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Original Article

Dural venous sinus stenting for idiopathic intracranial hypertension: An updated review[☆]

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ABSTRACT

Background. – Dural venous sinus stenting (DVSS) is an accepted treatment option in selected patients with medically refractory idiopathic intracranial hypertension and obstructive venous outflow physiology prior to cerebrospinal flow diversion (CSFD) surgery. There are no randomized controlled studies focusing on outcomes and complication rates for dural venous sinus stenting.
Purpose. – We present the largest comprehensive meta-analysis on DVSS for idiopathic intracranial hypertension (IIH) focusing on success rates, complications, and re-stenting rates to date. We also present a simplified approach to direct retrograde internal jugular vein (IJ) access for DVSS that allows for expedited procedures.
Materials and methods. – We performed a retrospective electronic PubMed query of all peer-reviewed articles in the last 15 years between 2003 to 2018. We included all patients who underwent dural venous sinus stenting for a medically refractive IIH and excluded articles without sufficient data on outcomes, complication rates and re-stenting rates. We also evaluated and compared outcomes in patients undergoing direct retrograde IJ access DVSS to traditional transfemoral vein access.
Results. – A total of 29 papers and 410 patients who underwent DVSS met criteria for inclusion. DVSS was associated with high technical success [99.5%], low rates of repeated procedure [10%], and low major complication rates [1.5%].
Conclusion. – Our retrospective comprehensive review of DVSS for medically refractory IIH suggests that stenting in appropriately chosen patients is associated with low complication rates, high technical success, and low repeat procedure rates.

Introduction

Idiopathic intracranial hypertension (IIH) is a syndrome defined by elevated intracranial hypertension without radiographic evidence of a mass lesion in the brain [1]. IIH causes significant morbidity, including permanent visual loss in up to 25% of cases with reports of 1–2% of new cases being registered blind per year and disabling headache in the majority [2–5].The gold standard intervention in medically refractory patients is cerebrospinal fluid diversion surgery (shunting) versus optic nerve sheath fenestration. In patients whose main symptom is severe visual loss, optic nerve sheath fenestration is generally considered the first line surgery [6]. Recently there has been increasing recognition of the dural venous sinuses and associated stenosis as a potential cause of medically refractory IIH [5,7].

Criteria for DVSS is not strictly adhered to at all institutions, however it generally includes:

- medically refractory patient with progressive symptoms/vision loss;
- obstructive venous outflow pattern (isolated sigmoid sinus stenosis [SSS*], bilateral transverse/SSS*, and ipsilateral transverse/SSS* with contralateral transverse/sigmoid sinus hypoplasia or absence);

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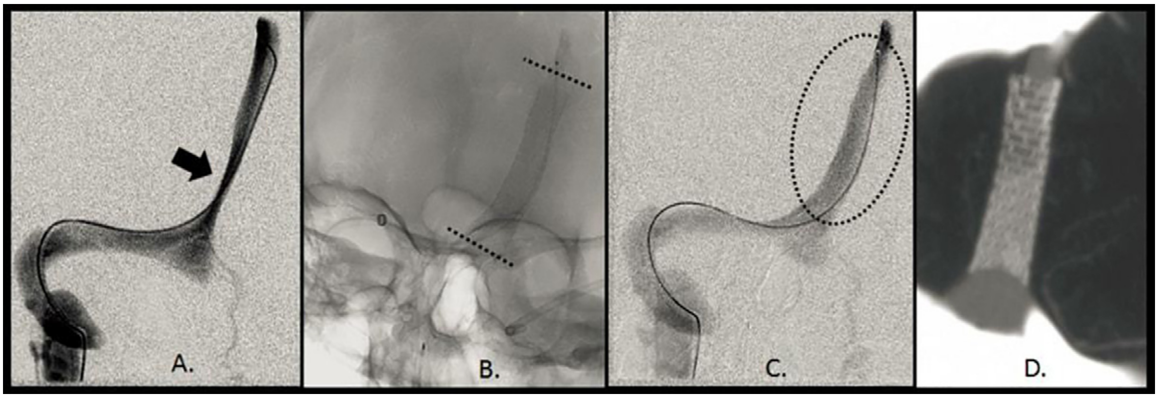

