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Idiopathic intracranial hypertension: 120-day clinical, radiological, and manometric outcomes after stent insertion into the dural venous sinus

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OBJECTIVE Idiopathic intracranial hypertension (IIH) is commonly associated with venous sinus stenosis. In recent years, transvenous dural venous sinus stent (DVSS) insertion has emerged as a potential therapy for resistant cases. However, there remains considerable uncertainty over the safety and efficacy of this procedure, in particular the incidence of intraprocedural and delayed complications and in the longevity of sinus patency, pressure gradient obliteration, and therapeutic clinical outcome. The aim of this study was to determine clinical, radiological, and manometric outcomes at 3–4 months after DVSS in this treated IIH cohort.

METHODS Clinical, radiographic, and manometric data before and 3–4 months after DVSS were reviewed in this single-center case series. All venographic and manometric procedures were performed under local anesthesia with the patient supine.

RESULTS Forty-one patients underwent DVSS venography/manometry within 120 days. Sinus pressure reduction of between 11 and 15 mm Hg was achieved 3–4 months after DVSS compared with pre-stent baseline, regardless of whether the procedure was primary or secondary (after shunt surgery). Radiographic obliteration of anatomical stenosis correlating with reduction in pressure gradients was observed. The complication rate after DVSS was 4.9% and stent survival was 87.8% at 120 days. At least 20% of patients developed restenosis following DVSS and only 63.3% demonstrated an improvement or resolution of papilledema.

CONCLUSIONS Reduced venous sinus pressures were observed at 120 days after the procedure. DVSS showed lower complication rates than shunts, but the clinical outcome data were less convincing. To definitively compare the outcomes between DVSS and shunts in IIH, a randomized prospective study is needed.

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KEY WORDS endovascular; dural venous sinus stenting; venous sinus pressure; intracranial pressure; cerebrospinal fluid; idiopathic intracranial hypertension; interventional neurosurgery

IDIOPATHIC intracranial hypertension (IIH) affects 1–3 per 100,000 patients and presents clinically with disabling headaches, tinnitus, and risk of blindness.[15] It is characterized by raised intracranial pressure (ICP) and elevated CSF opening pressure on lumbar puncture with normal CSF composition in the absence of hydrocephalus and CNS space-occupying lesions.[19]

Despite being first described in the late 19th century and more common in the obese and women of childbearing age, the pathophysiology behind IIH remains unclear.[3,12,15] IIH is initially managed medically with weight loss and ICP-lowering drugs. When medication fails, surgical management options include CSF diversion, which is typically shunt insertion, or optic nerve sheath fenestration. How-

ever, surgical approaches are not benign and involve their own set of risks, and multiple surgical revisions for IIH are normal.[10] Furthermore, narrow lateral ventricles combined with increased tissue adiposity can make shunt surgery more complex, with potential difficulty in adjusting valves and increased shunt failure rates.[1]

Several interacting causative mechanisms have been postulated in IIH, including venous hypertension and impaired CSF absorption.[4] Imaging studies often demonstrate venous sinus narrowing, either from intrinsic intraluminal impediments such as prominent arachnoid granulations, or from extrinsic compression from swollen brain tissue.[23] Endovascular obliteration of these narrowings with dural venous sinus stenting (DVSS) has therefore emerged as a minimally invasive alternative to surgery in resistant cases of IIH.[7]

Although early clinical improvement following stent insertion has been described, sustained obliteration of anatomical stenosis, manometric gradient, control of ICP, and symptomatic improvement remain unproven. Furthermore, the causal relationship between radiographic anatomical stenosis and raised ICP remains unclear.[3,23] A recent Cochrane review suggested neither stent insertion nor CSF diversion as a preferential technique. Stent placement remains a contentious first-line procedure for IIH.[13]

In the authors' unit, all patients with clinicoradiological diagnosis of IIH resistant to conventional medical therapy are offered continuous ICP monitoring and formal catheter cerebral venography with pressure measurements. If a stenosis with a significant pressure gradient is demonstrated, then patients are counseled and offered the option for DVSS as an alternative to the standard therapy of surgical CSF diversion. All patients treated with endovascular stenting undergo routine clinical review and repeat venography with pressure measurements at 3–4 months after the procedure.

In this study we review the clinical, radiological, and manometric outcomes in patients with IIH and the efficacy of stent insertion (as determined by the requirement for a further procedure) at 3–4 months follow-up.

Methods

Study Design and Participants

We reviewed a single-center retrospective case series of patients with a diagnosis of IIH who underwent DVSS between September 2010 and March 2016. Demographic data included age, sex, and previous operative or medical management for raised ICP. Two patient groups were defined: 1) primary, DVSS as a first-line procedure; and 2) secondary, DVSS as a second-line procedure. All patients consented to the stent procedure. Ethical approval was not required for this retrospective study of current practice.

Clinical Data

Clinical data including patient-reported symptoms and clinical signs were retrospectively collected from standard neurosurgery and neuroophthalmology assessments at the two time points: presenting, and at 3–4 months after stent placement.

