Presentation and management of lateral sinus thrombosis following posterior fossa surgery

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OBJECTIVE There are no guidelines for the management of postoperative lateral sinus thrombosis following posterior fossa surgery. Introducing treatment-dose anticoagulant therapy during the immediate postoperative period increases the risk of intracranial bleeding. This study assessed the incidence of and risk factors associated with postoperative lateral sinus thrombosis and the complications related to thrombosis and/or anticoagulation.

METHODS This study was a retrospective monocentric analysis of adult patients who underwent surgical removal of a posterior fossa space-occupying lesion with available postoperative imaging. Postoperative lateral sinus thrombosis was defined as a T2* hypointensity within the venous sinus and/or a filling defect on postcontrast MRI or CT scan.

RESULTS Among 180 patients, 12 (6.7%; 95% CI 3.0–10.4) were found to have lateral sinus thrombosis on postoperative imaging, none of whom were symptomatic. Unadjusted risk factors for postoperative lateral sinus thrombosis were a history of deep venous thrombosis ($p = 0.016$), oral contraceptive pill ($p = 0.004$), midline surgical approach ($p = 0.035$), and surgical exposure of the sinus ($p < 0.001$). Seven of the patients (58.3%) with a postoperative lateral sinus thrombosis received immediate treatment-dose anticoagulant therapy. Lateral sinus recanalization occurred radiologically at a mean time of 272 ± 23 days in 85.7% of patients (6 of 7) undergoing treatment-dose anticoagulant therapy and in 20% of patients (1 of 5) not receiving treatment-dose anticoagulant therapy. Postoperative complications occurred in 56.2% of patients (9 of 16) who received treatment-dose curative anticoagulant therapy and in 27% of patients (45 of 164) who did not.

CONCLUSIONS Incidental radiological lateral sinus thrombosis following posterior fossa surgery has an incidence of 6.7%. To further define the benefit-to-risk ratio of a treatment-dose anticoagulant therapy, a prospective trial should be considered.

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KEY WORDS anticoagulation; lateral sinus; posterior fossa; surgery; thrombosis; vascular disorders

PATIENTS who undergo neurosurgical procedures are at risk for perioperative deep venous thrombosis, especially in the case of intracranial surgery. The overall incidence of deep venous thrombosis and pulmonary embolism has been reported to be between 6% and 50% in patients undergoing a craniotomy.^{1,7} Therefore, prophylactic anticoagulation during the postoperative period is recommended, although it is estimated to increase the risk of intracranial hemorrhage from 1% to 11%.^{1,14} Neurosurgical patients are also at risk for postoperative cerebral venous thrombosis, mainly of the lateral sinus in the case of

posterior fossa surgery. It has been reported that following surgery for cerebellopontine angle tumors, the incidence of postoperative lateral sinus thrombosis is 11.6% (95% CI 2.0–20.2).¹³ There is a broad range of clinical presentations, from asymptomatic to potentially severe, such as hydrocephalus, epilepsy, and death.¹² There are no other studies regarding posterior fossa for other lesions. Therefore, the incidence, clinical presentation, and prognosis of postoperative lateral sinus thrombosis are largely unknown. In the absence of practical guidelines and to inform decision making, we assessed the following: 1) the

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incidence of postoperative lateral sinus thrombosis following surgery for any posterior fossa lesion in adults; 2) the risk factors associated with this condition; and 3) the thrombosis- and anticoagulation-related complications.

Methods

Data Source and Study Design

We retrospectively analyzed all patients who underwent surgical treatment at a single institution for a posterior fossa space-occupying lesion between January 2008 and May 2014. Inclusion criteria were: 1) patients ≥ 18 years old; 2) posterior fossa craniectomy (midline, paramedian, or lateral suboccipital approach) for the removal of a space-occupying lesion; 3) available preoperative imaging (MRI and/or postcontrast CT scan); 4) available digitized postoperative follow-up imaging (MRI and/or postcontrast CT scan); and 5) at least 6 months of postoperative clinical and imaging follow-up.