Fig. 1. A. Venous phase of right LAO ICA angiogram showing high grade focal stenosis of the distal superior sagittal sinus. This image was used as a roadmap for subsequent venous sinus stenting. B. Unsubracted LAO ICA post Cordis Precise 10 mm × 40 mm stent placement across the superior sagittal sinus stenosis. C. Post-stent direct venogram showing no residual stenosis and brisk outflow through the dominant right transverse sinus. D. 6 month follow-up CT venogram performed because the patient complained of recurrent headaches. CTV shows widely patent stent and no recurrent stenosis.

- direct pressure gradient across target lesion ranging from > 8 mmHg [8].

In the last 15 years, there have been many studies and case reports supporting this procedure for patients with medically refractive IIH as well as patients who have failed other surgical procedures [7–10]. We present an updated comprehensive meta-analysis on DVSS focusing on success rates and complications.

Occasionally, traditional common femoral vein access to DVSS procedure challenging and can be sometimes associated with femoral vein access site complications including pseudo aneurysm, arteriovenous fistula, retroperitoneal hemorrhage and longer post-procedural recovery times. We present 2 case examples of a simplified approach to direct retrograde internal jugular (IJ) access for DVSS [10]. We also highlight some important technical considerations, potential advantages and disadvantages of a retrograde IJ approach.

Materials and methods: meta-analysis

Materials used

We performed a PubMed search of all peer-reviewed articles from 2003 to 2018 with the following combination of key words including: "idiopathic intracranial hypertension", "pseudotumor cerebri", "benign intracranial hypertension", "dural venous sinus stenting" and "intracranial venous shunts."

Research design

All studies and case reports with patients that had undergone DVSS that were either medically refractory or failed other CSF diversion procedures for IIH were included in the analysis. Forty-nine patients had failed CSFD, 24 had failed ONSF, and 5 had failed subtemporal decompression contributing to a total of 77 failed prior surgeries in our meta-analysis.

We standardized data from these studies focusing on outcomes, complications, and re-stenting rates, with the major limitation being variability between institutes and operators using different protocols. All studies written before 2003, non-English articles; and reports with insufficient information (patient selection criteria or incomplete follow-up data) were excluded.

Using Microsoft Excel, we calculated the means and percentages for the combined subset of patients with data available for each parameter or outcome. Patients with inadequate data were excluded from the analysis to avoid bias and to produce reliable results e.g. Mean body mass index (BMI) was not available in Ahmed et al., 2011, and hence the total number of patients in Ahmed et al was excluded from the denominator in the calculation for mean BMI [11]. Similarly stent location was not reported in 6 papers (104 cases) and they were excluded from the calculation [9,12–15]. Although all parameters were analyzed, we focused mainly on the success rates and complications of DVSS in the following results and discussion.

The traditional approach to DVSS is via the femoral route. We also report here two cases of DVSS via the IJ approach and performed a subset analysis of technical success and complications rates comparing IJ and femoral access for DVSS.

Case 1

Our first case was a 40-year-old female with a past medical history of IIH, left frontal cranial fossa arachnoid cyst status post shunting, left eye blindness secondary to childhood surgery and a gastric bypass for weight loss. Despite medical management with acetazolamide, Lasix, and Diamox, she had progressive worsening of right eye visual acuity. She underwent angiography and direct venography with pressure measurements under local anesthesia, which confirmed left transverse sinus occlusion and a short segment focal stenosis of the right transverse sinus (associated gradient of 8 mmHg). After multidisciplinary review and informed consent, DVSS was performed via a right IJ approach with successful placement of a Cordis Precise 10 × 40 mm self-expanding carotid stent across the stenosis with resolution of the pressure gradient. A follow-up CT venogram at seven months showed widely patent right transverse sinus stent without re-stenosis (Fig. 1).

