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Noninvasive Monitoring and Neurointerventional Management of Idiopathic Intracranial Hypertension

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Abstract

Idiopathic intracranial hypertension (IIH) is characterized by isolated rise in intracranial pressure (ICP) leading to chronic, debilitating headaches, tinnitus, and vision loss. Conventional diagnostics and monitoring primarily require the use of invasive procedure like lumbar puncture to measure ICP, while traditional management strategies involve weight reduction and medical treatment with acetazolamide. In an effort to reduce the need for invasive procedures, noninvasive methods of ICP monitoring such as optic nerve sheath diameter measurements and two-depth transcranial Doppler ultrasonography have been developed. In cases of refractory and fulminant IIH, surgical management strategies such as optic nerve sheath fenestration (ONSF), ventriculoperitoneal (VP) and lumboperitoneal (LP) shunting, and transverse venous sinus stenting are used to relieve symptoms via ICP reduction. While ONSF and VP/LP shunting exhibit utility primarily for the treatment of vision loss and headache, respectively, venous sinus stenting may prove to be an effective option in the management of all symptoms of IIH. Most importantly, consideration of the patient's individual symptoms and values should be taken into account when choosing the optimal surgical management strategy for patients with IIH.

Keywords

- idiopathic intracranial hypertension
- optic nerve sheath
- transcranial Doppler ultrasonography
- optical coherence tomography
- electroretinography
- ventriculoperitoneal shunt
- lumboperitoneal shunt
- venous sinus stenting

Introduction

The term idiopathic intracranial hypertension (IIH) refers to a condition of elevated intracranial pressure (ICP) without a detectable cause. IIH is a relatively rare condition with an incidence of 1.2 per 100,000 people per year. More specifically, young, obese females are disproportionately affected by IIH with incidence rates as high as 10.3 per 100,000 people annually among the female population aged between 14 and 45.[1] Common presenting symptoms of IIH include headache, vomiting, tinnitus, transient visual abnormalities, papilledema, and vision loss.[2] Vision loss in IIH, specifically visual field defect, is often long term and can be permanent, making it the primary focus of monitoring and treatment strategies. Visual acuity can also be affected in patients with IIH, especially in cases of fulminant IIH associated with severe papilledema and optic neuropathy.[3] Visual function in medically treated patients with IIH has been demonstrated to improve overtime[4-6]; however, permanent damage is possible in cases of fulminant IIH.[7]

While there is currently no consensus regarding an established pathophysiologic cause of IIH, a variety of theories have been proposed. One such theory suggests that aldosterone excess, as seen in obese patients, acts at the mineralocorticoid receptor of the choroid plexus resulting in increased cerebral spinal fluid (CSF) production. Another theory proposes that estrogen or retinoic acid may be affecting outflow resistance of the CSF.[8] Transverse venous sinus stenosis, which has been identified in over 90% of IIH patients,[9] is also a proposed contributor to elevated ICP in IIH patients and is of particular relevance due to the growing use of venous sinus stent procedures for ICP reduction in patients with IIH.

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Due to the unclear pathophysiology of IIH and the frequent occurrence of new findings in the literature, the diagnostic criteria for IIH have been revised multiple times since Walter Dandy first developed a set of criteria in 1937. Most recently, the criteria have been modified by the American Academy of Neurology as well as for the Idiopathic Intracranial Hypertension Treatment Trial (IIHTT). Conventional diagnosis requires physical symptoms associated with raised ICP, absence of localized neurological or radiographic findings, and opening pressure greater than 250 mm H_2O (normal reference range: 60–250 mm H_2O[10]) with normal CSF composition detected by lumbar puncture. More recently, radiographic findings such as transverse venous stenosis and empty sella have been incorporated into the diagnosis of IIH; yet, these findings are not sufficient on their own to make a definitive diagnosis.[11,12] Additionally, while it does not replace the gold standard method of invasive ICP detection by lumbar puncture, noninvasive measurement of ICP has been made possible by emerging techniques such as measurement of optic nerve sheath diameter (ONSD) as well as two-depth transcranial Doppler (TCD) ultrasonography.