Diagnosis of Postoperative Lateral Sinus Thrombosis

One reader (C.A.), who was blinded to clinical data, reviewed all preoperative images to ensure that no lateral sinus thrombosis was patent before surgery. Two readers (C.A. and O.K.), who were blinded to clinical data, independently reviewed postoperative images to search for lateral sinus thrombosis. A senior neuroradiologist (C.O.) adjudicated all cases of postoperative lateral sinus thrombosis and resolved discordances. Lateral sinus thrombosis was defined as a T2* hypointensity within the venous sinus and/or by a flow defect on a postoperative contrast-enhanced 3D T1-weighted sequence or postcontrast CT scan. In case of a postoperative lateral sinus thrombosis, all available subsequent follow-up images were analyzed to document whether and when the thrombus disappeared.

Data Collection

The following variables were collected from the medical records, using a standardized form: sex, age, history of neoplasm, deep venous thrombosis, smoking, medications (e.g., oral contraceptives, anticoagulant therapy, or antiplatelet drugs), Karnofsky Performance Scale score, location of lesion, lesion size, and histopathological diagnosis. Surgery-related details collected included the following: duration of surgery, extent of craniectomy, lateral sinus exposure, lateral sinus opening, dural coagulation toward lateral sinus, and duraplasty. Follow-up-related characteristics included the following: early and long-term postoperative complications (e.g., lateral sinus thrombosis, other deep venous thrombosis, pulmonary embolism, surgical bed hemorrhage, second-look surgery, hydrocephalus, scar defect, infection, or other complication), postoperative anticoagulation, postoperative imaging, and clinical follow-up.

Statistical Analyses

Continuous variables are described as the mean $\pm$ SD (range). Categorical variables are described as percentages. We assessed risk factors for postoperative lateral sinus thrombosis in patients who underwent a posterior fossa craniectomy for resection of a space-occupying lesion and

who had a postoperative lateral sinus thrombosis (thrombosis group) compared with those who did not (nonthrombosis group). Univariable analyses were performed, computing unadjusted odds ratios and using the chi-square or Fisher's exact test for comparing categorical variables, and the unpaired t-test or Mann-Whitney U-test for continuous variables, as appropriate. Multivariable analyses were not performed given the low number of events. A p value < 0.05 was considered significant. Statistical analyses were performed using JMP version 11.0.0 (SAS Institute) and SPSS Statistics version 20.0 (IBM Corp.) software.

Results

Study Population

A total of 201 patients were screened. We excluded 21 patients (10.4%) who did not have the required postoperative imaging ($n = 12$) or imaging follow-up ($n = 9$), leaving 180 patients for the present analysis. The included patients (99 women and 81 men) had a mean age of 52 ± 7 years (range 18–81 years). Eighty-six patients (48%) had metastases, 43 (24%) had primary cerebral neoplasms, 27 (15%) had meningiomas, 16 (9%) had acoustic schwannomas, and 8 (4%) had nonneoplastic mass lesions. The patients' main characteristics are summarized in Table 1.

Postoperative Lateral Sinus Thrombosis

Twelve patients (6.7%; 95% CI 3.0–10.4) had lateral sinus thrombosis on postoperative imaging (169 of 180 patients underwent MRI and 11 had postcontrast CT scans), which was performed at a mean of 2.5 ± 0.2 days (range 0–52 days) following surgery. Lateral sinus thromboses were ipsilateral to the operating site in all cases. They were limited to the sigmoid sinus in 4 cases, to the transverse sinus in 1 case, or extended to both transverse and sigmoid sinuses in the remaining 7 cases. An illustrative case is shown in Fig. 1. None of the thromboses were present on preoperative imaging (145 of 180 patients underwent MRI and 35 had postcontrast CT scans) performed at a mean of 15.1 ± 1.5 days (range 1–170 days) before surgery. Nine lateral sinus thromboses (75%) were detected at the time of initial radiological reporting, whereas the other 3 cases were undiagnosed until the present retrospective analysis. Of the 12 patients harboring a lateral sinus thrombosis, none had any related neurological symptoms or signs during the early postoperative period and within 6 months of follow-up. The main characteristics of the patients with lateral sinus thrombosis are summarized in Table 2.