Case 2

A 26-year-old obese female with medically refractive IIH (progressive debilitating headaches), prior right parietal VP shunt (status post two revisions) and MRV suggesting an obstructive CSF outflow pattern, was referred for venography and direct pressure measurements. Cerebral angiography, direct venography and venous pressure measurements confirmed a hypoplastic left transverse sinus and a focal stenosis of the right transverse sinus with associated gradient of 10 mmHg. After multidisciplinary view per institutional protocol she underwent successful DVSS via a right IJ approach (Cordis Precise 8 × 30 mm self-expanding stent). Her headaches improved significantly after stent placement, 8 months

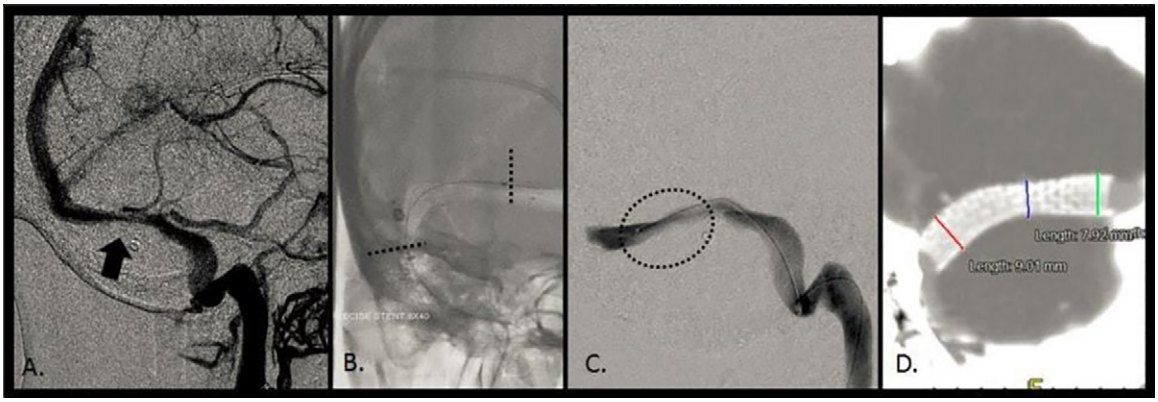

Fig. 2. Pre-stenting venogram: severe focal stenosis of right transverse sinus just proximal to Labbe (black arrow). A. Direct venogram Post-stenting: resolution of pressure gradient with less than 20% residual stenosis after placement of Cordis precise stent (dotted line). B. Immediate post-stenting venogram showing less than 20% residual stenosis of transverse sinus stenosis with excellent antegrade flow and no residual pressure gradient. C. CT venogram at 7 months: mild residual stenosis in right transverse sinus and widely patent stent.

later her VP shunt was removed and at 1-year clinical follow-up, her symptoms are well controlled (Fig. 2).

Procedure: direct retrograde IJ access for DVSS

Ultrasound guided retrograde access of the ipsilateral jugular vein was obtained with a 4F micro-puncture system comprised of a sheath, 21 g needle and 0.018-inch nitinol wire (Cook Medical LLC, Bloomington IN), a confirmation venogram was performed prior to retrograde placement of a 7F or 8F 10 cm Terumo Pinnacle sheath (Terumo Medical Corporation, Somerset, NJ) was placed over the provided 45 cm 038 in wire and attached to continuous flush. A tri-axial system was established using a Cook 5F shuttle sheath (Cook Medical LLC, Bloomington, IN) or Neuron Max 088 guiding sheath (Penumbra Inc., Alameda, CA), 5F 135 cm Penumbra BER Select catheter (Penumbra Inc., Alameda, CA) and a 0.027-inch Marksman microcatheter (Medtronic, Minneapolic, MN) with a Boston Scientific .016 in Fathom microwire (Boston Scientific, Quincy, MA). The stenosis was crossed using the microwire and microcatheter. Hand injection through the microcatheter was performed to confirm an intradural location prior to crossing the stenosis with the 5F diagnostic catheter and long sheath. Once the shuttle sheath was advanced across the target stenosis the diagnostic and microcatheters were removed. Most self-expanding carotid stents up to a 8 mm diameter can be readily delivered through a Cook 5F shuttle sheath. Whereas stents with diameters of 10 mm or greater require a Neuron Max 088 guiding sheath. We found the short sheath (7 or 8 French) were important to provide support at the IJ access site, frequently requiring support to prevent kickback during advancement and crossing of the target stenosis.