Venography and Manometry

The authors found cross-sectional imaging (including CT/MR venography) unreliable in identifying patients with manometric stenosis, and therefore this was principally used to exclude other causes of raised ICP only. Catheter venography was performed by an experienced interventional neuroradiologist under local anesthesia, via common femoral venous access with the patient supine. Contrast injected via a microcatheter in the superior sagittal sinus (SSS) and digital subtraction venography demonstrated anatomical sinus detail. Venous measurements were recorded at stereotypical locations in the SSS, torcula, transverse and sigmoid sinuses, internal jugular veins, superior vena cava, right atrium, and inferior vena cava. Stenoses were characteristically demonstrated at the transverse sigmoid sinus junction and a pressure gradient of 8 mm Hg was considered significant. In cases in which stenoses with significant manometric gradients were present, the choice of subsequent DVSS or CSF diversion surgery was offered with appropriate consent and counseling. In all patients choosing DVSS, clinical reassessment and catheter venography and manometry measurements were repeated 3–4 months after treatment.

Stent Placement

All venous sinus stenting procedures were performed under general anesthesia and full intravenous heparinization by interventional neuroradiologists with more than 5 years of experience. A standard unit protocol was followed. A large flexible guide catheter was positioned in the affected sigmoid sinus (typically 0.088-inch Neuronmax, Penumbra Inc.), and the stenosis crossed with a 0.027-inch microcatheter/0.014-inch microwire to obtain planning venography and measure pre-stenting venous pressures. The stent (typically 9-mm self-expanding carotid Wallstent, Boston Scientific) is deployed over a stiff 0.014-inch microwire (usually a Platinum Plus microwire) under biplane fluoroscopic imaging (Axiom Artis, Siemens). An immediate poststenting venogram confirmed satisfactory stent deployment and 500 mg intravenous aspirin was given, with a subsequent lifelong prescription of 75 mg oral aspirin.

Statistical Analysis

Data were processed using GraphPad Prism software (version 6.0c) and Microsoft Excel. Stenting manometric outcomes were compared with a paired 2-tailed t-test. A chi-square test was performed to determine if there was a significant difference in numbers of patients on various medications (acetazolamide, furosemide, and topiramate), and clinical and radiographic patency outcomes between the primary and secondary groups. An unpaired 2-tailed t-test compared age, SSS, and pressure gradient reductions between the 2 groups. Retreatment (equivalent to survival) was defined as number of days from stent insertion until the next intervention or end of the follow-up period. Kaplan-Meier curves were compared using the log-rank (Mantel-Cox) test. Differences in positive clinical outcomes (either resolution or improvement of signs and symptoms) between the primary and secondary groups

were assessed using a Wilcoxon matched-pairs signed-rank test. A p value < 0.05 was considered significant.

Results

Demographics

Between September 2010 and March 2016, 41 patients (2 men and 39 women) underwent DVSS and 3–4 month poststenting venography/manometry. The mean age of the entire study population was 35.7 years (range 19–55 years). The mean time for the follow-up venography/manometry was 101 days (range 91–120 days).

All patients had confirmed IIH and had previously undergone unsuccessful medical management. At the time of stent placement 23 patients were receiving 250 mg of acetazolamide twice daily; 1 of these patients was also taking furosemide (20 mg once daily) and 10 were also receiving topiramate (100 mg once daily). One patient was taking topiramate only (100 mg once daily). One patient was receiving furosemide only (20 mg once daily) due to acetazolamide tolerance. One patient was being treated with nocturnal continuous positive airway pressure (Table 1).

Twenty-six patients had DVSS as a primary procedure and 15 had DVSS as a secondary procedure (due to persistent signs and symptoms despite surgical revision). In the secondary group, 3 had a lumboperitoneal (LP) shunt, 7 had a ventriculoperitoneal (VP) shunt, 1 VP shunt was placed during a foramen magnum decompression, 1 VP shunt was placed during a bifrontal cranioplasty, and 3 patients had failed LP shunts with secondary VP shunts (Table 1). Once stents were placed, patients in the secondary group did not have the shunt settings adjusted within the study's time period.

Clinical Symptoms

All 41 patients presented with headaches; 40 were followed up, and these headaches completely resolved in 7 patients, improved in 19, remained the same severity in 13, and worsened in 1 patient (Fig. 1A). Thirty-five patients reported associated blurred vision, which resolved in 8, improved in 16, remained the same in 10, and worsened in 1 patient (Fig. 1B). Twenty-one patients had associated tinnitus, and 19 were followed up, in which it resolved in

9, improved in 3, and remained unchanged in 7 patients (Fig. 1C).

Clinical Signs

Thirty patients had papilledema; following stent insertion, this resolved in 12, improved in 7, and remained stable in 11 individuals (Fig. 1D). In the positive outcome group, 13 (68.4%) reported an improvement in their blurred vision (9 primary and 4 secondary).

Twenty had visual field defects; of the 18 with available follow-up data, 7 demonstrated complete resolution of the defect, 1 improved, and 10 remained stable after stent placement (Fig. 1E). In the patients with positive outcomes, 6 (75%) reported improved blurred vision (5 primary and 1 secondary).

