Acute Sigmoid Sinus Compromise Following Skull Base Procedures: Is a “Laissez-Faire” Approach Best?

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Abstract

Objective Venous sinus compromise (VSC) of the sigmoid sinus can manifest as either venous sinus thrombosis, stenosis, or a combination of the two. It may occur following retro and presigmoid craniotomy, even in the absence of overt intraoperative sinus injury. Currently, the optimal management of VSC in the perioperative period is not well established. We report our incidence and management of VSC following skull base surgery around the sigmoid sinus.

Patients and Methods A retrospective chart review of all patients undergoing presigmoid, retrosigmoid, or combined approach by the senior author from 2014 to 2019 was performed.

Main Outcome Measures Charts were reviewed for patient demographics, surgical details, details of venous sinus compromise, and patient outcomes. Statistical analyses were performed using R 3.6.0 (R Project).

Results A 115 surgeries were found with a total of 13 cases of VSC (overall incidence of 11.3%). Nine cases exhibited thrombosis and four stenosis. There were no statistically significant differences between the groups with (group 1) or without (group 2) VSC. Operation on the side of the dominant sinus did not predispose to postoperative VSC. Five patients received antiplatelet medication in the perioperative period. There was no difference in outcomes in the group that did not receive antiplatelet medication versus those who did.

Conclusion Acute iatrogenic sigmoid sinus compromise can be managed expectantly. We believe that the treatment for each instance of VSC must be individualized, considering the symptoms of the patient, rather than applying a universal algorithm.

Keywords

- dural venous sinus thrombosis
- cerebral venous sinus thrombosis
- sigmoid sinus
- skull base surgery
- neurosurgery
- retrosigmoid
- translabyrinthine

Introduction

Venous sinus compromise (VSC) of the sigmoid sinus can manifest as either venous sinus thrombosis, stenosis, or a combination of the two. It may occur following retro and

presigmoid craniotomy, even in the absence of overt intraoperative sinus injury. The risk of VSC following retro or presigmoid craniotomy is reported to be up to 32.4%, and VSC is asymptomatic in most cases.¹ The optimal management of VSC in the perioperative period is not well established and

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presents a difficult management decision. While anticoagulation is considered standard of the care for spontaneous cerebral venous sinus thrombosis,² the risk of hemorrhage in the postoperative period must be weighed against the risk of venous hypertension, hydrocephalus, and other sequelae of sinus thrombosis propagation and occlusion. Small series of perioperative sigmoid VSC have been reported, with management strategies ranging from observation to antiplatelet therapy or full dose anticoagulation.^{1–6} Still, the efficacy, safety, and timing of antiplatelet therapy and anticoagulation in the perioperative period for treatment of iatrogenic VSC is not well established.

We therefore report the incidence of VSC following skull base surgery around the sigmoid sinus in our patient series. We outline the management of such instances to identify clinical outcomes and perioperative risk factors for postoperative VSC in these patients.

Patients and Methods

Approval was obtained from the Colorado Multiple Institutional Review Board under COMIRB Protocol 18–2342. A retrospective chart review of all patients undergoing presigmoid, retrosigmoid, or combined approach by the senior author from 2014 to 2019 was performed. Patients were excluded if there was preoperative infiltration or occlusion of the transverse sinus, sigmoid sinus, or jugular bulb. Additionally, patients in whom the sinus was sacrificed as part of the surgical approach were excluded. To accurately collect outcomes data on all patients with new VSC after surgery both patients with venous sinus stenosis and thrombosis were included in this study. Data collected included patient demographics, comorbidities, radiological characteristics of the tumor location, size, dominant venous drainage pattern, surgical approach, intraoperative sinus injury, length of surgery, blood loss, surgical complications, deep vein thrombosis, time to diagnosis, venous sinus thrombosis or stenosis, consequences of VSC, management strategy for VSC, related complications of VSC treatment, sinus patency at last follow-up, hospital length of stay, and discharge destination. Modified Rankin scale (mRS) prior to surgery, at discharge, and last follow-up was also noted. Patients undergoing craniotomy at this institution during this period underwent standard postoperative day 1 magnetic resonance imaging (MRI) brain with and without contrast as part of the senior author's practice pattern.