Management of Postoperative Lateral Sinus Thrombosis

Of the 9 patients who were contemporaneously diagnosed with postoperative lateral sinus thrombosis, 7 received immediate treatment-dose anticoagulant therapy with enoxaparin (8000 IU twice per day), and 1 patient was switched from enoxaparin to oral anticoagulation. Immediate treatment-dose anticoagulant therapy was decided on an individual basis in the absence of institutional guidelines: introduction in 7 cases (intraoperative lateral sinus damage in 2 cases, history of pulmonary embolism in 1 case, extensive lateral sinus thrombosis in 1 case, associated cerebellar ischemia in 1 case, and unknown reasons in

TABLE 1. Main characteristics of 180 adult patients who underwent surgical removal of a posterior fossa space-occupying lesion*

Parameter	Whole Series (n = 180)		Nonthromb Group (n = 168)		Lateral Sinus Thromb Group (n = 12)	
	No.	%	No.	%	No.	%
Clinical						
Sex						
M	81	45	78	46	3	25
F	99	55	90	54	9	75
Age in yrs, mean ± SD	52 ± 7		52 ± 7		51 ± 8	
No. of surgeries						
1	165	92	154	92	11	92
2	6	3.3	6	4	0	0
3	1	0.6	0	0	1	8
Medical history						
Deep venous thromb	8	4	5	3	3	25
Hormonal contraception	2	1	0	0	2	17
Smoking	38	21	35	21	3	25
Neoplasm	78	43	74	44	4	33
AC therapy	13	7	12	7	1	8
Antiplatelets	11	6	11	7	0	0
Imaging & histopathological						
Lesion location						
Intradural	139	77	131	78	8	67
Extradural	41	23	37	22	4	33
Lesion in contact w/ lateral sinus	23	13	22	13	1	8
Lesion in contact w/ midline	70	39	68	40	2	17
Lesion diameter in mm, mean ± SD	35 ± 6		35 ± 6		36 ± 8	
Histopathological Dx						
Malignant	98	54	93	55	5	42
Nonmalignant	82	46	75	45	7	58
Metastases	86	48	81	48	5	42
Primary cerebral tumors	43	24	40	24	3	25
Meningiomas	27	15	24	14	3	25
Schwannomas	16	9	15	9	1	8
Abscess	1	<1	1	<1	0	0
Cavernoma	2	1	2	1	0	0
Epidermoid cysts	5	3	5	3	0	0
Surgical & therapeutic						
Duration of op in mins, mean ± SD	221 ± 55		218 ± 54		266 ± 69	
>120 mins	110	86	101	60	9	75
≤120 mins	18	14	17	10	1	8
Lateral sinus exp	45	25	36	21	9	75
Midline exp	95	53	92	55	3	25
Dura mater extensive coagulation	13	7	12	7	1	8
Lateral sinus injury	8	4	6	4	2	17
Duraplasty	53	29	51	30	2	17
Postop management						
Postop complications						
Extracranial venous thromb	6	3	5	3	1	8

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TABLE 1. Main characteristics of 180 adult patients who underwent surgical removal of a posterior fossa space-occupying lesion*

Parameter	Whole Series (n = 180)		Nonthromb Group (n = 168)		Lateral Sinus Thromb Group (n = 12)	
	No.	%	No.	%	No.	%
Postop management (<i>continued</i>)						
Postop complications (<i>continued</i>)						
Lateral sinus thromb	12	7	NA	NA	—	—
Infection	20	11	18	11	2	17
Hydrocephalus	21	12	20	12	1	8
Intracerebral hemorrhage	19	11	19	11	0	0
Scar opening or collection	25	14	23	14	2	17
Postop management						
Preventive AC	144	80	135	80	9	75
Curative AC	16	9	9	5	7	58
Need for a 2nd op	27	15	26	15	2	17

AC = anticoagulation; Dx = diagnosis; exp = exposure; NA = not applicable; thromb = thrombosis.

* Characteristics of the whole study population (n = 180), divided into nonthrombosis group (n = 168) and thrombosis group (n = 12), for clinical, imaging, histopathological, and surgical parameters. The thrombosis group includes all cases with a postoperative lateral sinus thrombosis.

the remaining 2 cases) and no introduction in 2 cases (late diagnosis in 1 case and small lateral sinus thrombosis in 1 case). Anticoagulant therapy was stopped when imaging follow-up showed sinus recanalization, or after 3 months when patients remained stable. The 5 untreated patients (2 detected and 3 undetected lateral sinus thromboses at the time of initial radiological reporting) received a standard prophylactic dose of anticoagulant therapy with low-dose enoxaparin (4000 IU per day) until discharge. Follow-up

imaging demonstrated a lateral sinus recanalization in 7 patients (58.3%) after 272 ± 23 days (range 6–1464 days) and a persisting lateral sinus thrombosis in 5 patients (41.7%) on the most recent follow-up imaging at 1393 ± 338 days (range 839–2364 days). The treatment-dose anticoagulant therapy seemed to increase the rate of long-term lateral sinus recanalization (85.7%; 6 of 7 patients) compared with untreated patients (20.0%; 1 of 5 patients), without reaching statistical significance ($p = 0.189$).