Twenty-seven patients had abnormal visual acuity prior to venous stent insertion, which resolved in 10, improved in 2, remained stable in 10, and worsened in 1. Four patients were lost to follow-up (Fig. 1F). In the positive outcome group, 7 (58.3%) reported blurred vision improvement (5 primary and 2 secondary).

Figure 2 graphically depicts patients who experienced a positive outcome in their clinical symptoms (Fig. 2A) and signs (Fig. 2B), either a resolution or improvement.

Radiographic Outcome

Twenty-six patients underwent stent placement as a primary procedure, of whom 21 had a sustained transstenotic gradient obliteration at 3–4 months. Two of these 21 patients developed a stenosis of their contralateral nonstented transverse sinuses. These were subsequently treated with stents and their trans-stenotic gradients were obliterated at the later 3–4-month follow-up venography and manometry follow-up (Fig. 3).

Three patients developed an ipsilateral radiographic stenosis distal to the DVSS, but none of these warranted re-stenting as there were no significant pressure gradients across the new stenoses. Two patients developed in-stent thrombosis, of whom 1 was treated successfully with intravenous unfractionated heparin and the other treated with a second stent procedure with gradient obliteration on follow-up venography 3–4 months after revision.

Of the 15 patients who underwent stent placement as a secondary procedure, 12 had radiographic stent patency and stenosis obliteration on 3–4-month follow-up venography. Three patients developed restenosis ipsilateral to the DVSS, of which 1 was distal and 2 were proximal to the stent. A significant pressure gradient was found across 1 of the proximal stenoses and a second stent procedure was performed. In the remaining 2 restenoses, no significant pressure gradient was found and further treatment was not indicated.

Complications

There were no procedural complications. Ipsilateral frontal headache, often severe and lasting for hours to days, is a common and previously well-described early phenomenon, believed to be caused by dural irritation immediately following stent placement. There were 2 cases of delayed in-stent thrombosis requiring readmission and

TABLE 1. Study population demographics

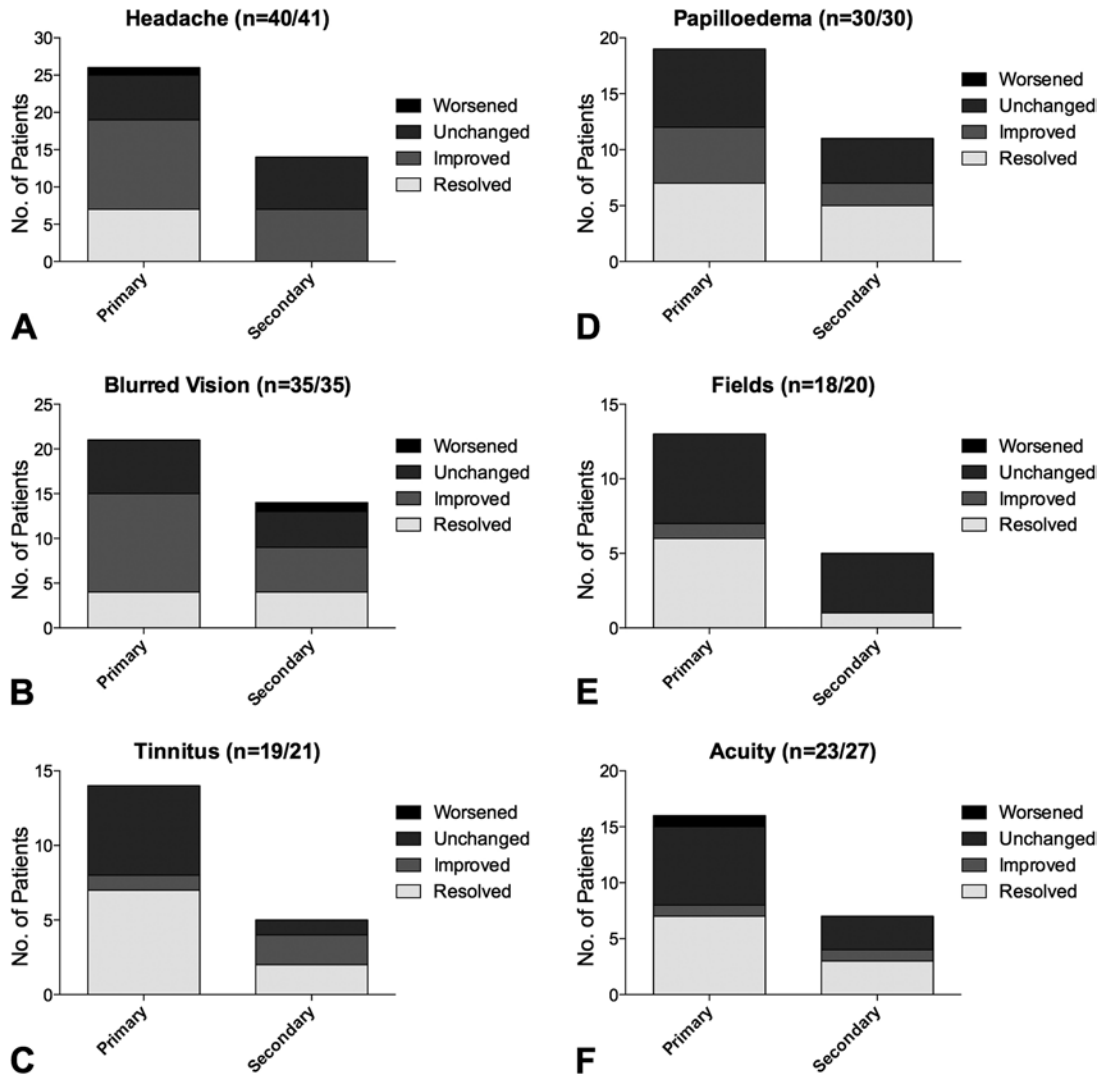| Demographic	Total (%)	DVSS Procedure		p Value
		Primary (%)	Secondary (%)	
No. of patients	41	26	15	
M/F	2/39	0/26	2/13	0.1
Mean age ± SD (yrs)	35.7 ± 9.23	36.7 ± 8.92	34.1 ± 9.86	0.4
Acetazolamide	23 (56.1)	16 (61.5)	7 (46.7)	0.5
Furosemide	2 (4.9)	1 (3.8)	1 (6.7)	1.0
Topiramate	11 (26.8)	6 (23.1)	5 (33.3)	0.5
LP shunt	3 (7.3)	NA	3 (20.0)	NA
VP shunt	9 (22.0)	NA	9 (60.0)	NA
LP & VP shunts	3 (7.3)	NA	3 (20.0)	NA