Diagnosis of sinus thrombosis or stenosis was initially indicated by neuroradiology read of imaging ordered either as routine postoperative or venography obtained for clinical concern. All imaging was also independently reviewed by the neurosurgical team and patients underwent treatment for VSC if the two interpretations concurred.

Statistical Analysis

Statistical analyses were performed using R 3.6.0 (R Project). Univariate analyses were performed using the unpaired *t*-test for continuous variables, and Chi-square or Fisher's exact test for comparing categorical variables, as appropriate. A *p*-value <0.05 was considered significant.

Results

A total of 115 surgeries were done on 113 patients. Two patients had two surgeries, one had neurofibromatosis type 2 and underwent bilateral surgeries 4 years apart, and the other underwent staged resection of a large vestibular schwannoma 42 days apart due to large volume and hypervascularity of the tumor. Preoperative characteristics are listed in ▶Table 1. The average age was 49 years and the most common pathology was schwannoma (65.2%), followed by meningioma (20%). The retrosigmoid approach was the most frequently utilized (51.3%), followed by presigmoid

Table 1 Baseline and preoperative comparison of groups with and without venous sinus compromise

	VSC (%)	No VSC (%)	p-Value
Total cases	13	102	
Average age (y)	51	49	0.59
Sex			
Female	9 (69.2)	56 (54.9)	0.38
Male	4 (30.8)	46 (45.1)	
BMI	29.85	27.92	0.48
Smoking	1 (7.7)	18 (17.6)	0.69
HTN	4 (30.8)	45 (44.1)	0.55
DM	0	11 (10.8)	0.35
HLD	3 (23.1)	19 (18.6)	0.71
PVD	0	3 (2.9)	0.99
Hypercoagulable state	0	1 (0.98)	0.99
Coagulopathy	1 (7.7)	2 (2.0)	0.30
Pathology			
Schwannoma	9 (69.2)	66 (64.7)	0.99
Meningioma	3 (23.1)	20 (19.6)	
Epidermoid	0	5 (4.9)	
Trigeminal neuralgia	0	2 (2.0)	
Other ^a	1 (7.7)	9 (8.8)	
Approach			
Retrosigmoid	7 (53.8)	52 (51)	0.51
Presigmoid (translabyrinthine or infralabyrinthine)	4 (30.8)	41 (40.2)	
Combined approach	1 (7.7)	6 (5.9)	
Far lateral	1 (7.7)	3 (2.9)	
Tumor volume mm ³	1,3892.57	9,223.49	0.48
mRS baseline	1.23	1.24	0.92
Side = preoperative dominant sinus	6 (46.1)	33 (32.3)	0.54

Abbreviations: BMI, body mass index; DM, diabetes mellitus; HLD, hyperlipidemia; HTN, hypertension; PVD, peripheral vascular disease; mRS, modified Rankin scale; VSC, venous sinus compromise.

^aGiant cell tumor, chondrosarcoma, metastasis, glial tumor, heman-gioblastoma, cavernoma, and endolymphatic sac tumor.

Table 2 Tumor, patient, and surgical characteristics of patients with postoperative venous sinus compromise. Included are patient age, sex, , pathology and World Health Organization grade, approach, approach side, dominant sinus side, presence of intraoperative sinus injury, intraoperative maneuvers to address a sinus injury if present, and other surgical complications