Results

Meta-analysis

Our meta-analysis of DVSS included 29 articles with 410 patients. Among the patients, 88.2% (337/382 cases) were females and 11.8% (45/382 cases) were males. The mean age was 34.7 year and the mean follow-up time was 22.4 months. The mean BMI was 39.9 kg/m^2 (normal range: 18.5–24.9 kg/m^2). The mean CSF pressure pre-dural venous sinus stenting was 34.8 mmHg (normal range: 8–15 mmHg).

Post-stenting, headache improved in 82% (294/359 cases) and papilledema improved in 92% (291/318) of patients. Visual acuity changes improved in 78% (193/249) patients after treatment. The mean pre-stent pressure gradient was 18.1 ± 9.5 mmHg (n = 24), and the mean post-stent pressure gradient was 2.8 ± 3.1 mmHg (n = 17). Sixty-four of stents were placed in the right transverse sinus, 23% of stents were placed in the left transverse sinus, and 13% were bilateral. Stent location was not reported in 6 papers (104 cases) [9,12–15].

Of the 410 patients who underwent stent placement, the major and total complication rates were, 1.5% (6/410) and 4.9% (20/410), respectively (Tables 1 and 2). The major complications were defined as intracranial hemorrhage, subdural hematoma and subarachnoid hemorrhage. There were two subdural hematoma (SDH) [11,16] and one patient who had SDH, subarachnoid hemorrhage (SAH) and intracerebral bleeding, which occurred at the time of emergency treatment for fulminant IIH but, contralateral to stent placement treatment. Both patients underwent immediate craniotomy and made a full recovery [11]. There was no mortality or permanent morbidity directly related to the DVSS procedures. The only neurologic deficits reported was a mild right sided leg weakness at 6 months which was likely due to a concomitant parasagittal arteriovenous malformation (AVM) obliteration [16].

The minor complication rate was 3.4% (14/410) and, largely, related to access site complications. They included one retroperitoneal hemorrhage, 1 retroperitoneal hematoma, 5 femoral artery pseudo aneurysms, 1 femoral vein thrombosis, 2 neck hematoma, and 2 transient hearing losses (THL). Buell et al reported the first case of dural arteriovenous fistula after a DVSS procedure, which the authors described was due to refractory elevated post-stenting venous pressure, subclinical cortical vein thrombosis, and post-stent inflammation with upregulated VEGF and PDGF expression. However, we have not included this into our meta-analysis.

Re-stenting was required in 10% (41/410) of all patients. Five patients were re-stented secondary to in-stent restenosis and seventeen were stented adjacent to the initial stent. There were, however, 5 contralateral stents. Two patients of these required stents in a different location [10,16] and re-stenting location was not specifically reported in 6 patients.

We defined our treatment failure rate as a conversion to other treatment modality including CSFD and ONSF, giving us an overall treatment failure rate of 2.4% or 10/410 patients. One patient underwent optic nerve sheath fenestration (ONSF) due to persistent symptoms, including worsening central acuity as well as color vision, visual field and a new afferent pupillary defect 3 months after stenting despite the normal ICP by repeat LP. The subject underwent ONSF with no improvement in vision postoperatively [15]. Nine patients underwent CSF diversion procedures (1 LPS and 8 VPS) [15,24,29–31].

Table 1
Complications and Repeat Procedure reported in studies in the last 15 years.