NA = not applicable.

FIG. 1. Bar graphs showing changes in symptoms (**A–C**) and clinical signs (**D–F**) following DVSS in primary and secondary groups.

managed successfully with intravenous unfractionated heparin in 1 case and stent revision in the other. Three patients required early retreatments due to failed clinical response and manometrically significant stenotic recurrence outside the stent; 1 for ipsilateral proximal stenosis and 2 for contralateral stenoses.

Pressure Measurements Before and After Stent Placement

In all 41 patients, the mean (± SD) pre-stent SSS pressure was 28.2 ± 9.01 mm Hg. Mean SSS pressure at 3–4 months after stent placement was 17.5 ± 6.94 mm Hg (p < 0.0001; Fig. 4A). Pre-stent pressure gradients across the stenoses were reduced from 17.5 ± 8.01 mm Hg to 6.17 ± 4.40 mm Hg 3–4 months after stent placement (p < 0.0001; Fig. 4B).

In the primary group (n = 26), the mean pre-stent SSS pressure was 28.6 ± 9.33 mm Hg. Mean SSS pressure at 3–4 months after stent placement was 16.8 ± 7.38 mm Hg (p < 0.0001; Fig. 4C). Pre-stent pressure gradients across stenoses were reduced from 17.9 ± 7.36 mm Hg to 5.42

± 4.17 mm Hg 3–4 months after stenting (p < 0.0001; Fig. 4D).

In the secondary group (n = 15), the mean pre-stent SSS pressure was 27.6 ± 8.71 mm Hg. The mean SSS pressure at 3–4 months after stent insertion was 17.8 ± 4.40 mm Hg (p < 0.001; Fig. 4E). Pre-stent pressure gradients across stenoses were reduced from 17.0 ± 8.89 mm Hg to 7.13 ± 4.31 mm Hg 3–4 months after stenting (p < 0.001; Fig. 4F).

DVSS Retreatment Rate Analysis

Stent "nonsurvival" or retreatment rate was therefore considered to have occurred where further intervention was required. Of the 5 patients requiring further surgical intervention, 1 (3.85%) was in the primary group and 4 (26.7%) were in the secondary group. Retreatment rate analysis revealed that, overall, 87.8% did not require further intervention at 120 days in 41 patients (Fig. 5A). In the primary group, this increased to 96.2% at 120 days in 26 patients. Those who underwent DVSS as a secondary
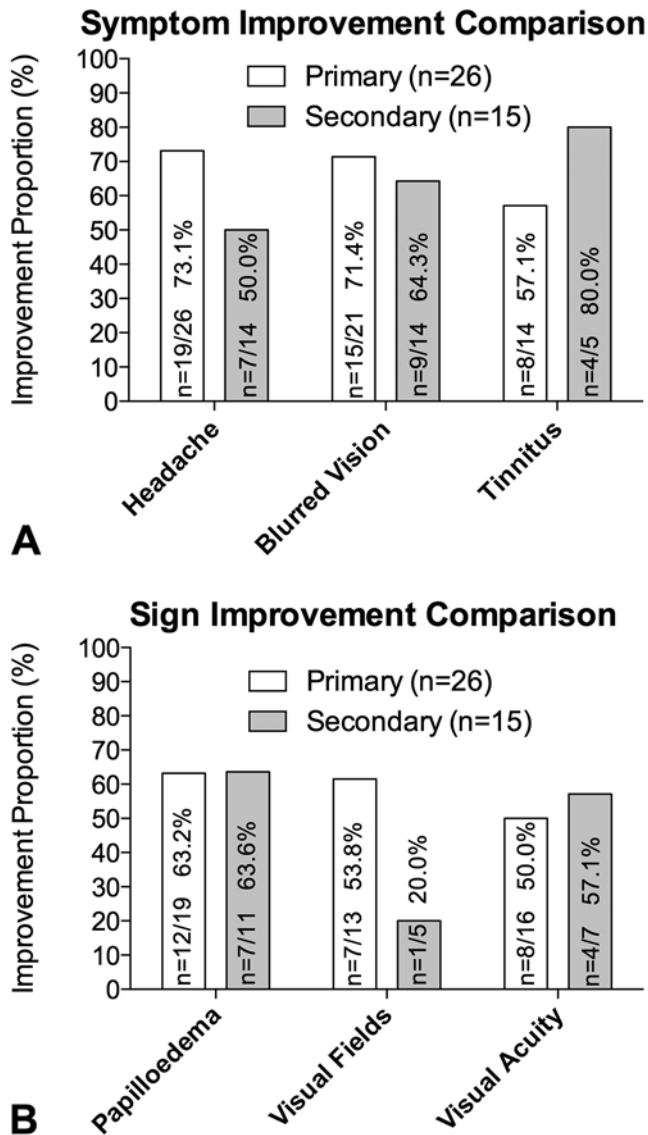
Symptom Improvement Comparison