Patient	Age	Sex	Pathology (WHO grade)	Approach	Approach side	Dominant sinus	Intraoperative sinus injury?	Intraoperative sinus injury treatment	Other surgical complications
1	63	F	Endolymphatic sac tumor	PS/RS	R	R	N		CSF leak SSI
2	49	F	Vestibular schwannoma (I)	RS	L	R	Y	Sutured	N/A
3	64	F	Schwannoma (I) CN 9 at JF	RS	R	R	Y	Tamponade with absorbable gelatin sponge	N/A
4	69	M	Vestibular schwannoma (I)	RS	R	CO	N		Meningitis
5	61	F	Meningioma (I)	RS	L	R	N		N/A
6	68	F	Vestibular schwannoma (I)	TL	R	R	Y	Decompressed jugular bulb	N/A
7	46	M	Facial schwannoma (I)	TL	R	CO	N		Sural nerve grafting Pseudomeningocele
8	43	M	Meningioma (I)	FL	L	L	N		N/A
9	37	F	Schwannoma (I) CN XI at JF	RS	R	CO	N		N/A
10	63	F	Vestibular schwannoma (I)	TL	L	CO	N		CSF leak Meningitis
11	49	F	Vestibular schwannoma (I)	RS	R	CO	N		N/A
12	33	F	Meningioma (I)	RS	L	CO	N		N/A
13	20	M	Vestibular schwannoma (I)	TL	L	L	N		SSI

Abbreviations: CO, codominant; CSF, cerebrospinal fluid; F, female; FL, far lateral; M, male; PS/RS, combined presigmoid/retrosigmoid; L, left; N, no; N/A, nonapplicable; R, right; SSI, surgical site infection; TL, translabyrinthine; Y, yes; VSC, venous sinus compromise; WHO, World Health Organization.

(translabyrinthine or infralabyrinthine, 39.1%), combined (6.1%), and far lateral approach (3.5%). Average follow up was 401 days (median 329 days; range = 8–1,488 days). All 115 patients underwent postoperative MRI with and without contrast. In addition, four had a CTV and seven had a magnetic resonance venography (MRV).

In the 115 patients undergoing postoperative imaging, there were a total of 13 cases of VSC for an overall incidence of 11.3%. The details for each instance of VSC are listed in ►Tables 2 and 3. Among the 13 cases of VSC, 9 cases exhibited dural venous sinus thrombosis, while the remaining 4 cases were characterized by sinus stenosis without overt evidence of thrombosis. Nine cases were diagnosed in the immediate postoperative hospital stay, while four were found between 2 and 3 weeks after surgery: two during workup of infection, one for headaches, and the other during imaging for a pseudomeningocele. One patient became symptomatic with chronic headaches, though without hydrocephalus or increased intracranial pressure which were beyond the duration and severity expected for routine postoperative headaches. Four sinuses were completely occluded postoperatively, two of which recanalized by last follow-up. Overall, 11 sinuses were patent at last follow-up, 7 of which improved or resolved from the prior imaging (►Fig. 1).

There were no statistically significant differences between the groups with (group 1) or without (group 2) VSC of the transverse/sigmoid sinus with respect to patient demographics, comorbidities, pathology, tumor volume, or surgical approach. Furthermore, operation on the side of the dominant sinus did not predispose to postoperative VSC.

The intraoperative characteristics and outcomes of each group are listed in ►Table 4. There was no significant difference between the groups with respect to extent of resection, length of surgery, blood loss, development of hydrocephalus, CSF leak, infection, length of stay, discharge destination, or modified Rankin's score at discharge and last follow-up.

Treatment

Five patients received antiplatelet medication in the perioperative period. Four received antibiotics for a concomitant infection. A comparison of the groups receiving antiplatelet treatment versus not is listed in ►Table 5. There was no difference in complication rate, hospital length of stay, discharge destination, eventual patency of the sinus, or mRS in the group that did not receive antiplatelet medication versus those who did. No patients were anticoagulated in the perioperative period. In an outside facility, one patient who developed symptomatic chronic headaches received a delayed 21-week

Table 3 Postoperative characteristics of patients with venous sinus compromise. Including type of venous sinus compromise (stenosis vs. dural venous sinus thrombosis), venous sinus compromise location, sinus patency on postoperative imaging, imaging modality on which venous sinus compromise was diagnosed whether the patient was symptomatic or not, whether the venous sinus compromise was treated, treatment regimen if treated, treatment complications, and whether the sinus was patent on last clinical follow-up

