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Review

Neuroendovascular Cerebral Sinus Stenting in Idiopathic Intracranial Hypertension

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Keywords
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Abstract
Idiopathic intracranial hypertension (IIH) is a rare, ill-understood disease of significant morbidity. Because the pathophysiology is poorly understood, treatment protocols are not uniform and are directed towards alleviating the most common symptoms: headache and visual loss. In this review, we analyze 25 case series, all of which included IIH patients (*n* = 408) who were treated with placement of a venous sinus stent. Among 342 patients who had headache, 240 patients (70.2%) had improvement or resolution of headache after the stent insertion. Of the 217 patients documented to have visual problems, visual acuity was improved or stabilized in 161 patients (74.2%). Of the 304 patients with papilledema, 257 showed resolution or improved (84.5%). Of the 124 patients who presented with pulsatile tinnitus, it was resolved in 110 patients (88.7%) after stent placement. Endovascular management of dural sinus stenosis is therefore clinically efficacious in patients with IIH who have failed medical and surgical therapy.

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Introduction

Idiopathic intracranial hypertension (IIH), also known as pseudotumor cerebri, is a progressive disease characterized by headache, visual symptoms, tinnitus, and evidence of elevated CSF pressure on lumbar puncture. It has a prevalence of 0.9–1.07/100,000 in North America; however, when the criteria are modified to include only overweight women aged 20–44 years, the prevalence rises to 15–19/100,000 [1]. The original diagnostic criteria were proposed by Dandy, but with deeper understanding of the disease and advances in neuroimaging, these criteria have been modified over time. The current criteria as proposed by Friedman and Jacobson [2] in 2002 include: (1) signs and symptoms attributable only to elevated intracranial pressure (ICP), (2) CSF opening pressure of >25 cm H_2O, (3) normal CSF composition, and (4) no evidence of mass lesion or other structural causes using modern imaging techniques [2].

Pathophysiology

The pathophysiology of IIH has been a subject of constant debate and many theories have been proposed to explain the underlying mechanism of decreased CSF reabsorption and intracranial venous hypertension. Some of these theories include structural abnormalities within arachnoid granulations, dural venous sinus stenosis, or a combination of both. A hypothetical mechanism has been proposed which states that regardless of the initial cause of focal stenosis, venous hypertension proximal to the stenotic area leads to a further increase in ICP and subsequent worsening of stenosis, resulting in a positive feedback cycle [3]. Given the fact that stenosis of the transverse sinus is also present in asymptomatic patients, it is unclear whether it is a cause or a consequence of increased ICP. Nonetheless, there exists a hypothesis that by breaking the positive feedback and treating the focal stenosis, there is a chance to lower the ICP [4].

Diagnosis and Assessment

When papilledema is identified, it is critical to measure the blood pressure to exclude malignant hypertension. All mandatory tests of visual function should be recorded, including visual acuity, color vision, pupil examination, a dilated eye examination to document the optic nerve head, and macular findings to exclude an ocular cause of bilateral disc edema [5]. Quantification of disc edema is done using optical coherence tomography, which permits high-resolution noninvasive cross-sectional imaging of the neurosensory retina. Once papilledema has been diagnosed, brain imaging has a central role in excluding space-occupying lesions, obstructive hydrocephalus, and cerebral venous thrombosis. MRIs of the head and orbits with intravenous contrast and MR/CT venography should be performed [5]. The most commonly observed radiological signs of raised ICP are an empty sella, flattening of the posterior globes at the insertion of the optic nerves, protrusion of the optic nerve head into the vitreous, tortuosity of the intraorbital optic nerve, and demonstration of sinus stenosis on MR venography. Following imaging, lumboperitoneal shunting is mandatory to record the CSF opening pressure and exclude secondary causes of increased ICP. In addition to contemporary diagnostic modalities, venography with manometry and intravascular ultrasound should also be considered to assess the transmural pressure gradient across the stenotic segment.