FIG. 3. A: Transverse sinus stenosis with a significant pressure gradient before stent insertion. **B:** Obliteration of the sinus stenosis and pressure gradient after stenting. The values represent pressure (mm Hg) measured at these locations.

Sign Improvement Comparison

FIG. 2. Proportional representation of resolution or improvement in symptoms (**A**) and signs (**B**), comparing primary and secondary groups.

procedure had a 73.3% survival rate at 120 days in 15 patients. The log-rank (Mantel-Cox) test comparing retreatment rates between the primary and secondary groups found the difference to be significant (p = 0.04; Fig. 5B).

Discussion

This study reviewed radiographic, clinical, and manometric outcomes in patients who underwent DVSS as either a primary or secondary procedure to treat IIH. We also performed retreatment rate analysis of stents in the 2 groups of patients.

Radiographic and Manometric Outcomes

We found objective evidence of the effectiveness of DVSS in radiographic stenosis obliteration, 80.8% (21 of 26) in the primary group versus 80.0% (12 of 15) in the secondary group. Therefore, DVSS is equally effective
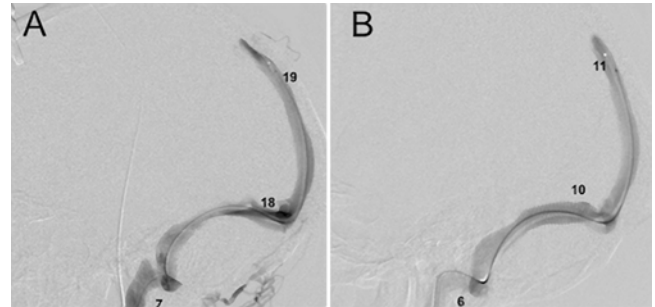
regardless of whether it is a primary or secondary procedure.

Eight (19.5%) of the 41 developed venographic restenosis after DVSS, 6 of which were stent-adjacent and 2 of which were contralateral stenosis at their nonstented transverse sinuses. However, only 5 (12%) of 41 were manometrically significant (2 contralateral, 1 ipsilateral, and 2 in-stent thromboses) warranting retreatment; 4 (9.8%) of 41 with stent insertion and 1 (2.4%) of 41 with intravenous heparin.

Given the unpredictability of location and laterality of restenosis, the population of patients suffering restenosis after DVSS warrants further investigation to identify risk factors and stenosis mechanisms. High rates of restenosis following stent insertion has been previously reported and may be suggestive of an underlying pathophysiology of sinus stenosis or reflect the choice of stent technology.[9,18,22] Patterns of restenosis in our patients conform to the hypothesis that raised ICP is the primary event in many patients with swollen brain parenchyma extrinsically compressing venous sinuses, with increasing venous hypertension and further increase in ICP.[4]

Although there was a strong correlation between anatomical and manometric sinus findings in our data, it is the presence of a significant pressure gradient across the stenosis that defines a functionally significant stenosis, and this distinction is critical for appropriate patient selection and management.[5] Our poststent pressure gradient reductions concur with those observed in a recent systematic review of 17 studies of 185 patients.[20] These investigators observed a reduction in pressure gradient of 15.7 mm Hg, not dissimilar to our overall reduction by 11.5 mm Hg.[20] Interestingly, in our study the primary group pressure gradient was reduced by 12.4 mm Hg, which was greater than the secondary group's decrease of 9.87 mm Hg, despite similar prestent pressure gradients of 17.9 mm Hg and 17.0 mm Hg, respectively.