Patient	VSC location	VSC type	Sinus patent postoperation?	Imaging modality	Symptomatic (symptoms)	Treated Y/N	Treatment	Treatment complication	Sinus patent last follow-up?
1	SS	Stenosis	Y	MRI	Asx	N	None	NA	Y
2	SS/IJ	DVST	N	MRI	Asx	Y	ASA 81 (3 months)	N	Y
3	SS/JB	Stenosis	Y	MRI	Asx	N	None	NA	Y
4	SS/JB	DVST	N	MRI	Asx	N	None	NA	N
5	SS	DVST	Y	MRI	Asx	N	None	NA	Y
6	SS/JB	DVST	Y	MRI	Asx	Y	ASA 325 (3 months)	N	Y
7	SS/JB	Stenosis	Y	MRI	Asx	N	None	NA	Y
8	SS	DVST	N	MRI CTV	Sx (HA)	Y	ASA 325 (3 months) ASA 81 (3 months) Eliquis (3 months) ASA 81 (indefinitely)	N	N
9	SS	DVST	N	MRI CTV	Asx	Y	ASA 81 (3 months)	N	Y
10	SS/IJ	DVST	Y	MRI CTV	Asx	N	None (antibiotics/meningitis)	NA	Y
11	TS/SS	DVST	Y	MRI	Asx	Y	ASA 325 (3 months) ASA 81 (3 months)	N	Y
12	SS	Stenosis	Y	MRI	Asx	N	None	NA	Y
13	TS/SS	DVST	Y	MRI	Asx	N	None (antibiotics/SSI)	NA	Y

Abbreviations: Asx, asymptomatic; CTV, computed tomography venography; HA, headache; IJ, internal jugular vein; JB, jugular bulb; MRI, magnetic resonance imaging; N, no; SS, sigmoid sinus; Sx, symptomatic; TS, transverse sinus; Y, yes; VSC, venous sinus compromise.

Fig. 1 Preoperative axial (A) and coronal (B) T1 postcontrast MRI and venogram (C) showing a large left posterior fossa meningioma and patent sigmoid sinus. Postcontrast sagittal T1 MRI showing sigmoid thrombosis (D) that resolved on interval follow-up imaging 7 months later (E). MRI, magnetic resonance imaging.

course of a factor Xa inhibitor as an empiric treatment in an attempt to resolve the headaches more than 18 months after his surgery with symptoms remaining unchanged.

Discussion

The ramifications of operating around the sigmoid sinus can include bleeding, air embolism, sinus thrombosis, stenosis,

and/or occlusion. Managing iatrogenic sigmoid venous sinus thrombosis presents a dilemma in absence of clear guidelines balancing the risks of postoperative hemorrhage with antiplatelet or anticoagulation therapy against the risks of extension of the thrombosis, sinus occlusion, and resultant venous hypertension. In our series, careful observation led to favorable outcomes, and treatment with antiplatelet medication did not impact the overall outcome. We do not

Table 4 Operative and postoperative parameters of groups with and without ventricular systolic index

	VSC	No VSC	p-Value
Extent of resection			
Gross total	7 (53.8)	65 (63.7)	0.40
Near total	3 (23.1)	24 (23.5)	
Subtotal	3 (23.1)	10 (9.8)	
Length of surgery (min)	437.3	400.6	0.47
EBL (cc)	115.38	133.00	0.40
Hydrocephalus	0	5 (4.9)	0.99
CSF leak	2 (15.4)	8 (7.8)	0.31
Surgical infection	2 (15.4)	7 (6.9)	0.26
Meningitis	2 (15.4)	3 (2.9)	0.097
Any infection ^a	4 (30.8)	10 (9.8)	0.052
Any complication ^b	4 (30.8)	16 (15.7)	0.23
Hospital LOS (d)	5.3	8.7	0.36
Discharge destination			
Home	10 (76.9)	88 (86.3)	0.45
Rehab	3 (23.1)	13 (12.7)	
Nursing facility	0	1 (0.98)	
mRS discharge	1.76	1.33	0.26
mRS last follow-up	1.23	0.97	0.24

Abbreviations: CSF, cerebrospinal fluid; EBL, estimated blood loss; LOS, length of stay; mRS, modified Rankin scale; VSC, venous sinus compromise.