FIG. 1. Example of a thrombus of the left sigmoid sinus following the resection of a left cerebellar hemangioblastoma (A and B) in a 63-year-old man who presented with headaches and a cerebellar syndrome. The sigmoid sinus thrombosis is demonstrated on 1-day postoperative MRI as a hypointense clot on T2* (C) and as a hypointense filling defect on the postcontrast T1-weighted sequence (D). The white arrow in panel B, black arrowhead in panel C, and white arrowhead in panel D point to the clot.

TABLE 2. Clinical, histopathological, imaging, and surgical characteristics of 12 patients in the lateral thrombosis group*

Case No.	Sex	Age (yrs)	Medical Hx	Histology	Op		Lateral Sinus Thromb			Tx			Date of Thromb Res	
					Duration (mins)	Sinus Exp	Surgical Events*	Postop	Date of Dx	Dx at the Time	Location	Complications*		Preventive AC
1	M	53	Smoking, alcoholism	Metastasis	180	Yes		Day 2	No	SS & TS	Seizures	No	No (no initial Dx)	P
2	F	66	Deep venous thromb, breast cancer, HT, hep B, dyslipidemia	Meningioma	300	Yes	Extensive dural coagulation	Day 21	Yes	SS	Minor scar leaking	Yes	No (surgeon's choice, late Dx)	4 yrs, 23 days
3	F	48	Psychosis	Meningioma	290	No		Day 2	No	SS & TS	Tracheotomy, deglutition difficulties, facial palsy	Yes	No (no initial Dx)	P
4	F	56	Smoking	Metastasis	140	Yes	Bleeding & clipping of sinus	Day 2	Yes	SS & TS		Yes	Yes (surgeon's choice, extensive thromb, & intraop sinus clipping)	68 days
5	F	60	PE, smoking, uterine cancer	Metastasis	240	Yes		Day 103	Yes	SS & TS		No	Yes (surgeon's choice, Hx of PE)	10 mos, 25 days
6	F	25	Iron deficiency, asthma	Pilocytic astrocytoma	Missing data	Yes	Bleeding controlled by pressure & hemostatic material, synthetic dural plasty	Day 4	Yes	SS & TS	2nd op for HC	Yes	Yes (surgeon's choice, intraop sinus compression by hemostatic material)	42 days
7	F	62	Small cell lung carcinoma, HT	Meningioma	270	No		Day 1	Yes	SS & TS		Yes	Yes (surgeon's choice, extensive thromb)	P
8	F	64	Hypothyroidism, renal stones, cardiac arrhythmia	Metastasis	540	Yes		Day 16	No	SS	Facial palsy	Yes	No (no initial Dx)	P
9	M	63	Missing data	Hemangioblastoma	160	Yes		Day 1	Yes	SS		No	Yes (unknown, surgeon's choice)	18 days
10	M	49	Diabetes mellitus, asthma, HT	Acoustic schwannoma	440	Yes		Day 6	Yes	SS & TS	2nd op for scar reopening & infection	Yes	Yes (unknown, surgeon's choice)	53 days
11	F	53	Deep venous thromb, oral contraception, hypothyroidism	Metastasis	100	Yes		Day 1	Yes	SS		Yes	No (surgeon's choice, small thromb restricted to SS)	P

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TABLE 2. Clinical, histopathological, imaging, and surgical characteristics of 12 patients in the lateral thrombosis group*

Case No.	Sex	Age (yrs)	Medical Hx	Histology	Duration (mins)	Sinus Exp	Op		Lateral Sinus Thromb			Tx			Date of Thromb Res
							Surgical Events*		Date of Dx Postop	Dx at the Time	Location	Complications*	Preventive AC	Curative AC (reason)	

12	F	29	Oral contraceptive, dyslipidemia	Pilocytic astrocytoma	Missing data	No	Natural dural plasty		Day 1	Yes	TS	HC, meningitis, subcutaneous collection, PE	Yes	Yes (surgeon's choice, cerebellar ischemia)	6 days
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HC = hydrocephalus; hep = hepatitis; HT = hypertension; Hx = history; P = persistent; PE = pulmonary embolism; pts = patients; res = resolution; SS = sigmoid sinus; TS = transverse sinus; Tx = treatment.