Clinical Outcome

Despite excellent radiographic and manometric outcomes, the clinical outcomes were modest with 65.0% of patients reporting a subjective improvement or resolution in their headache symptoms, and 63.3% having an objective improvement or resolution of papilledema on ophthalmological examination. It would be useful to confirm that
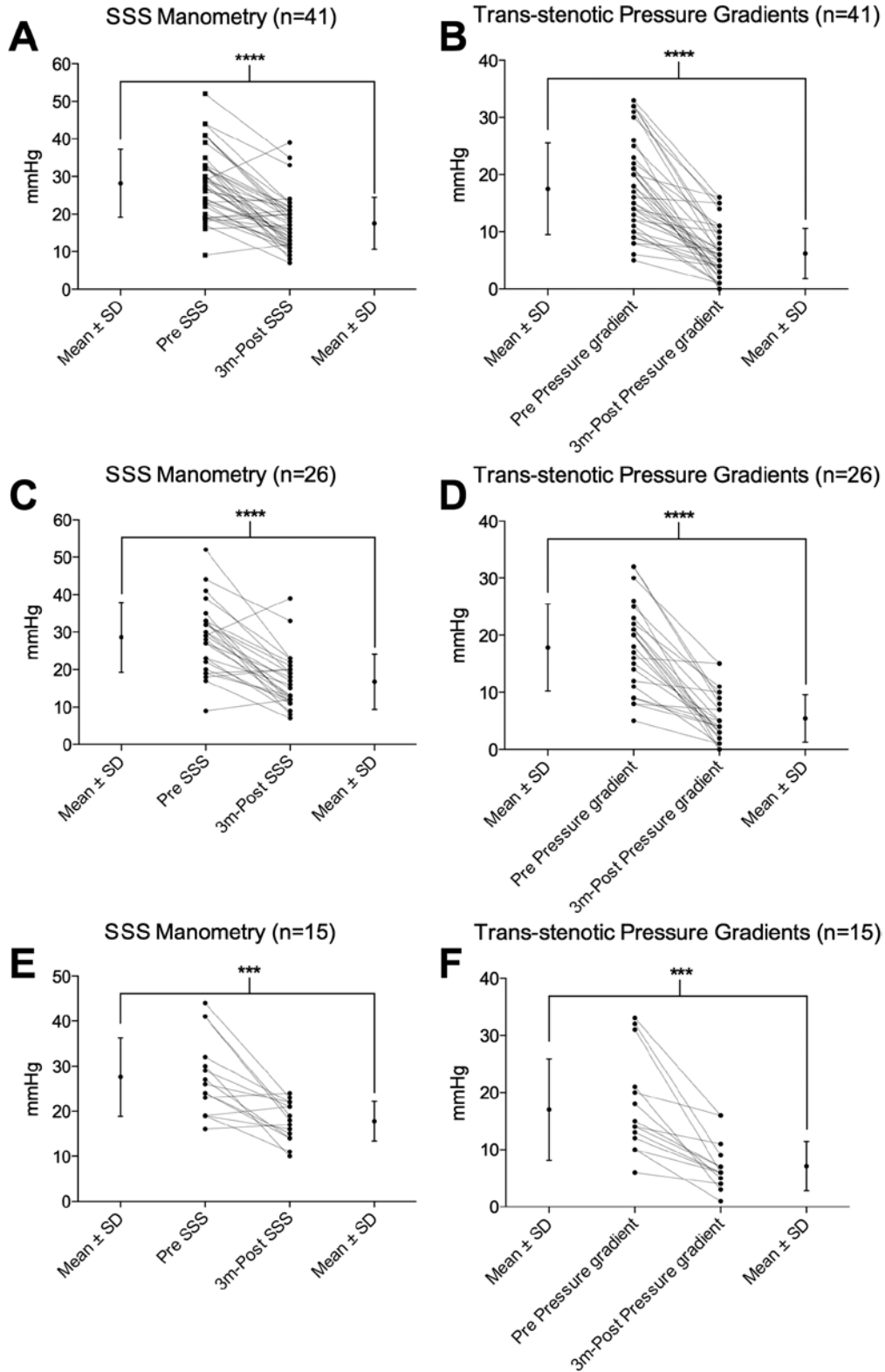
FIG. 4. Graphs of mean and individual patient results for SSS pressure. **A and B:** The total present SSS pressure of 28.2 ± 9.01 mm Hg was reduced to 17.5 ± 6.94 mm Hg 3–4 months (3m) after stent placement (p < 0.0001). The present pressure gradient was reduced from 17.5 ± 8.01 mm Hg to 6.17 ± 4.40 mm Hg 3–4 months after stenting (p < 0.0001). **C and D:** The primary procedure present SSS pressure of 28.6 ± 9.33 mm Hg was reduced to 16.8 ± 7.38 mm Hg at 3–4 months after stenting (p < 0.0001). The present pressure gradient was reduced from 17.9 ± 7.36 mm Hg to 5.42 ± 4.17 mm Hg 3–4 months after stenting (p < 0.0001). **E and F:** The secondary procedure present SSS pressure of 27.6 ± 8.71 mm Hg was reduced to 17.8 ± 4.40 mm Hg at 3–4 months after stent placement (p < 0.001). The present pressure gradient was reduced from 17.0 ± 8.89 mm Hg to 7.13 ± 4.31 mm Hg 3–4 months after stenting (p < 0.001). ****p < 0.0001, ***p < 0.001.

symptomatic improvement correlated between objective and subjective measures to exclude placebo effect. However, our study design limited this and only papilledema was truly an objective measure, as the others required some degree of patient subjectivity.