^aSurgical infection or meningitis.

^bHydrocephalus, CSF leak, surgical infection, or meningitis.

use anticoagulation to avoid serious perioperative hemorrhagic complications.

Existing Evidence

Little is reported regarding the risks and ramifications of postoperative VSC. In some cases, the diagnosis is made purely by radiological findings in the absence of clinical signs or symptoms. Much depends on the inherent venous drainage pattern and collateral circulation to the occluded pathway. Furthermore, in cases of postoperative wound infection or meningitis, it is unclear whether the occluded sinus predisposes to infection, or the infectious process causes thrombosis due to a local inflammatory response. In the latter cases, after appropriate antibiotic treatment, the sinus may often naturally recanalize.⁷

Initial studies looking at postoperative VSC tended to collect data on symptomatic patients only when they presented back to the hospital with a complication.^{8,9} More recently, however, a relatively high rate of asymptomatic postoperative VSC has been appreciated.^{1,4,10} Shew et al analyzed 127 cases of cerebellopontine angle tumor resection, noting that official radiology reads of postoperative imaging significantly underreported the incidence of postoperative VSC compared with a neuroradiologist's retrospective review (3.1 vs. 17.3%, respectively).¹⁰ A recent prospective report by Benjamin et al studied

Table 5 Comparison of treatments among venous sinus compromise patients

	No antiplatelet (n = 8)	Aspirin (n = 5)	p-Value
Hydrocephalus	0	0	
CSF leak	2 (25)	0	0.48
Surgical infection	2 (25)	0	0.48
Meningitis	2 (25)	0	0.48
Any infection (surgical infection + meningitis)	4 (50)	0	0.10
Any complication ^a	4 (50)	0	0.10
Hospital LOS (d)	5.75	4.60	0.42
Discharge destination			
Home	6 (75)	4 (80)	0.99
Rehab	2 (25)	1 (20)	
Nursing facility	0	0	
mRS discharge	1.6	2.2	0.45
mRS last follow-up	1.3	1.0	0.28
Sinus patent ^b	6 (75)	2 (40)	0.29

Abbreviations: CSF, cerebrospinal fluid; EBL, estimated blood loss; LOS, length of stay; mRS, modified Rankin scale.

^aHydrocephalus, CSF leak, surgical infection, or meningitis.

^bAt last follow-up.

74 consecutive cranial surgical cases for postoperative venous sinus thrombosis, citing a 32.4% incidence of postoperative thrombosis. It should be noted that only 48 of such surgeries were adjacent to the sigmoid sinus, and all instances of VSC were asymptomatic.¹

Symptomatic VSC is reported from 0.15 to 4.7% following skull base surgery, and can manifest in the immediate postoperative period or in a delayed fashion.^{8,9} The most dreaded acute complications from VSC are acute hydrocephalus, venous infarct, and intracranial hemorrhage; all of which are life threatening with potentially devastating neurological consequences.^{11,12} However, the most common acute presenting symptom is headache, followed by seizure.^{5,13} Late sequelae can also develop, which include hydrocephalus, papilledema, increased intracranial pressure, and dural arteriovenous fistula.^{6,8} Intraoperative sinus injury may predispose to VSC, and such cases may confer higher risk of patients developing symptoms. Ohata et al found sigmoid sinus occlusion in seven of 143 patients after presigmoidal-transpetrosal approach, 4/7 (57%) of which were symptomatic; however, in the majority of these cases, an intraoperative sinus laceration was noted, with the remainder having compression of the sinus by bone chips on postoperative CT.¹⁴