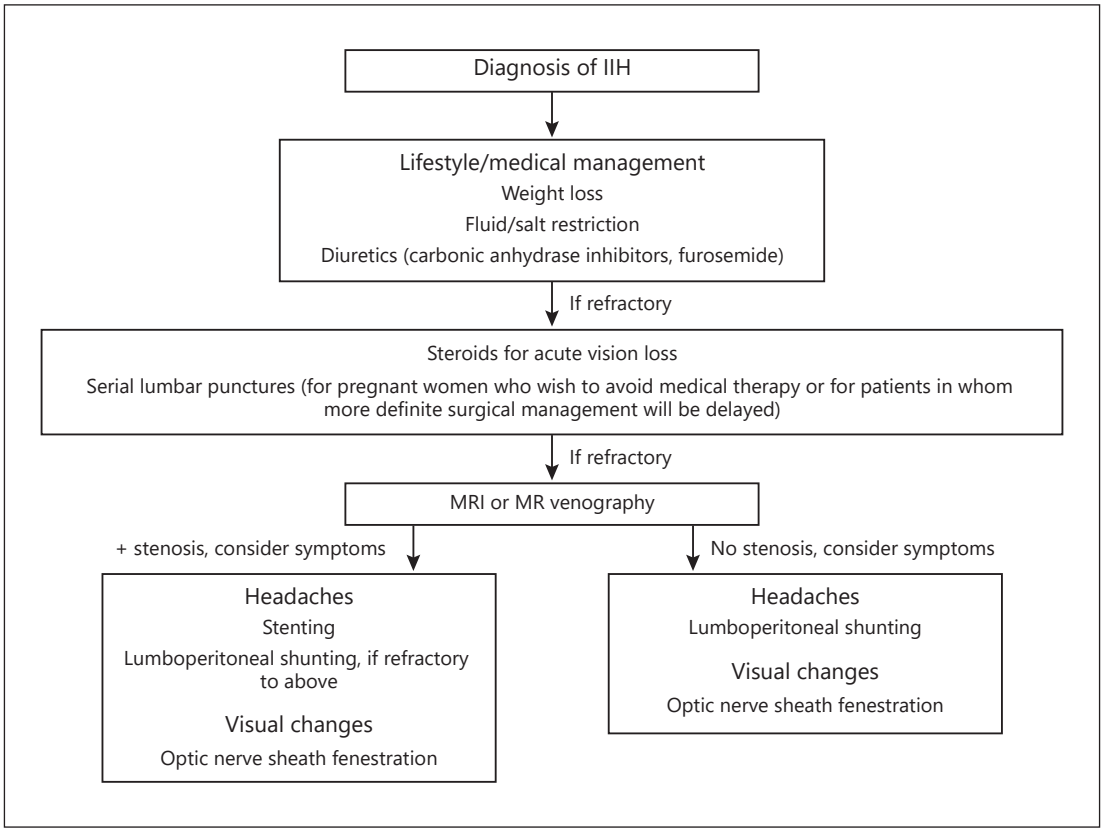

Fig. 1. Treatment algorithm for idiopathic intracranial hypertension (IIH).

Treatment

Because CSF dynamics are complex and not very well understood, the management algorithm is not well established (Fig. 1). It can be subdivided into conservative or medical management, followed by surgical management if the patient fails the medical management or alarming symptoms are present. The goal of the management is to preserve visual function and reduce headache disability. Obese patients are encouraged to lose weight and carbonic anhydrase inhibitors are the first line of medical therapy [6]. Traditionally, repeated lumbar punctures were performed but the evidence of this practice having any long-term benefit is lacking in the literature.

If the patient fails medical management or there is evidence of severe optic neuropathy that can lead to permanent vision loss, surgical options are then considered. These include optic nerve sheath fenestration (ONSF), CSF diversion procedures, including either lumboperitoneal or ventriculoperitoneal shunting [7], bariatric surgery for obesity [8], and the newly introduced transverse sinus stenting. In IIH patients with focal venous sinus stenosis, emphasis on the management of sinus stenosis by stenting is a novel, emerging treatment option providing very satisfactory clinical outcomes and low rates of complication and revision. Among all of the surgical options, the long-term outcomes of endovascular stenting with regards to visual function and headache when followed for 1 year were most promising, with improvement in visual acuity in 78% of cases and headache resolution in 77% of cases.