* An empty cell means there was no particular event in the collected data (no particular surgical event/no postoperative complication). Postoperative imaging consisted of MRI in all patients except the one in Case 3, who underwent CT scanning.

Surgical Outcomes

The incidence of surgical complications was 28.0% (47 of 168 patients) in the nonthrombosis group and 50.0% (6 of 12 patients) in the thrombosis group. A postoperative hydrocephalus requiring internal shunting was seen in 16.7% of patients (2 of 12) with lateral sinus thrombosis versus 11.3% of patients (19 of 168) without lateral sinus thrombosis. The incidence of surgical complications was significantly higher in patients who received treatment-dose anticoagulant therapy for postoperative lateral sinus thrombosis ($n = 7$) or other postoperative thromboembolic events ($n = 9$) (56.2%; 9 of 16 patients) than in patients who did not receive such therapy (27.0%; 45 of 164 patients) ($p = 0.020$). Indeed, a second-look surgery was performed in 6 of 16 patients (37.5%) versus 22 of 164 patients (13.4%); a surgical bed hemorrhage was observed in 3 of 16 patients (18.8%) versus 17 of 164 patients (10.4%); and a scar defect was observed in 3 of 16 patients (18.8%) versus 14 of 164 patients (8.5%). Of note, 1 patient with a postoperative lateral sinus thrombosis who received treatment-dose anticoagulant therapy had a scar defect secondary to a subcutaneous hematoma that required a surgical evacuation during the early postoperative period. No treatment-related complications were observed at 6 months of follow-up. Patients with untreated postoperative lateral sinus thrombosis did not develop neurological worsening, ischemic events, symptomatic pulmonary embolism, or deep venous thrombosis during the early postoperative period and at 6 months of follow-up.

Risk Factors for Postoperative Lateral Sinus Thrombosis

As shown in Table 3, risk factors associated with postoperative lateral sinus thrombosis in univariable analysis were oral contraceptive pill usage ($p = 0.004$), medical history of venous thrombosis ($p = 0.016$), midline surgical approach ($p = 0.035$), and intraoperative lateral sinus exposure ($p < 0.001$). None of the other surgical parameters, such as accidental opening of the lateral sinus ($p = 0.097$), dura mater coagulation over the sinus ($p = 0.619$), or duraplasty ($p = 0.412$), were significantly associated with postoperative lateral sinus thrombosis.

Discussion

The incidence, clinical impact, risk factors, and evolution of radiological postoperative lateral sinus thrombosis following posterior fossa surgery of a space-occupying lesion have been largely unknown. We show for the first time, in a retrospective, single-institution series of 180 adult patients, that postoperative lateral sinus thromboses occur in approximately 7% of cases following a posterior fossa surgery, are not restricted to cerebellopontine angle tumor resection, and are well tolerated without long-term impairment. In addition, we identified history of deep venous thrombosis, oral contraceptive pill use, midline surgical approach, and surgical exposure of the lateral sinus as risk factors.

Incidence of Postoperative Lateral Sinus Thrombosis

No previous study has examined the incidence of radiological postoperative lateral sinus thrombosis following suboccipital craniectomy. Herein, we show that it is

TABLE 3. Logistic regression model of risk factors for postoperative lateral sinus thrombosis in 180 adult patients*