When managing patients with IIH, first-line treatment strategy involves weight reduction, often combined with the use of the carbonic anhydrase inhibitor acetazolamide, to reduce the production of CSF and consequently lower ICP.[13,14] A reduction of 10% of current body weight with a target of 1 to 2 lbs per week has been shown to be effective in improvement of symptoms.[15] The effects of acetazolamide have been proven efficacious in improving visual field, CSF opening pressure, and papilledema by the IIHTT, the first and only randomized, double-blinded control trial prospectively studying the treatment of IIH. While the results of the IIHTT are promising, use of acetazolamide failed to demonstrate improvement in headaches and transient visual obscurations and the improvements due to acetazolamide use were only demonstrated in patients with mild vision loss.[16] For IIH patients with more severe symptoms or rapidly progressing vision loss, surgical procedures are necessary to prevent permanent loss of vision. Optic nerve sheath fenestration (ONSF), CSF shunting, and transverse venous sinus stenting are the current surgical methods used to reduce ICP and provide symptomatic relief in patients with IIH. ONSF has traditionally been demonstrated to be most effective in improving visual function, while CSF shunting has been more closely associated with headache relief.[17,18] The emergence of transverse venous sinus stenting, however, may challenge the more conventional surgical treatment approaches.

In an era of high cost healthcare technology and development of a more personalized approach to patient care, it is critical to establish diagnostic and treatment options that can be applied to each individual without the need for repeat procedures or extraneous expenditures due to surgical complications. The current review, therefore, provides an up-to-date and comprehensive summary of the evolving noninvasive diagnostic and monitoring strategies for IIH as well as an investigative comparison of the efficacy, safety, and cost of the major surgical procedures used to manage symptoms in patients with IIH.

Methods

PubMed searches were conducted through July 2019 with the following keywords: pseudotumor cerebri, optic nerve sheath, TCD ultrasonography, optical coherence tomography, electroretinography, ventriculoperitoneal (VP) shunt, lumboperitoneal (LP) shunt, and venous sinus stenting. References from all relevant articles were also reviewed to capture all pertinent articles. Threshold, sensitivity, and specificity data of noninvasive ICP monitoring techniques was compiled and ranges were used to summarize data from a total of 14 studies using ONSD (3 meta-analyses and 5 prospective observational studies, 5 retrospective observational studies) and a total of 5 prospective observational studies using two-depth TCD data describing improvement in vision, papilledema, and headache due to neurointerventional management strategies was piled and ranges were used to summarize data from a total of 7 meta-analyses that each reported pooled data for one, two, or all three neurointerventional management strategies for IIH. No formal statistical analysis was performed.

Noninvasive Diagnostics and Monitoring

Noninvasive Measurement of ICP with ONSD and Two-Depth Transcranial Doppler

The development of noninvasive diagnostic methods to monitor ICP in patients with IIH could reduce the requirement for gold standard, invasive approaches such as lumbar puncture. A variety of noninvasive strategies for ICP monitoring have been studied including measurements of ONSD, TCD ultrasound, tympanic membrane displacement, magnetic resonance imaging (MRI), computed tomography (CT), pupillometry, visually evoked potentials, near-infrared spectroscopy, optoacoustic emission, venous ophthalmodynamometry, anterior fontanelle assessment, and electroencephalogram.[19] Of these methods, ONSD and TCD, in particular two-depth TCD, appear to be the most extensively studied and most promising methods of noninvasive ICP monitoring. The measurement of the ONSD by use of ultrasonography, CT, or T2-weigted MRI has proven to be an effective and efficient way to measure ICP noninvasively as enlargement of the optic nerve head is a direct consequence of increased ICP since the optic nerve sheath is continuous with the meningeal layers. ONSD by ultrasonography provides valuable bedside assessment of ICP especially in the emergency setting.[20] Recent studies using any of these three methods of ONSD measurement have demonstrated that the enlargement of ONSD in patients with elevated ICP or cerebral edema ranges from 4.58 to 6.9 mm versus 3.55 to 5.2 in healthy controls. These methods have been used to detect elevated ICP with sensitivity and specificity ranging from 84 to 98% and 42 to 92%, respectively (►**Table 1**).[21-36] The values can be compared with the results of two different meta-analyses from 2011 and 2015 that demonstrated the ability of ONSD ultrasonography to yield average sensitivity and specificity ranging from 90 to 95% and 85 to 92%, respectively.[29,30] A more recent meta-analysis found sensitivity and specificity to range from 88 to 95% and 74 to 96%, respectively.[31]