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Table 1. Summary of clinical outcomes

Study	Total patients	Headache	Vision improvement	Papilledema	Pulsatile tinnitus
Higgins et al., 2002 [10]	1	1/1	NR	1/1	NR
Higgins et al., 2003 [15]	12	7/12	7/12	5/8	NR
Ogungbo et al., 2003 [19]	1	1/1	1/1	1/1	NR
Owler et al., 2003 [20]	4	4/4	4/4	2/3	NR
Rajpal et al., 2005 [21]	1	1/1	1/1	1/1	NR
Donnet et al., 2008 [22]	10	8/10	7/8	10/10	5/5
Paquet et al., 2008 [23]	1	1/1	1/1	1/1	NR
Arac et al., 2009 [24]	1	1/1	NR	NR	1/1
Bussière et al., 2010 [25]	10	10/10	4/4	10/10	NR
Zheng et al., 2010 [26]	1	1/1	1/1	1/1	NR
Albuquerque et al., 2011 [14]	15	12/15	NR	NR	NR
Kumpe et al., 2012 [11]	18	10/13	15/15	15/16	NR
Ahmed et al., 2011 [12]	52	35/43	9/13	45/45	17/17
Lazzaro et al., 2012 [27]	3	2/3	3/3	2/2	1/1
Fields et al., 2013 [28]	15	10/15	13/14	15/15	11/14
Radvany et al., 2013 [29]	12	7/12	11/12	11/12	11/11
Elder et al., 2015 [30]	4	4/4	2/4	3/4	2/2
Teleb et al., 2015 [31]	18	10/18	14/18	18/18	4/5
Boddu et al., 2016 [32]	37	NR	NR	NR	28/29
Satti et al., 2017 [33]	43	27/43	15/35	13/22	NR
Aguilar-Pérez et al., 2017 [34]	51	31/37	31/38	42/50	9/9
Dinkin and Patsalides, 2017 [35]	13	11/13	10/10	11/13	11/11
Shields et al., 2019 [36]	42	18/42	NR	29/39	NR
Asif et al., 2018 [38]	41	26/40	12/23	19/30	10/19
Miyaichi et al., 2018 [37]	2	2/2	NR	2/2	NR
Totals	408	240/342 (70.2%)	161/217 (74.2%)	257/304 (84.5%)	110/124 (88.7%)

NR, not reported.

Methods

Using PubMed, we performed a search of the English language literature with several combinations of the keywords "Idiopathic Intracranial Hypertension," "Pseudotumor Cerebri," "Benign Intracranial Hypertension," "Endovascular," "Stent," and "Venous Sinus Stenting" to identify studies published after 1970 in which cases of IIH were treated with placement of a venous sinus stent. We identified 24 case series (a total of 367 patients) that met our inclusion criteria.

Results

Among 342 patients who had headache, 240 patients (70.2%) had improvement or resolution of headache after the stent insertion. Of the 217 patients documented to have visual problems, visual acuity was improved or stabilized in 161 patients (74.2%). Of the 304 patients with papilledema, 257 showed resolution or improved (84.5%). Of the 124 patients who presented with pulsatile tinnitus, it was resolved in 110 patients (88.7%) after stent placement. Table 1 summarizes the patient outcomes for each of the included studies. A

Table 2. Major and minor criteria for cerebral sinus stenting [9]

Major criteria for cerebral sinus stenting (all required)
Refractory to maximal medical therapy
Pressure gradient across stenosis 8 mm Hg
ICP 22 mm Hg
Visual changes, papilledema, focal neurological deficits, severely disabling headache
No contraindication to dual platelet therapy
Minor criteria for cerebral sinus stenting (one required)
Intolerance to repeated lumbar puncture or lumbar drain
Dural sinus stenosis of 50% on CT or MR venography
Failed surgical interventions, including shunting or optic nerve fenestration
Pulsatility detected by manometry which is reduced after stenosis
Patient preference

common complication of venous sinus stenting is ipsilateral headache, which occurs in 20–100% of cases and normally resolves within a few days after the procedure. Intracranial hemorrhage is a serious complication that is rarely seen after the procedure (4–6%). Proximal stent stenosis was found in some studies with unclear etiology. In contrast to arterial stenting, in-stent restenosis is very rare in venous sinus stenting. Aspirin and clopidogrel are generally required for 3–4 days prior to stent placement and are continued for 3–6 months, after which time clopidogrel is discontinued.

Discussion

Pathophysiology

IIH is a disorder of poorly understood pathophysiology that is progressive in nature; permanent vision loss is found in 25% of cases and 1–2% of new cases each year are registered blind [5]. Recently, several groups have been investigating this pathophysiology by undertaking catheter studies in the venous sinuses (cerebral venography) and recording intra-sinus pressures (manometry). These groups have documented high pressures in the venous sinuses in patients with IIH. The high pressures are occasionally secondary to systemic venous hypertension but are more often the result of stenotic lesions of the venous sinuses, causing partial obstruction to cranial venous outflow. This has led some investigators to propose intracranial venous hypertension as the common pathway in the etiology of IIH [4].