Studies	Total patients undergoing DVSS	Complications	Adverse effects	Femoral access	IJ access
Owler et al., 2003 [17]	4	None	None	NR	NR
Ogungbo et al., 2003 [18]	1	None	None	0	1 RJV
Higgins et al., 2003 [9]	12	None	Most patients had postop HA on stented side	0	12
Rajpal et al., 2005 [19]	1	None	None	NR	NR
Crosa et al., 2007 [20]	1	None	None	NR	NR
Paquet et al., 2008 [21]	1	None	None	NR	NR
Donnet et al., 2008 [22]	10	None	None	10	0
Arac et al., 2009 [23]	1	None	None	1	0
Bussiere et al., 2010 [24]	10	None	Transient mild HA ipsilateral to the stented side - 2 patients	10	0
Zheng et al., 2010 [25]	1	None	None	NR	NR
Spilberg et al., 2010 [26]	1	None	None	1	0
Ahmed et al., 2011 [11]	52	SDH - 1 (secondary to vein perforation) SDH, SAH &ICH - 1 (same patient-C/L to stent side) Full recovery s/p immediate craniotomy - both patients Transient hearing loss - 2 (Resolved on its own in a few days)	Most patients had ipsilateral frontal HA Allergic reactions to aspirin or clopidogrel - 2 patients Anaphylactic reaction to the anesthetic (muscle relaxant) but made a full recovery - 1 patient	52	0
Albuquerque et al., 2011 [10]	15	Retroperitoneal hematoma - 1 Resolved on its own	None	15	0
Kumpe et al., 2012	18	Subdural hematoma - 1, SAH - 1(same patient) Resolved in 24 hour, s/p EVD placement Same patient had small concomitant para-sagittal AVM that was obliterated before stenting. There was trace right leg weakness in 6 months due to the AVM	UTI – 1 & Brief syncopal episode postop day - 1 (same patient)	NR	NR
Ahmed et al., 2012 [12]	18	None	None	NR	NR
Lazzaro et al., 2012 [27]	3	None	None	NR	NR
Fargen et al., 2012 [28]	1	None	None	1	0
Radvany et al., 2013 [29]	12	None	Stagnation of contrast raising concern for dissection in 1 case, procedure aborted	NR	NR
Fields et al., 2013 [30]	15	Femoral pseudo aneurysm - 1 Treated successfully with US guided compression	None	15	
Ducruet et al., 2013 [31]	30	Right common femoral pseudo aneurysm - 1 s/p placement of femoral artery stent	Proximal stenosis - 5/30 In stent stenosis - 4/30	NR	NR
Elder et al., 2015 [32]	4	None	None	NR	NR
Teleb et al., 2015 [33]	18	None	DVT - 1 (Not related to the procedure)	18	0
Smith et al., 2016 [34]	17	None	5 proximal stenosis-remove	NR	NR
Dinkin et al., 2016 [35]	13	Small retroperitoneal hemorrhage - 1 (At the site of femoral artery puncture Resolved spontaneously)	Headache ipsilateral to stent-6/13 patients	13	0
Perez et al., 2017 [36]	51	Femoral pseudoaneurysm - 3 Neck hematoma - 2 Femoral vein thrombosis - 1	Ipsilateral retro-orbital pain - 20 patients 3 Anticoagulation complications-(Melena - 1, Hypermenorrhea - 1, Epistaxis - 1)	50	34
Asif et al., 2017 [13]	41	None	Frontal HA - self resolved in a few days Delayed in-stent thrombosis - 2 Restenosis outside stent - 3	NR	NR
Matloob et al., 2017 [14]	10	None	None	NR	NR
Satti et al., 2017 [5]	43	None	In stent stenosis - 3	43	0
Shazly et al., 2017 [15]	6	None	None	NR	NR

NR: not reported; HA: headache; IJ: internal jugular; EVD: extraventricular drain; DVT: deep vein thrombosis; AVM: arteriovenous malformation; UTI: urinary tract infection; SDH: subdural hematoma; SAH: subarachnoid hemorrhage; ICH: intracerebral hemorrhage; S/P: status post; US: ultrasound; RJV: right jugular vein.

Table 2
Complication rates of DVSS.