Table 1 Studies evaluating the diagnostic value of ONSD techniques for measurement of ICP

ONSD					
Study, year	*n*	Technique	Threshold (mm)	Sensitivity (%)	Specificity (%)
Dubourg et al, 2011[29a]	231	ONSD by ultrasound	5–5.9	90	85
Ohle et al, 2015[30a]	478	ONSD by ultrasound	5	96	92
Robba et al, 2018[31a]	320	ONSD by ultrasound	4.8–6.3	88–94	74–96
Wang et al, 2015[21]	279	ONSD by ultrasound	4.2	95	92
Lee et al, 2016[22]	134	ONSD by ultrasound	5.5	99	85
Amini et al, 2013[23]	50	ONSD by ultrasound	5.5	100	100
Strumwasser et al, 2011[35]	10	ONSD by ultrasound	–	36	38
Salahuddin et, al 2016[24]	102	ONSD by CT	5.7	84	71
Sekhon et al, 2014[25]	57	ONSD by CT	6	97	42
Bekerman et al, 2016[37]	35	ONSD by CT	5.5	–	–
Vaiman et al, 2016[28]	443	ONSD by CT	5.5	–	–
Vaiman et al, 2016[32]	312	ONSD by CT	5.5	–	–
Geeraerts et al, 2008[26]	38	ONSD by MRI	5.82	90	92
Ozturk et al, 2017[27]	16	ONSD by MRI	5	–	–
Range			**4.2–6.3**	**36–100**	**38–100**

Abbreviations: CT, computed tomography; ICP, intracranial pressure; MRI, magnetic resonance imaging; ONSD, optic nerve sheath diameter.
[a]Indicates meta-analysis.

In testing for elevated ICP, Vaiman et al have proposed an ideal cutoff ONSD diameter of 5.5 mm[32]; yet, others have used cutoff diameters ranging from 4.1 to 6.0 mm (►**Table 1**). In a retrospective study of patients specifically with IIH, increased ONSD, defined by a cut-off diameter of 5.5 mm, was identified in 94.3% of the study cohort and ONSD was found to be 6.2 1.2 mm and 6.3 0.9 mm in the right and left eye, respectively.[33] Based upon these findings and the proposal made by Vaiman et al, use of ONSD with cutoff diameter of 5.5 mm is found to be adequate in detecting IIH with high sensitivity. Shofty et al also found ONSD to be enlarged in IIH patients versus healthy controls; however, these findings were described in a sample of children aged between 4 and 17.[34] While ONSD has been proven effective in patients with IIH, Bekerman et al noted a potential limitation with the ONSD method in that, cases with narrow optic canal lumen (< 10 mm^2) result in false-negative tests and conclude that if the lumen of the canal is < 10 mm^2, the ONSD method should not be used.[37] It should also be noted that one study found the ONSD method of ICP measurement was unreliable, with sensitivity and specificity values of 36 and 38%, respectively.[35] Despite these findings as well as the fact that invasive ICP measurement via lumbar puncture remains the gold standard, measurement of ONSD has overall demonstrated efficacy and offers an efficient, cost-effective, noninvasive method of diagnosis and monitoring of ICP in patients with IIH.

TCD ultrasonography takes advantage of the relationship between ICP and the blood flow velocity in the middle cerebral artery. Multiple studies have exhibited a positive correlation between the TCD-derived pulsatility index (PI) and ICP with correlation coefficients ranging from 0.90 to 0.93.[36,38] The sensitivity and specificity of TCD as a test of elevated ICP have been found to range from 81 to 88% and 96 to 97%, respectively, using a PI cutoff range of 1.26 to 1.33.[36,39] Despite these findings, other studies indicate that PI is not a reliable predictor of elevated ICP.[38,40] Zweifel et al do, however, specify that extreme values of PI may be useful in making the decision to undergo invasive ICP monitoring.[41]