The efficacy of stenting is predicated on the notion that venous outflow obstruction plays some part in the etiology of signs and symptoms in IIH patients. If venous outflow obstruction were the cause, then dilating the stenosis and abolishing the pressure gradient should be curative. If the lateral sinus stenoses were secondary to raised ICP in patients who benefited from stenting, these stenoses must have been responsible for an increase in ICP large enough to render them symptomatic. In the review series, the endovascular stent placement does appear to be an efficacious treatment option with significant resolution of headache, papilledema, and pressure gradients but the analysis is limited by the retrospective nature of the studies analyzed and the lack of coordinated data reported in the studies considered. This leads to a decreased power in the analysis of certain variables included in this report. Moreover, the criteria for considering endovascular stenting as the treatment modality needs to be defined. One study proposed a set of criteria for cerebral venous stenting, which included major and minor criteria [9]. According to this study, the major criteria the patient should demonstrate to indicate cerebral venous stenting are failed maximal medical therapy or

fulminant course refractory to medical treatment with rapidly worsening vision, a pressure gradient across the stenosis of greater than or equal to 8 mm Hg, an ICP of greater than or equal to 22 mm Hg, visual changes, papilledema, other focal objective neurological symptoms, or severely disabling headaches, and no contraindications to dual antiplatelet therapy. In addition to demonstrating all of the aforementioned major criteria, the patient must also demonstrate at least one of the following minor criteria: intolerance to repeated lumbar puncture or lumbar drain, dural sinus stenosis of greater than or equal to 50% on CT or MR venography, failed surgical shunting procedure or optic nerve fenestration, pulsatility demonstrated by manometry which is reduced after stenosis, or the patient's own preference for the procedure [9]. These major and minor criteria as described by Teleb et al. [9] are summarized in Table 2.

Complications of Stenting

Even though endovascular stenting has shown promising results in alleviating the symptoms associated with IIH, it is not without its complications. A common complication of venous sinus stenting is ipsilateral headache, which occurs in 20–100% of cases and normally resolves within a few days after the procedure. Much more uncommon is the incidence of intracranial hemorrhage. These complications may be due to residual venous outflow obstruction [10, 11]. Ahmed et al. [12] reported two patients out of 52 (4%) with major cerebrovascular complications. One patient developed a subdural hematoma caused by the guidewire perforating a vein and another patient developed subarachnoid and intracerebral bleeding at the time of emergency treatment for fulminant IIH [12]. Other potential complications include venous sinus perforation, the development of a new stenosis proximal to the stent, and thrombosis [12–15]. The necessity to re-stent is not common, but it is nonetheless an appreciable possibility for some patients [12]. In their retrospective review of 52 patients, Ahmed et al. [12] found that 6 (12%) required re-stenting.

Comparisons with Other Treatments

In addition to endovascular stenting, other surgical procedures have resulted in some success in alleviating the symptoms of IIH. Some patients are treated with ONSF; however, ONSF seems to be more effective in treating symptoms specific to visual impairment and it is less effective in treating the most commonly cited symptom (headaches) [16]. ONSF was specifically shown to improve visual acuity, visual fields, and color vision. Another surgical procedure routinely conducted is ventriculoperitoneal shunting. Compared to lumboperitoneal shunting, ventriculoperitoneal shunting results in a lesser likelihood of need for shunt revision, decreased length of stay, and decreased overall charges to the health care system [17]. However, compared to endovascular stenting, ventriculoperitoneal shunting demonstrated less of an improvement in visual acuity and headaches [18]. Overall, endovascular stenting for IIH seems to be a much safer and efficacious treatment when compared to ONSF, lumboperitoneal shunt, and ventriculoperitoneal shunt. Although the preliminary data supports this observation, more comprehensive clinical trials are needed to support the procedure's efficacy and safety.

Conclusion

Endovascular management of dural sinus stenosis appears technically feasible and safe. It is clinically efficacious in patients with IIH who have failed medical and surgical therapy with dural sinus stenosis. Nonetheless, there is a need for a formal multicenter clinical trial to prospectively measure safety and long-term efficacy of this procedure.

Disclosure Statement

The authors have no personal or institutional interest with regards to the authorship and/or publication of this paper.

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