Parameters	No.	OR	95% CI	p Value
Clinical				
Sex				
M	3	1 (ref)	—	—
F	9	2.67	0.76–12.31	0.128
No. of ops				
1	165	1 (ref)	—	—
≥2	15	0.99	0.12–8.27	1.00
Age, yrs				
<50	3	1 (ref)	—	—
≥50	9	1.96	0.56–9.08	0.304
Medical history				
Deep venous thromb	3	8.94	1.92–41.70	0.016
Oral contraception	2	—	—	0.004
Smoking	3	1.21	0.31–4.72	0.508
Neoplasm	4	0.63	0.18–2.17	0.335
AC therapy	1	1.17	0.14–9.88	0.607
Antiplatelets	0	—	—	1.00
Imaging & histopathological				
Lesion location				
Extradural	4	1 (ref)	—	—
Intradural	8	0.57	0.16–2.00	0.475
Lesion contacting lateral sinus	1	0.59	0.07–4.81	0.520
Lesion contacting midline	4	0.75	0.22–2.59	0.448
Mean lesion diameter, mm				
<35	3	1 (ref)	—	—
≥35	6	1.79	0.43–7.45	0.505
Histopathological Dx				
Nonmalignant	7	1 (ref)	—	—
Malignant	5	0.06	0.17–31.86	0.260
Histopathological subtype				
Other	11	1 (ref)	—	—
Schwannoma	1	0.92	0.11–7.63	1.00
Surgical & therapeutic				
Duration of op, mins				
≤120	1	1 (ref)	—	—
>120	9	1.51	0.18–12.73	1.00
Lateral sinus exp	9	10.50	2.70–40.83	<0.001
Midline exp	3	0.26	0.07–0.98	0.035
Dura mater extensive coagulation	1	1.14	0.14–9.56	0.619
Lateral sinus injury	2	5.20	0.93–29.14	0.097
Duraplasty	2	0.54	0.09–3.36	0.412
Postop management				
Preventive AC	9	0.71	0.18–2.78	0.427
Extracranial deep venous thromb	1	4.97	0.48–51.80	0.467
Surgical bed infection	2	1.66	0.34–8.16	0.710
Scar opening, subcutaneous collection	3	2.32	0.58–9.25	0.495
Hydrocephalus	2	1.56	0.32–7.65	0.763
Surgical bed hemorrhage	0	—	—	—
Need for a 2nd op	3	2.09	0.53–8.29	0.510

Ref = reference (referral for statistical analyses); — = no event.

* Unadjusted odds ratios for potential risk factors and complications compared in the nonthrombosis and thrombosis groups.

not a rare event (incidence 6.7% [95% CI 3.0–10.4]) in an observational retrospective series of 180 adult patients who underwent suboccipital craniectomy for a variety of conditions. This is in agreement with a previous study by Keiper et al., which reported 5 postoperative lateral sinus thromboses (4.7%) following 107 suboccipital craniectomies or translabyrinthine craniectomies, without detailing the thrombosis rate by surgical approach.¹² However, postoperative lateral sinus thrombosis appears to be less frequent following suboccipital craniectomy than following a cerebellopontine angle surgery; Moore et al. reported 5 postoperative lateral sinus thromboses (11.6%) following 43 cerebellopontine angle surgeries.¹³ Here, the systematic analysis of preoperative MR images allowed us to conclude that the observed lateral sinus thromboses are consequences of the surgery. There is a differential diagnosis for the radiological appearance of sinus thrombosis, including endosinus granulations,⁶ surgical material in the sinus, and extrinsic compression. To enhance the diagnostic accuracy, we checked that thrombosis was visible on several acquisition planes, and on several MR sequences. We also verified that the filling defect was not present on preoperative MRI, to formally exclude the possibility of large endosinus granulation. In addition, the actual incidence of postoperative lateral sinus thrombosis following posterior fossa surgery might even be higher than reported here, because some clots might have resolved spontaneously between surgery and the first postoperative imaging.

Risk Factors for Postoperative Lateral Sinus Thrombosis

Oral contraception pill usage and medical history of venous thrombosis were significant risk factors for postoperative lateral sinus thrombosis in univariable analysis. These results are consistent with known risk factors for spontaneous cerebral vein or sinus thromboses, which also include female sex and oral contraception.⁸ Interestingly, a history of metastatic disease or meningioma, which are classic risk factors for deep venous thrombosis, were not found to be significant risk factors in the present study.^{5,10,15}

Regarding surgical technique, exposing the midline and exposing the lateral sinus, even without damaging it, were significant risk factors for postoperative lateral sinus thrombosis, as previously suggested.¹² However, we did not observe a higher risk of postoperative pseudotumor cerebri or hydrocephalus in patients with a postoperative lateral sinus thrombosis.¹² The lateral sinus exposure may lead to its thrombosis through the desiccation of the dura surrounding the sinus or traction or suspension of the sinus itself, or of draining veins. Thus, good surgical practice should avoid unnecessary lateral sinus exposure and retraction. When the sinus has to be exposed or manipulated during surgery, it should be protected by regular dampening and the application of protective material such as damp cottonoids⁹ and by regular release of any retraction, if applied.