While the use of standard TCD has not been proven to be a reliable method for ICP monitoring, two-depth TCD, which utilizes the simultaneous measurement of two different segments of the ophthalmic artery to determine an absolute value of ICP, may be more promising. This method involves simultaneous measurement of intracranial and extracranial blood flow velocity through the ophthalmic artery. While measurements are being made, an external pressure is applied to the extracranial segment of the artery. The external pressure at which the blood flow velocities equalize between the intracranial and extracranial segment is an accurate estimator of ICP.[42] Sensitivity and specificity of the TCD and two-depth TCD approaches combined range from 68 to 89% and 84 to 97%, respectively (►**Table 2**).[36,38,39,43,44] One study comparing the two-depth approach versus invasive ICP monitoring demonstrated both accuracy with a low systematic error of 0.12 mm and precision with a standard deviation of recordings of 2.19 mm Hg.[44] Additionally, Koskinen et al identified a positive correlation between invasive ICP monitoring and two-depth TCD ICP monitoring with $r = 0.74$.[45] Interestingly, in a comparative analysis of two-depth TCD and ONSD, it was found that two-depth TCD displayed greater diagnostic reliability versus ONSD. The sensitivity and specificity were found to be 37 and 58%, respectively, for ONSD and 68 and 84.3%, respectively, for two-depth TCD.[46] It should be noted that these findings for the ONSD group do not align with the previously discussed sensitivity and specificity ranges using this technique. Furthermore, there are

Table 2 Studies evaluating the diagnostic value of TCD techniques for measurement of ICP

TCD					
Study, year	***n***	**Technique**	**Threshold (PI)**	**Sensitivity (%)**	**Specificity (%)**
Bellner et al, 2004[36]	81	TCD	–	89	92
Prunet et al, 2012[43]	20	TCD	1.35	80	90
Wakerly et al, 2015[38]	78	TCD	1.26	81	96
Wang et al, 2014[39]	93	TCD	1.34	89	97
Ragauskas et al, 2012[44]	85	2-depth TCD	–	68	84
Range			**1.26–1.35**	**68–89**	**84–97**

Abbreviations: ICP, intracranial pressure; TCD, transcranial Doppler.

fewer studies conducted using the two-depth TCD method as compared with ONSD. Two-depth TCD also involved the use of an extracranial pressure apparatus limiting its ease of use especially as compared with normal TCD.[47] However, two-depth TCD does retain the superior ability to record an absolute value of ICP and does not require a patient-specific calibration. Nonetheless, it is clear that more research and development are necessary before replacing the gold standard invasive ICP measurement strategies with noninvasive methods that can become a serious consideration.

Radiographic Imaging Signs for IIH Diagnosis

As previously discussed in the conventional diagnostic criteria for IIH, radiographic imaging has, in the past, only been used for the purposes of diagnostic exclusion. Recent findings in the literature, however, suggest that specific radiographic signs, while not sufficient on their own, may provide significant support toward a diagnosis of IIH. A recent meta-analysis combining the results of 21 different studies with a total of 724 patients with IIH found transverse venous sinus stenosis to offer the greatest diagnostic reliability compared with other MRI signs and calculated a pooled sensitivity and specificity for transverse venous stenosis as an indicator of IIH of 84.4 and 94.9%, respectively. MRI findings of “empty” sella, posterior displacement of pituitary stalk, meningoceles, posterior globe flattening, optic nerve head protrusion, optic nerve enhancement, optic nerve sheath distension, optic nerve tortuosity, slit-like ventricles, tight subarachnoid spaces, and inferior position of cerebellar tonsils demonstrated high specificity, but very low sensitivity as indicators of IIH.[48] The idea that transverse venous sinus stenosis offers the best predictive value in the diagnosis of IIH as compared with other radiographic signs is strengthened by the identification of venous attenuation on CT in 96% of patients in one particular cohort of patients with IIH.[49]

Surgical Management Strategies

Optic Nerve Sheath Fenestration

When the primary complaints are related to visual field and papilledema, ONSF is a valuable treatment option. A medial transconjunctival orbitotomy is performed and the retrobulbar portion of the optic nerve is exposed. Micropunctures are made in the optic nerve sheath to relieve CSF pressure within the optic nerve sheath compartment.[50] ONSF allows for direct relief of CSF pressure in the optic nerve sheath making it a promising surgical intervention for patients with IIH who have failed medical treatment. Recent studies have demonstrated improvement or stability of visual acuity and visual fields in 86.2 to 94.4% and 86.7 to 95.9% of patients with IIH, respectively.[51-53] Yaqub et al also reported improved papilledema in 87.1% of IIH patients undergoing ONSF and indicated a significant change in papilledema as well as visual acuity from preoperative values. These findings can be compared with the results of four meta-analyses from 2007 to 2017 that calculated average improvement in visual acuity ranging from 59 to 85% of IIH patients undergoing ONSF (►**Table 3**).[17,18,54,55] Additionally, results of the meta-analyses showed average improvement in papilledema and headaches ranged from 80 to 81% and 44 to 81% of IIH patients undergoing ONSF, respectively (►**Tables 4** and **5**).[18,54-58] While there are few reports of major complications due to ONSF, common minor complications include diplopia, corneal dellen, and tonic pupil.[59] Several risk factors have been identified for ONSF failure and include CSF opening pressure of > 50 cm H_2O, male sex, poor visual acuity at presentation, and longer duration of symptoms before surgery.[53,60] Despite potential minor complications and the risk of failure, ONSF provides an effective and relatively safe option for patients whose primary symptoms are related to visual acuity and papilledema.