	Number of complications	Complication rates (%)
Major complications	6	1.5
SDH	3	0.7
SAH	2	0.5
ICH	1	0.2
Minor complications	14	3.4
Retroperitoneal hemorrhage	1	0.2
Femoral pseudo aneurysm	5	1.2
Neck hematoma	2	0.5
Retroperitoneal hematoma	1	0.2
Femoral vein thrombosis	1	0.2
THL	4	1.0
Overall	20	4.9

SDH: subdural hematoma; SAH: subarachnoid hemorrhage; ICH: intracerebral hemorrhage; THL: transient hearing loss.

Cases

In our experience of two patients that underwent IJ access for DVSS, there were no associated procedural or access site complications and no need for retreatment. At their latest clinical follow-up (> 1 year), both patients had improvement of symptoms without need of CSF flow diversion.

Discussion

Based on evidence from the literature, the incidence of IIH has been noted to be between 1–3/100,000/year in the general population. When stratified for reproductive age, female gender and weight, the incidence rises by 12–28/100,000/year. The prevalence of IIH is 0.9–1.07/100,000 but increases to 15–19/100,000 amongst overweight female population of the age group 20–44 years in the United States [37–39]. Given growing obesity rates in the United States, the total number of affected patients may continue to rise.

CSF flow diversion is an invasive procedure for IIH that is associated with a small, but significant complication rate and moderate rate of repeated procedures [5]. Although only a small percentage of total IIH patients meet criteria for DVSS, this treatment modality is minimally invasive and associated with high technical/procedural success, low associated complication rate and does not preclude patients from CSF flow diversion in the setting of treatment failure.

DVSS was first reported as a treatment by Higgins et al. [9]. DVSS is increasingly being considered in the setting of medically refractory IIH when patients have a hemodynamically significant pressure gradient across the stenosis. Although there is not a strict criterion for pressure gradient threshold, many operators would use a direct pressure gradient of 8 mmHg or greater [5,6,8].There has been an explosion of literature implicating dural venous sinus stenosis as a potentially treatable etiology for a subset of patients with IIH [34,40,41]. Bilateral transverse sinus stenosis has been seen in 90% of the patients with IIH (or stenosis and hypoplasia/absence of the contralateral transverse sinus), in 3D gadolinium enhanced MRV studies [42,43].

Pathophysiology

The proposed physiologic relationship between dural sinus stenosis and IIH is impaired venous drainage. Impaired venous drainage may lead creation of a pressure gradient across the proximal and distal end of the stenosis leading to impaired venous drainage and decreased absorption by the pressure sensitive arachnoid granulations. Hence DVVS can relieve this pressure by removing a Starling-like resistor, thereby removing the positive feedback loop [11]. Although elevated intracranial pressure is seen in all patients, the underlying etiology is unclear and may be multifactorial. Altered CSF flow dynamics is implicated and includes imbalance between CSF overproduction, decreased absorption or impaired drainage.

DVSS targets venous outflow obstruction as a potentially treatable cause of IIH and is therefore, best suited to patients with an obstructive venous outflow pattern. We define this obstructive pattern as isolated superior sagittal sinus stenosis (SSS**), bilateral transverse sinus stenosis, or unilateral transverse sinus stenosis with contralateral hypoplasia or absence. There is a tremendous variation in the dural venous sinuses; therefore, DVSS in a non-obstructive pattern will likely have clinical benefit. For example, an isolated hypoplastic or absent transverse sinus with normal appearance of the SSS** or contralateral TS.

Dural sinus stenosis is generally described as intrinsic or extrinsic, although some patients may have both. An intrinsic obstruction pattern is a focal filling defect secondary to arachnoid granulation (often round/oval abutting a dural sinus wall). Whereas, an extrinsic stenosis may be related to scarring or related to elevated intracranial hypertension itself (often long, tapered and smooth narrowing) [43].

The extrinsic pattern may be technically more difficult to initially cross, have more rebound after angioplasty and make intracranial stent placement technically challenging. Potentially, using balloon expanding stents rather than self-expanding stents in these patients may be considered, although in our analysis there was high technical success and of the reported stents all were self-expandable stents. Another technical consideration in difficult extrinsic compression patterns is the potential increased risk of bleeding complications. In the two cases of intracranial hemorrhage related to DVSS, these more tenacious types of extrinsic compression may be more common, although in the reviewed articles for this meta-analysis not specifically detailed.