Common Practice Treatments

Because previous studies and clinical series dealt with symptomatic patients, treatment of VSC has traditionally been aggressive, which often meant full dose anticoagulation

with heparin and a bridge to oral vitamin K antagonists. Moore et al reported an 11.6% rate of transverse and/or sigmoid sinus thrombosis in a series of 43 patients following resection of cerebellopontine angle tumors; all of which were treated with full dose anticoagulation. Only one patient experienced mild vaginal hemorrhage, but no adverse neurological events were noted. They concluded that “early postoperative initiation of systemic anticoagulation is safe and appears to be effective in the prevention of progression of thrombosis and symptom development.”¹⁵ Other subsequent series, however, have warned of increased complications with anticoagulants in the postoperative period. In their series of 180 patients, 7/12 receiving full dose anticoagulation for the treatment of postoperative sinus thrombosis, Apra et al noted a significantly higher rate of surgical complications in patients who received therapeutic postoperative anticoagulation (which included patients with lateral sinus thrombosis in addition to those with other thromboembolic events in the perioperative period).⁴ In another series of 116 vestibular schwannoma surgeries, of three patients receiving full dose anticoagulation for the treatment of postoperative sinus thrombosis, one patient developed subdural and intracranial hemorrhage as a result requiring subsequent emergency surgery.³

Antiplatelet medications are also commonly used for the treatment of VSC in the immediate postoperative setting despite the efficacy of this practice being unknown. Antiplatelet medications are generally considered to be safer than anticoagulation in the perioperative period, and the safety of resuming these medications soon after certain neurosurgical procedures has been established.¹⁶

Current Study

Our results indicate that for asymptomatic patients, antiplatelet initiation does not change outcomes with respect to mRS, length of hospital stay, discharge destination, or eventual sinus patency. For patients with nonocclusive thrombosis, progression of thrombosis to complete occlusion is a concern. However, we did not find this to be the case on follow-up imaging in this study. In fact, recrudescence of the sigmoid sinus was noted in 50% cases of previously occluded sinuses.

The translabyrinthine approach has previously been associated with a higher risk of postoperative VSC.^{10,15} However, we did not find this to be the case in our series. This may be due to varying degrees of sigmoid sinus manipulation and coagulation, especially pertaining to the jugular bulb, that may occur to provide a larger surgical window.¹⁷

There was a trend toward increased infection in the VSC group and double the proportion of CSF leaks. Although this did not reach statistical significance in our study, several other groups have noted potentially higher rates of CSF leak following VSC.^{1,10} None of these studies examined whether or not treatment changed this effect. It should be noted that all of the infections and CSF leaks in our series occurred in the group that did not receive aspirin. It is difficult to draw conclusions of venous hypertensive etiology as the study was not designed, nor powered accordingly, to detect a potential benefit of treatment with antiplatelet medication in pre-

venting CSF leak. Although we are unable to define a relationship in our study, future prospective multicenter studies may be warranted to investigate the effect of antiplatelet medication or anticoagulation on the rate of postoperative CSF leaks following asymptomatic VSC. Asymptomatic patients were managed conservatively in two thirds of our cases, with no resultant neurological deficit.

Study Limitations

Our series is retrospective and limited in number. Not all patients had formal venography, with diagnosis being made solely on postcontrast MRI images in some cases. This reflects the standard of care in diagnosis and follow-up. No patients received full dose anticoagulation in the immediate postoperative period, limiting the conclusion that can be drawn about the true safety of this practice. No patients in our series suffered development of significant postthrombosis complications such as hydrocephalus, seizures, or hemorrhage. Although this may reflect treatment effect, case-controlled studies with a larger patient sample and longer follow-up would better evaluate the incidence of these complications.

Conclusion

Postoperative VSC following skull base surgery presents a difficult management decision. Our patient series has shown us that for asymptomatic patients' careful observation lead to favorable outcomes. From these results, we conclude that expectant management of VSC in asymptomatic patients is a reasonable clinical strategy. For symptomatic patients, treatment should be individualized for their unique clinical circumstances. Clarifying the relationship of increased complications, especially CSF leak, to VSC remains an important investigation for future work.

Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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None.

Conflict of Interest

None declared.