CSF Shunting

Shunt procedures for the management of IIH provide a method of CSF shunting into the peritoneum to decrease ICP. The shunts are placed in the ventricles or the lumbar space and the CSF is directed to drain into the peritoneum. In a recent study, visual acuity, papilledema, and headaches were improved at a mean follow-up of 15 months in 93, 100, and 84%, respectively, of IIH patients undergoing VP shunting.[61] Meta-analyses conducted from 2007 to 2019 demonstrate that shunting, whether VP or LP, show improvement in visual acuity, papilledema, and headaches in an average of 38 to 56%, 70%, and 62 to 80% of patients with IIH, respectively (►**Tables 3**, **4** and **5**).[17,18,54-58] In consideration of the differential efficacy of VP versus LP shunts, one analysis reports that LP shunts are associated with a significantly increased likelihood of shunt revision and subsequent greater healthcare costs ($3.7 vs. $5.4 million) as compared with VP shunts.[62] A more recent study, however, demonstrates statistically similar rates of shunt failure and complication between VP

Table 3 Comparison of percentage of IIH patients with improved visual acuity symptoms by procedure type calculated by different meta-analyses

Study, year	ONSF			Shunt			Stent		
	n	MFU (mo)	VA impr.	*n*	MFU (mo)	VA impr.	*n*	MFU (mo)	VA impr.
Satti et al, 2015[18]	712	21	59	435	41	54	136	22	78
Lai et al, 2014[54]	332	38	67	61 (VP); 287 (LP)	46 (VP); 48 (LP)	49 (VP); 56 (LP)	88	21	84
Feldon, 2007[17]	252	21	80	31 (VP); 44 (LP)	48 (VP); 58 (LP)	38 (VP); 44 (LP)	17	11	47
Tarrats et al, 2017[55]	34	–	85	–	–	–	–	–	–
Range			**59–85**			**38–56**			**47–84**

Abbreviations: IIH, idiopathic intracranial hypertension; impr., improvement; LP, lumboperitoneal; MFU, mean follow up; ONSF, optic nerve sheath fenestration; VA, visual acuity; VP, ventriculoperitoneal.

Table 4 Comparison of percentage of IIH patients with improved papilledema by procedure type calculated by different meta-analyses

Study, year	ONSF			Shunt			Stent		
	n	MFU (mo)	Papilledema impr.	*n*	MFU (mo)	Papilledema impr.	*n*	MFU (mo)	Papilledema impr.
Satti et al, 2015[18]	712	21	80	435	41	70	136	22	83
Tarrats et al, 2017[55]	34	–	81	–	–	–	–	–	–
Nicholson et al, 2019[56]	474	–	–	–	–	–	474	–	93
Starke et al, 2015[57]	185	22	–	–	–	–	185	22	94
Puffer et al, 2013[58]	143	22	–	–	–	–	143	22	97
Range			**80–81**			**70**			**83–97**

Abbreviations: IIH, idiopathic intracranial hypertension; impr., improvement; MFU, mean follow up; ONSF, optic nerve sheath fenestration.