The intraoperative unintentional opening of the lateral sinus and the location of the lesion were not significant risk factors for postoperative lateral sinus thrombosis in our series. Although the lesion size has been previously identified as a risk factor for lateral sinus thrombosis following surgery for cerebellopontine angle tumors,¹³ we did not find such an association in our series. Other surgical

mechanisms could be involved that could not be assessed retrospectively; for instance, the exact position of the head and neck that could lead to cervical vein compression, or the presence of a central venous jugular catheter that could induce extensive jugular vein thrombosis. Moreover, we may have failed to identify additional risk factors for postoperative lateral sinus thrombosis due to the limited size of our population.

Consequences of Postoperative Lateral Sinus Thrombosis

None of the 12 cases of postoperative lateral sinus thrombosis identified here were symptomatic. Generally, the most common symptom for spontaneous cerebral vein or sinus thrombosis is headaches, reported in 70% of cases,⁸ but during the postoperative period this symptom is both common and nonspecific. The good tolerance we observed is strikingly different when compared with spontaneous lateral sinus thrombosis.² This may be explained by the existence of collateral veins, by a dominant contralateral lateral sinus, or by incomplete sinus occlusion allowing for some venous flow. Indeed, from a surgical point of view, it is agreed that unilateral sacrifice of a lateral sinus is well tolerated,¹¹ although it can also lead to other more serious complications, such as pseudotumor cerebri or hydrocephalus.¹² Moreover, postoperative sinus thrombosis is a local phenomenon secondary to surgery close to the sinus; thus, it probably cannot be compared with spontaneous cerebral venous thrombosis, which is a systemic problem.

However, postoperative lateral sinus thrombosis could lead to serious complications. Keiper et al. reported a 4.7% incidence of hydrocephalus secondary to a lateral sinus thrombosis after suboccipital or translabyrinthine craniectomy.¹² Zuurbier et al. reported a 15.1% incidence of hydrocephalus secondary to a spontaneous cerebral sinus thrombosis.¹⁶ In the present study, hydrocephalus, requiring internal CSF diversion but not leading to permanent impairment, appeared in 2 of 12 patients (16.7%) with a postoperative lateral sinus thrombosis. However, the exact origin of the hydrocephalus is a matter of debate during the early postoperative period because the underlying disease, surgical procedure, and location of the lesion may equally account for it.

Anticoagulation Therapy

The decision whether to treat an asymptomatic patient with postoperative lateral sinus thrombosis during the early postoperative period is a dilemma. There are no guidelines addressing how these patients should be managed. Despite modest available evidence, spontaneous cerebral sinus thromboses are treated with treatment-dose anticoagulant therapy, which appears to be safe and associated with a reduction in the risk of death or dependency.^{3,4} However, treatment-dose anticoagulant therapy during the immediate postoperative period carries a high risk of hemorrhage. The problem for the surgeon is how to balance the risks of the sinus thrombosis with the risks of causing iatrogenic hemorrhage with anticoagulation therapies.

The treatment-dose anticoagulant therapy seemed to increase the rate of long-term lateral sinus recanalization (85.7% vs 20%; not statistically significant, probably due to a lack of statistical power) but, on the other hand, it in-

creased significantly the incidence of surgical complications (56.2% vs 27%; $p = 0.020$). Moore et al.¹³ reported that 5 patients who were treated with immediate treatment-dose anticoagulant therapy (intravenous heparin, followed by Coumadin for 6 months) for lateral sinus thromboses after resection of a cerebellopontine tumor did not have any iatrogenic complications.

The present observational study does not allow suggestion of guidelines on whether to introduce treatment-dose anticoagulant therapy for postoperative lateral sinus thrombosis. This is because the practical management of each case was discussed on an individual basis, with the incorporation of medical history, intraoperative findings, extent of the lateral sinus thrombosis, timing of diagnosis, postoperative complications, and surgeon's preference. In our series, immediate postoperative treatment-dose anticoagulant therapy was not associated with a higher risk of intracranial hemorrhage complications, but 3 treated patients developed scar problems and 1 of them required repeated lumbar punctures and a second-look surgery.