Our finding that treatment of sinus stenosis does not universally result in improved visual symptoms has previously been reported.[17] There was no significant difference in clinical outcome between those who had DVSS as a primary or secondary procedure (Table 2). However, other research groups have found better clinical outcomes, with 2 groups demonstrating functional improvements in symptoms and signs, including headache (81%–88%), papilledema (90%–97%), visual symptoms (87%), and tinnitus (93%).[14,22]

To compare these figures with CSF diversion in IIH, Abubaker et al. demonstrated 89% and 80% postoperative symptom improvement rates after LP and VP shunting, respectively (n = 18 for LP, n = 10 for VP).[1] Revision rates were 60% for LP shunts and 30% for VP shunts over an average follow-up of 4 years.[1] Tarnaris et al. found that headaches improved in 71% and 60%, and papilledema improved in 42% and 40%, after LP and VP shunt placement, respectively (similar to DVSS outcomes in this study). Revision rates in this study were 40% for LP shunts and 22% for VP shunts (n = 24 for LP shunts, n = 5 for VP shunts) over a follow-up of 29 months.[21]

The discrepancy between radiological stenosis obliteration and clinical outcome may be explained by a number of factors. First, 68% of patients with IIH have a defined coexisting headache disorder such as migraine and tension-type headache, which would continue despite treatment of their raised ICP.[6] Second, there may be distinct entities under the diagnosis of IIH that may need subclassification, i.e., DVSS-responsive and DVSS-unresponsive disease. The main contributor to raised ICP may be a focal intramural venous sinus stenosis in DVSS-responsive IIH and multifactorial in DVSS-unresponsive IIH.

Stent Retreatment Analysis

This is the first analysis comparing DVSS retreatment rates as primary and secondary procedures in IIH. The overall DVSS survival rate (defined by no requirement for a further procedure) was 87.8% at 120 days, which compares favorably to survival rates of VP shunts where failure rates range from 23% to 46.3%, albeit over a longer time course.[8,16] The higher retreatment rates of stents inserted as a secondary procedure could be related to the fact that shunts change the CSF hydrodynamics interfering with stent function, or simply due to the fact that DVSS as a secondary procedure is performed in patients with a more aggressive or different form of IIH.

Complications

There were no deaths or permanent morbidities associated with DVSS in our cohort, although self-limiting ipsilateral frontal dural headache in the days following the procedure can be severe. Two patients (4.9%) suffered delayed in-stent thrombus formation with recurrence of clinical symptoms, successfully treated using intravenous unfractionated heparin in 1 and DVSS revision in the other.
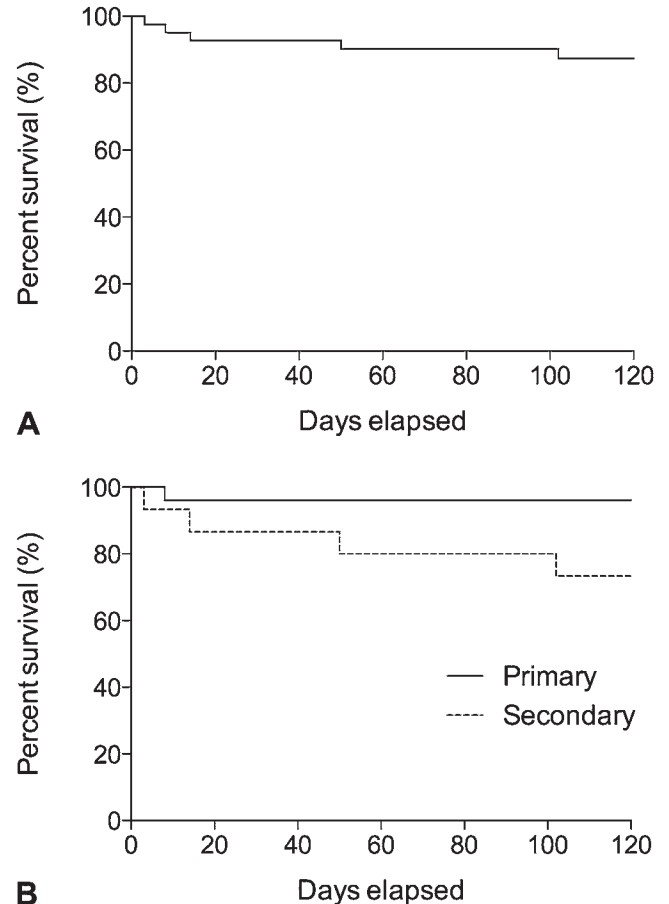

FIG. 5. Kaplan-Meier curves of the retreatment analysis for total stent retreatment rates (**A**) and primary versus secondary retreatment rates (**B**).

Further stenosis outside the stent requiring treatment occurred in 3 (7.3%) of 41, although such a "treatment failure" could be considered the natural history of the disease itself rather than a procedural complication. For comparison, a recent review by Puffer et al., reported a complication rate of 6% after DVSS.[14] The complication rates observed after DVSS are significantly lower than those observed following VP shunts (47.1%).[11] However, while the complication rate is lower, the severity of complications is not negligible (venous sinus thrombosis is potentially catastrophic). One case series of 52 patients reported a subdural hemorrhage, a subarachnoid hemorrhage, and an intracerebral hemorrhage after DVSS.[2]

The authors concur with Ahmed et al. and Higgins et al. that DVSS only has a place in treating venous sinus stenosis with significant trans-stenotic pressure gradients.[2,7] However, the literature lacks Class 1 evidence demonstrating the superiority of DVSS over CSF diversion in IIH with focal venous sinus stenosis.