Increasingly both neurosurgical and ophthalmic literature supports consideration of DVSS as first line treatment [40,41]. These recent multidisciplinary studies confirm the results of this meta-analysis of DVSS in regard to low associated complications and high success rates. Early assessment suggests that DVSS may also be cost effective, especially when calculating in life-time and re-procedure costs. Ahmed et al calculated the average cost of venous stenting and CSF shunting and found no significant difference between the 2, either as initial or subsequent procedures in the pediatric population [7,40].

The technical success rates of DVSS in our meta-analysis were 99.5%. In Radvany et al., the procedure was interrupted in one case after stagnation of contrast was observed in the venous sinus wall that raised concerns for dissection. The patient was discharged after overnight observation and subsequently treated successfully [29]. Teleb et al. reported a tracking difficulty that prevented placement of a stent and underwent angioplasty. Only one intra-procedural event of stent migration was reported, which was retrieved with no complication [33].

Potential complications from venous sinus stenting could include sinus perforation or rupture with resultant subdural or epidural hematoma, as well as complications associated with the diagnostic arteriography/venography including thromboembolism, dissection and access site complications [10] (Tables 1 and 2).

The standard approach to DVSS involves retrograde common femoral artery access. We have found that direct retrograde internal jugular access is an alternative access approach that is technically feasible and may have some inherent advantages. In our meta-analysis 83% (229/276) patients had the traditional femoral access. Seventeen percent (46/276) of patients had IJ access, 12 patients in Higgins et al. [9], who had no complications and 34 patients in Perez et al, who reported only 2 minor neck hematoma after direct puncture of the internal jugular vein and were treated conservatively [36] giving us a total complication rate of 4.3% (2/46) in IJ access as compared to 3.49% in femoral access (Table 1).

Access route was not mentioned in 15 papers, but are assumed to be conventional common femoral vein access [12–17,19–21,25,27,29,31,32,34].

There were a total 411 stents used in 336 reported patients. Four papers did not report the number of stents used [13–15,34]. The most common stents that were used were self-expanding stents – cordis precise and wallstent, Boston Scientific. The number of stents used, were not specifically identified in these papers, and we assumed that the brand used in each article was the same stent brand used in all the patients except for those that we data on [17,19,27] (Appendix 1).

In our 2 patients that underwent IJ access for DVSS, there was improvement of symptoms at one year follow-up and there were no associated complications postoperatively and there was no need of repeat treatment. Some potential advantages of direct IJ approach include: shorter procedure time, lesser access site complications (no retroperitoneal hemorrhages) and faster recovery (no bed rest).

Limitation

Meta-analysis

Our meta- analysis was limited by variability in available data secondary to reporting bias and institutional and operator protocols. But, to the best of our ability, the studied parameters were standardized and those variables that were not explicitly reported, we excluded from all calculations in the results.

Case series

Most stents that are currently implanted are off label use of self-expanding carotid stents and balloon mounted biliary or peripheral stents. Dedicated stents may improve ease of delivery and have less adjacent dural sinus stenosis (less stiff and less radial force versus currently used stents). These dedicated systems may reduce complications such as subdural hematomas and need for re-treatment with additional stent placement. Another limitation was a small cohort of only 2 patients. In patients with short and thick necks, IJ access may be more technically difficult.

Conclusion

Published data on dural venous sinus stenting over the last 15 years increasingly supports the procedures are associated with low complication rates, high technical success, good outcomes, and low failure or crossover to traditional surgical CSF flow diversion. Additionally, early evaluation of direct retrograde internal jugular access suggests it may be a reasonable alternative to the traditional femoral vein approach.

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Disclosure of interest

Sudhakar R. Satti, MD, Consultant Stryker Neurovascular and Penumbra Neurovascular.

The other authors declare that they have no competing interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found, in the online version, at https://doi.org/10.1016/j.neurad.2018.09.001.

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