Conclusions

Overall, postoperative lateral sinus thrombosis following posterior fossa surgery for a space-occupying lesion is asymptomatic and well tolerated in adults. Hence, there is still equipoise regarding the practical efficacy of treatment-dose anticoagulant therapy, which is limited to radiological lateral sinus recanalization and is associated with higher rates of postoperative complications. As a practical message, we propose that well-tolerated postoperative lateral sinus thrombosis following posterior fossa surgery in asymptomatic patients should be followed conservatively, without systematic introduction of a treatment-dose anticoagulant therapy, together with close clinical and radiological follow-up to identify early any thrombosis-linked complications. However, because the retrospective design of this observational study precludes the control of confounders that may have biased the introduction of treatment-dose anticoagulant therapy, no definite therapeutic guidelines can be drawn. A prospective trial should be considered and built in light of these preliminary epidemiological observations.

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References

1. Browd SR, Ragel BT, Davis GE, Scott AM, Skalabrin EJ, Couldwell WT: Prophylaxis for deep venous thrombosis in neurosurgery: a review of the literature. **Neurosurg Focus** 17(4):E1, 2004
2. Coutinho JM: Cerebral venous thrombosis. **J Thromb Haemost** 13 (Suppl 1):S238–S244, 2015
3. Coutinho JM, de Bruijn SFTM, deVeber G, Stam J: Anti-coagulation for cerebral venous sinus thrombosis. **Stroke** 43:e41–e42, 2012
4. Coutinho JM, Seelig R, Boussier MG, Canhão P, Ferro JM, Stam J: Treatment variations in cerebral venous thrombosis: an international survey. **Cerebrovasc Dis** 32:298–300, 2011
5. Eisenring CV, Neidert MC, Sabanés Bové D, Held L, Sarnthein J, Kraysenbühl N: Reduction of thromboembolic events in meningioma surgery: a cohort study of 724 consecutive patients. **PLoS One** 8:e79170, 2013
6. Farb RI: The dural venous sinuses: normal intraluminal architecture defined on contrast-enhanced MR venography. **Neuroradiology** 49:727–732, 2007
7. Flinn WR, Sandager GP, Silva MB Jr, Benjamin ME, Cerullo LJ, Taylor M: Prospective surveillance for perioperative venous thrombosis. Experience in 2643 patients. **Arch Surg** 131:472–480, 1996
8. 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** 85:211–220, 2014 (Ger)
9. Hervey-Jumper SL, Breshears J, Berger MS: Gelfoam scaffold for vein prolapse during brain tumor surgery. **World Neurosurg** 82:912.e11–912.e13, 2014
10. Hoefnagel D, Kwee LE, van Putten EHP, Kros JM, Dirven CMF, Dammers R: The incidence of postoperative thromboembolic complications following surgical resection of intracranial meningioma. A retrospective study of a large single center patient cohort. **Clin Neurol Neurosurg** 123:150–154, 2014
11. Kapp JP, Gielchinsky I, Deardourff SL: Operative techniques for management of lesions involving the dural venous sinuses. **Surg Neurol** 7:339–342, 1977
12. Keiper GL Jr, Sherman JD, Tomsick TA, Tew JM Jr: Dural sinus thrombosis and pseudotumor cerebri: unexpected complications of suboccipital craniotomy and translabrynthine craniectomy. **J Neurosurg** 91:192–197, 1999
13. 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** 75:402–408, 2014
14. Nurmohamed MT: Thromboprophylaxis in neurosurgical patients. **Semin Hematol** 37 (3 Suppl 5):15–18, 2000
15. Watson HG, Keeling DM, Laffan M, Tait RC, Makris M: Guideline on aspects of cancer-related venous thrombosis. **Br J Haematol** 170:640–648, 2015
16. Zuurbier SM, van den Berg R, Troost D, Majoie CB, Stam J, Coutinho JM: Hydrocephalus in cerebral venous thrombosis. **J Neurol** 262:931–937, 2015

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Conception and design: Pallud, Oppenheim. Acquisition of data: Pallud, Apra, Kotbi. Analysis and interpretation of data: Pallud, Apra, Corns. Drafting the article: Pallud, Apra, Corns, Oppenheim. Critically revising the article: Pallud, Turc, Corns, Pagès, Souillard-Scémama, Dezamis, Parraga, Meder, Sauvageon, Devaux, Oppenheim. Reviewed submitted version of manuscript: Pallud. Approved the final version of the manuscript on behalf of all authors: Pallud. Statistical analysis: Pallud, Apra, Turc. Administrative/technical/material support: Pallud. Study supervision: Pallud.

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