Table 5 Comparison of percentage of IIH patients with improved headache symptoms by procedure type calculated by different meta-analyses

Study, year	ONSF			Shunt			Stent		
	n	MFU (mo)	Headache impr.	*n*	MFU (mo)	Headache impr.	*n*	MFU (mo)	Headache impr.
Satti et al, 2015[18]	712	21	44	435	41	80	136	22	83
Lai et al, 2014[54]	332	38	36	61 (VP); 287 (LP)	46 (VP); 48 (LP)	62 (VP); 75 (LP)	88	21	82
Tarrats et al, 2017[55]	34	–	81	–	–	–	–	–	–
Nicholson et al, 2019[56]	474	–	–	–	–	–	474	–	79
Starke et al, 2015[57]	185	22	–	–	–	–	185	22	78
Puffer et al, 2013[58]	143	22	–	–	–	–	143	22	88
Range			**44–81**			**62–80**			**78–88**

Abbreviations: IIH, idiopathic intracranial hypertension; impr., improvement; LP, lumboperitoneal; MFU, mean follow up; ONSF, optic nerve sheath fenestration; VP, ventriculoperitoneal.

and LP shunts.[63] One major problem with shunts for surgical management of IIH is the high rate of major complications that has been calculated to be 40.5% in a sample of 435 patients.[18] Huang et al also demonstrated a decrease in functioning shunts over from 80 to 48% over 12 to 36 months post-surgery.[64] Despite its apparent efficacy in reducing the symptoms of papilledema and headache in patients with IIH, surgical shunting is also associated with a high rate of complication, decreased functioning overtime, and unclear efficacy in improving vision loss. The LP shunts with programmable valve systems are a potential alternative in avoiding brain injury, lower failure, and complication rates, lower incidence of intracranial hypotension, and flexibility in adjusting valve pressure settings postoperatively circumventing complications of under and over drainage.[65,66]

Venous Sinus Stenting

Venous sinus stenting is an emerging neurointerventional option for the surgical management that targets venous sinus stenosis in patients with IIH.[67] Using percutaneous transvenous access, sinusography is performed to measure the pressure gradient across the transverse sinus stenosis. If there is a pressure gradient of over 8 cm of water across the transverse sinus stenosis, the patient is placed on dual antiplatelets for 5 days. At a second sitting under general anesthesia, the stenosis is crossed using a microwire and microcatheter system over a roadmap obtained from carotid angiogram performed through a diagnostic catheter placed in the common carotid artery. Stenting with a self-expandable carotid stent of appropriate size and length is performed at the stenotic site (►**Fig. 1**). Most of the lesions resolve after stenting and angioplasty is rarely used. After stenting, pressure measurements are repeated across the stented segment to document that the pressure gradient is nullified. The patient is followed up in the clinic with CT venography to document that the stent is patent (►**Fig. 2**) and is placed on monotherapy for antiplatelet medication. The most recent and comprehensive meta-analysis to date on the topic of transverse venous sinus stenting, which includes analysis of 474 patients from 20 studies, calculated, on average, that 93.7 and 79.6% of IIH patients undergoing the stenting procedure showed improvement in

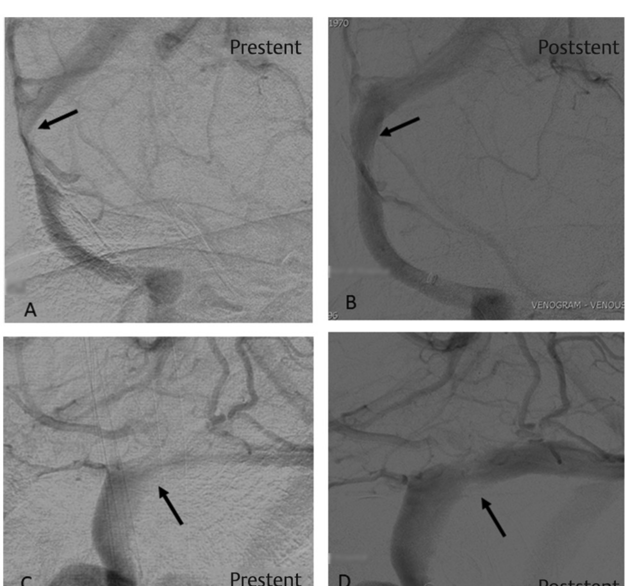

Fig. 1 (**A**–**D**) Digital subtraction angiography showing anteroposterior and lateral pre-stent images with narrowing (black arrows) of the right transverse–sigmoid sinus junction (**A** and **C**) and anteroposterior and lateral post-stent images showing improved caliber of the stenosis (black arrows) (**B** and **D**).