References

- 1 Benjamin CG, Sen RD, Golfinos JG, et al. Postoperative cerebral venous sinus thrombosis in the setting of surgery adjacent to the major dural venous sinuses. *J Neurosurg* 2018;1–7
- 2 Coutinho JM, de Bruijn SF, deVeber G, Stam J. Anticoagulation for cerebral venous sinus thrombosis. *Stroke* 2012;43(04):e41–e42
- 3 Abou-Al-Shaar H, Gozal YM, Alzhrani G, Karsy M, Shelton C, Couldwell WT. Cerebral venous sinus thrombosis after vestibular schwannoma surgery: a call for evidence-based management guidelines. *Neurosurg Focus* 2018;45(01):E4

- 4 Apra C, Kotbi O, Turc G, et al. Presentation and management of lateral sinus thrombosis following posterior fossa surgery. *J Neurosurg* 2017;126(01):8–16
- 5 Geisbüsch C, Lichy C, Richter D, Herweh C, Hacke W, Nagel S. [Clinical course of cerebral sinus venous thrombosis. Data from a monocentric cohort study over 15 years]. *Nervenarzt* 2014;85(02):211–220
- 6 Jean WC, Felbaum DR, Stemer AB, Hoa M, Kim HJ. Venous sinus compromise after pre-sigmoid, transpetrosal approach for skull base tumors: a study on the asymptomatic incidence and report of a rare dural arteriovenous fistula as symptomatic manifestation. *J Clin Neurosci* 2017;39:114–117
- 7 Agarwal A, Lowry P, Isaacson G. Natural history of sigmoid sinus thrombosis. *Ann Otol Rhinol Laryngol* 2003;112(02):191–194
- 8 Keiper GL Jr, Sherman JD, Tomsick TA, Tew JM Jr. Dural sinus thrombosis and pseudotumor cerebri: unexpected complications of suboccipital craniotomy and translabyrinthine craniectomy. *J Neurosurg* 1999;91(02):192–197
- 9 Roberson JB Jr, Brackmann DE, Fayad JN. Complications of venous insufficiency after neurotologic-skull base surgery. *Am J Otol* 2000;21(05):701–705
- 10 Shew M, Kavookjian H, Dahlstrom K, et al. Incidence and risk factors for sigmoid venous thrombosis following CPA tumor resection. *Otol Neurotol* 2018;39(05):e376–e380
- 11 Narra R, Kamaraju SK, Pasupaleti B, Juluri N. Case of cerebral venous thrombosis with unusual venous infarcts. *J Clin Diagn Res* 2015;9(04):TD08–TD10
- 12 Zuurbier SM, van den Berg R, Troost D, Majoie CB, Stam J, Coutinho JM. Hydrocephalus in cerebral venous thrombosis. *J Neurol* 2015;262(04):931–937
- 13 Rim HT, Jun HS, Ahn JH, et al. Clinical aspects of cerebral venous thrombosis: experiences in two institutions. *J Cerebrovasc Endovasc Neurosurg* 2016;18(03):185–193
- 14 Ohata K, Haque M, Morino M, et al. Occlusion of the sigmoid sinus after surgery via the presigmoidal-transpetrosal approach. *J Neurosurg* 1998;89(04):575–584
- 15 Moore J, Thomas P, Cousins V, Rosenfeld JV. Diagnosis and management of dural sinus thrombosis following resection of cerebellopontine angle tumors. *J Neurol Surg B Skull Base* 2014;75(06):402–408
- 16 Kamenova M, Lutz K, Schaedelin S, Fandino J, Mariani L, Soleman J. Does early resumption of low-dose aspirin after evacuation of chronic subdural hematoma with burr-hole drainage lead to higher recurrence rates? *Neurosurgery* 2016;79(05):715–721
- 17 Roche PH, Moriyama T, Thomassin JM, Pellet W. High jugular bulb in the translabyrinthine approach to the cerebellopontine angle: anatomical considerations and surgical management. *Acta Neurochir (Wien)* 2006;148(04):415–420