was performed because the transverse sinus became narrowed above the stent with recurrence of the original pressure gradient. Two other patients (13%) developed hemody-
namic deterioration—although not to their baseline pressure gradients—associated with narrowing of the transverse sinus above the stent.

There is 1 report of in-stent restenosis in a dural sinus stent. The restenosis occurred at 6 months following placement of a stent in a tight sigmoid sinus stenosis in a patient with an untreated AVM associated with venous hypertension. In our opinion this is a different hemodynamic situation that does not pertain to patients with IIH due to outflow stenosis.

Serious complications from stent placement have been rarely reported in the literature. Higgins et al. reported thrombosis in 2 stents shortly after stent placement, treated by thrombolysis. Our serious complication of intracranial hemorrhage due to transient venous outflow occlusion occurred during an urgent stent placement to attempt to preserve vision in a patient who had rapidly lost vision in 1 eye following ONSF. In the future, in a similar situation, we would consider performing a surgical cutdown of the anterior superior sagittal sinus to allow antegrade placement of the stent without compromising the outflow, as has been mentioned by Owler et al.

Comparison With Results of Conventional Therapy

Among patients who have appropriate anatomy for stent placement, as in this series, outcomes appear to be more durable and successful than standard medical or surgical results. All current medical and surgical treatments have a significant long-term failure rate. All surgical procedures have a potential for early complications.

Medical management of IIH is appropriate for patients without severe papilledema and/or visual deterioration and is not free of risk. In a study of 20 patients with IIH followed for at least 10 years and managed medically, 45% had either delayed worsening or recurrence of their visual symptoms and papilledema. Another study with a mean observation of 6.2 years showed a 38.4% recurrence rate of IIH.

Patients with papilledema have a more severe manifestation of IIH that can permanently damage their optic nerves and are frequently referred for a surgical procedure to preserve vision. Surgical management involves either a shunt procedure (lumboperitoneal, ventriculoperitoneal, or ventriculoatrial) or ONSF.

Surgical shunts have a high failure rate. Patients undergoing ventriculoperitoneal or lumboperitoneal shunt placement frequently require 1 or more shunt revisions within 3 years of placement. In a review of a 30-year experience of shunt placement for headache due to IIH at a single institution, McGirt et al. discussed 115 shunt placement procedures in 42 patients. Eighty percent of all shunts in this study required revision within 36 months. Cumulative failure at 1 year was 75% for lumboperitoneal shunts and 50% for ventriculoperitoneal and ventriculoatrial shunts. Ninety-five percent of patients experienced a significant improvement in their headaches immediately after the shunt was inserted. However, severe headache recurred despite a properly functioning shunt in 20 patients (48%) at 36 months. Papilledema was present in 60% of patients before shunt placement. There was no information about relief of papilledema.

Optic nerve sheath fenestration has been considered by some investigators to be more effective for treatment of papilledema with fewer complications than lumboperitoneal shunting. However, follow-up studies have indicated that ONSF is not as effective as originally believed. Optic nerve sheath fenestration is associated with significant complications, with as many as 40% in 1 series. As many as 33% of patients who have initial improvement in visual symptoms after ONSF for IIH experience deterioration of visual acuity and visual fields. In the series by Corbett et al. with 40 ONSFs in 26 patients, 6 patients (15% of eyes, 23% of patients) lost vision within 2 weeks of surgery. Five of the 6 had no vision return after lumboperitoneal shunting. One-third of patients undergoing ONSF have no relief of headaches. Shunting may still be required in these patients. Patients treated with ONSF must be followed carefully. Only approximately 75% of ONSFs appear to be functioning 6 months after surgery. The probability of functioning of ONSF steadily decreases thereafter, so that 66% are functioning at 12 months, 55% at 3 years, 38% at 5 years, and 16% at 6 years after surgery. The incidence of complications increased significantly with repeat ONSFs. Our experience in this series is consistent with the data in literature. Seven patients had undergone 8 total ONSFs. Five of these patients had deterioration of vision in the operated eye either immediately or within 2 months of surgery, and 2 patients became blind in the operated eye.

Thus, even though either shunting or ONSF may initially improve vision and prevent acute deterioration of vision in patients with IIH, both have significant early complication rates and high long-term failure rates, requiring repeat procedures. In contrast, stent placement appears to be a safer procedure initially, and more durable in follow-up. Papilledema, in particular, disappeared after the intracranial venous pressure gradient was eliminated by the stent. The hemodynamic success in 87% of patients and continued patency in 100% of the stents in our series suggest that the stabilization or improvement in vision may be durable without the need for repeat procedures.

Headache control following stent placement was less satisfactory. A similar phenomenon has been observed in patients who have undergone a shunt procedure or ONSF. The persistence of headache in some form among our female patients with IIH suggests that stenting may offer no advantages for headache relief compared with shunting. On the other hand, the persistent headaches in all these patients may simply reflect the more severe nature of their clinical syndrome, because all had papilledema.

Conclusions

Our experience indicates that there is a subgroup of patients meeting the diagnostic criteria of IIH who have focal dural sinus outflow obstruction that causes a substantial and documentable pressure gradient, in turn causing intracranial hypertension with papilledema. Normalization of this pressure gradient with stent placement results in resolution of the papilledema. Therefore, these patients have elevated ICP due to their venous sinus stenosis and are not “idiopathic.” We believe that stenting
Dural sinus stents for idiopathic intracranial hypertension

is the initial procedure of choice in this patient subgroup because it is safer and more durable than conventional surgical therapy. The proportion of this subgroup within the entire IIH population remains to be established.

Disclosure
Dr. Kumpe has received royalties from Cook, Inc.

Author contributions to the study and manuscript preparation include the following: Conception and design: Kumpe, Seinfeld. Acquisition of data: all authors. Analysis and interpretation of data: Kumpe, Bennett, Seinfeld, Pelak. Drafting the article: Kumpe, Seinfeld. Critically revising the article: Kumpe, Seinfeld. Statistical analysis: Kumpe. Administrative/technical/material support: Kumpe, Seinfeld. Study supervision: Kumpe, Seinfeld.

References

Manuscript submitted August 17, 2010.
Accepted October 24, 2011.
Please include this information when citing this paper: published online December 9, 2011; DOI: 10.3171/2011.10.JNS101410.
Address correspondence to: David Kumpe, M.D., Department of Radiology, 12401 East 17th Avenue, Mail Stop L-954, Aurora, Colorado 80045. email: david.kumpe@ucdenver.edu.