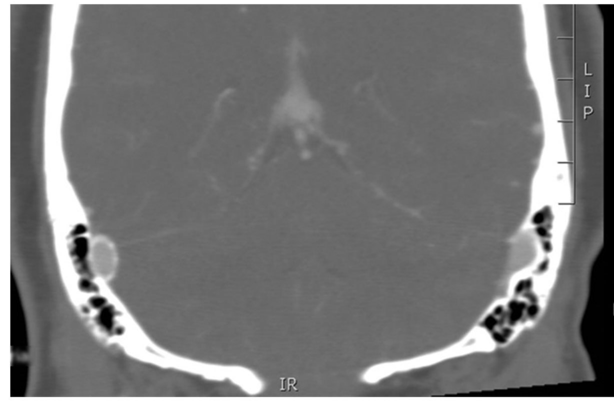

Fig. 2 Computed tomography venography of the same patient post-stenting on clinical follow-up after 6 weeks showing right transverse–sigmoid sinus stent to be widely patent (black arrow).

papilledema and headache, respectively.[56] While the former study did not perform analysis of visual improvement, other meta-analyses have demonstrated an improvement in visual acuity, papilledema, and headache in an average of 47 to 84%, 83 to 97%, and 78 to 88% of IIH patients undergoing transverse venous sinus stenting, respectively (►**Tables 3**–**5**).[17,18,54–58] It should be mentioned that one potential limitation of these findings is that these results are largely only applicable to those with patients who would have been documented with venous stenosis whereas those treated with ONSF or CSF shunting may or may not have demonstrated venous stenosis. Additional studies show venous stenting effectively reduces ICP immediately following the procedure and results in a significantly decreased CSF opening pressure for up to 3 months during the postoperative period.[68,69] Potential complications occur at a rate of 1.6 to 7.4% and include occlusion of the vein of Labbe, subdural hematoma, and subarachnoid hemorrhage.[18,56–58] This rate is lower than the identified rate of complication of 40.5% associated with CSF shunting identified by Satti et al and is suggested to contribute to the significantly lower financial cost of venous sinus stenting per 100 procedures as compared with CSF shunting.[70] Risk factors for failed stent procedures include high CSF opening pressure preoperatively, female gender, and compression of the transverse sigmoid junction.[71,72] There is some controversy whether venous sinus stenosis is a primary or secondary to IIH. Rohr et al presented three case reports where the patients developed a new stenosis of the transverse sinus proximal to the stent placement.[73] Ducruey et al did, however, find that at follow-up of 30 IIH patients undergoing transverse venous sinus stenting with mean follow-up of 23 months, all 30 patients exemplified patent stents demonstrating the long-term efficacy of the procedure.[74] Occasionally, chronic cerebral venous sinus thrombosis may be seen associated with IIH. Few studies have evaluated the role of thrombolysis or mechanical thrombectomy along with venous sinus stenting in these cases and found it be an effective form of management.[75,76] Transverse venous sinus stenting, therefore, offers a relatively safe and effective strategy for the improvement in visual acuity, headache, and papilledema in patients with IIH. In comparing different surgical options for IIH, transverse venous sinus stenting appears to be an effective surgical management strategy in terms of ability to provide comprehensive symptom relief for patients with IIH.

Conclusion

The development and application of noninvasive diagnostic strategies and reliable neurointerventional management strategies for patients with IIH are important as healthcare shifts toward a focus on precision care and cost-effectiveness. While no noninvasive method can currently measure ICP with the same accuracy as invasive ICP monitoring, use of ONSD measurements and two-depth TCD ultrasonography offers potential as screening tools for ICP determination in settings lacking the invasive options. While not used for ICP monitoring, various radiographic imaging modalities may be useful in supporting the diagnosis of IIH. When considering surgical management of patients with IIH, there is no clear optimal strategy. It appears that ONSF and shunting procedures are primarily associated with improvements in visual symptoms and headaches, respectively. Transverse venous sinus stenting demonstrates efficacy in improving visual acuity, papilledema, and headache with lower rates of complication than shunting. The choice of surgical management strategy should involve consideration of the individual patient's predominant signs and symptoms.

Conflicts of Interest

There are no conflicts of interest. Dr. Alon Harris would like to disclose that he receives remuneration from Shire, CIPLA, and AdOM for serving as a consultant. Dr. Harris also holds an ownership interest in AdOM and Oxymap. All relationships listed above are pursuant to Indiana University's policy on outside activities. None of the other authors listed have any financial disclosures.

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