Strengths and Limitations

This is the first case series demonstrating radiographic and clinical outcome, pressure gradients, and survival of DVSS in those who underwent this procedure as a primary versus a secondary procedure. However, one limitation of

TABLE 2. Clinical, radiographic, manometric, and survival comparisons between primary and secondary groups

| | | DVSS Procedure | | |
Variable	Overall (%)	Primary (%)	Secondary (%)	p Value*
Radiographic patency	33/41 (80.5)	21/26 (80.8)	12/15 (80.0)	1.00
Resolution/improvement				
Headache	26/40† (65.0)	19/26 (73.1)	7/14† (50.0)	0.18
Blurred vision	24/35 (68.6)	15/21 (71.4)	9/14 (64.3)	0.72
Tinnitus	10/19‡ (52.6)	8/14† (57.1)	4/5† (80.0)	0.63
Papilledema	19/30 (63.3)	12/19 (63.2)	7/11 (63.6)	1.00
Visual fields	8/18‡ (44.4)	7/13† (53.8)	1/5† (20.0)	0.31
Visual acuity	12/23¶ (52.2)	8/16† (50.0)	4/7§ (57.1)	1.00
Mean SSS pressure reduction ± SD (mm Hg)	11.1 ± 8.79	11.8 ± 9.01	9.80 ± 8.55	0.48
Mean pressure gradient reduction ± SD (mm Hg)	11.5 ± 7.47	12.4 ± 7.40	9.87 ± 7.58	0.30
120-day survival	36 (87.8)	25 (96.2)	11 (73.3)	0.04

* Primary versus secondary.
† One patient lost to follow-up.
‡ Two patients lost to follow-up.
§ Three patients lost to follow-up.
¶ Four patients lost to follow-up.

this study is that, as a case series, it has inherent selection bias and is, of course, nonrandomized and has no control cases. Second, although the follow-up duration is longer than other studies in the literature, it is still relatively short. Given the retrospective nature of the study, a considerable number of patients' objective clinical features were lost to follow-up. There is a paucity of evidence that directly correlates venous sinus pressure and ICP directly. We comment on SSS pressure, but this may not reflect ICP nor is it an appropriate surrogate marker.[17] This may explain why the majority of patients appeared to have good radiographic outcome, but many symptoms and signs persisted. Despite this, we believe it was valuable to report the changing SSS pressure and its relationship to outcome.

Future Research

There are a number of points that require further research. First, studying the SSS pressure with an ICP monitor in situ would enable us to determine the nature of the relationship, if any, between SSS pressure and ICP. Second, more long-term data on outcomes, ICP, and SSS pressure are needed. At the time of writing this paper we are accumulating the data for 6- and 9-month outcomes. Third, the morphological appearance of the stenosis, and the effect of extrinsic versus intrinsic compression, is another important element that needs further research. Finally, this study suggests that complication rates of DVSS are lower than shunts. A prospective study with randomization is needed to compare DVSS and shunt insertion in IIH.

Conclusions

This study provides objective evidence of the effectiveness of venous sinus stent insertion in reducing venous sinus pressure 3–4 months after the procedure in the majority of patients with intracranial hypertension and focal venous sinus stenosis. Radiographic evidence of patent sinuses correlated with reduction in pressure gradients.

While our study suggests DVSS has lower complication rates than shunts, the outcome data are less clear. To definitively compare the outcomes between DVSS versus shunts in IIH, a randomized prospective study is needed.

Key Points

1. DVSS is equally effective in reducing clinical signs and symptoms of IIH, regardless of whether it is a primary or secondary procedure.
2. Only 63.3% of patients showed an improvement or resolution of papilledema.
3. Almost 20% of patients with IIH develop restenosis following DVSS.
4. The 3–4-month reduction in pressure gradient after stent placement is high, between 11 and 15 mm Hg.
5. The pressure gradient reduction was greater in the primary group than the secondary group.
6. The DVSS survival rate was 87.8% at 120 days, which compares favorably to survival rates of VP shunts, in which failure rates range from 23% to 46.3%.
7. Excluding restenosis, the complication rate after DVSS is 4.9%.
8. There is no evidence demonstrating the superiority of DVSS over CSF diversion in IIH.

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Disclosures

Author Contributions

Conception and design: Asif, Craven, Toma. Acquisition of data: Asif, Craven, Shah. Analysis and interpretation of data: Asif, Craven. Drafting the article: Asif, Craven, Siddiqui. Critically revising the article: Asif, Craven, Robertson, Toma. Reviewed submitted version of manuscript: Asif, Craven, Siddiqui, Thorne, Robertson, Watkins, Toma. Approved the final version of the manuscript on behalf of all authors: Asif. Statistical analysis: Asif, Craven. Administrative/technical/material support: Matloob, Robertson. Study supervision: Thorne, Watkins, Toma.

Supplemental Information

Previous Presentations

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