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Original Article

Guidance value of intracranial venous circulation evaluation to parasagittal meningioma operation

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Abstract: Objective: This study is to investigate the value of intracranial venous circulation evaluation in guiding the surgery for parasagittal meningioma. Methods: A total of 44 parasagittal meningioma (PSM) patients received 3D CE-MRV scanning. The obtained images were reconstructed by virtual reality (VR) technology. Venous collateral circulation was evaluated. Postoperative follow-up was carried out. Results: Among 44 PSM patients, 41 cases were with resection of Simpson grade I/II (93.18%) and 6 cases were with permanent neurological dysfunction (13.64%). Venous sinus thrombosis occurred in the remaining 3 patients (6.82%), with 2 cases cured and 1 case died. The mortality rate was 2.27%. Recurrence occurred in one case (2.27%) after discharge. In 9 cases, tumor adjacent SSS was transected and the poor prognosis rate was 33.33%. SSS was opened in 3 cases and after removal of the tumor the broken end was sutured directly. The poor prognosis occurred in one case (33.33%). Electrocoagulation was carried out to the SSS wall in 32 cases without opening venous sinus and 2 cases were with poor prognosis (6.25%). The three different venous sinus treatment methods had no significantly difference on the prognosis of patients ($P > 0.05$). Conclusions: Preoperative evaluation of intracranial venous circulation with VR technology and 3D CE-MRV may help making individual surgical plans, reduce venous injury and improve the prognosis of PSM patients.

Keywords: Parasagittal meningioma, venous collateral circulation, venous protection, virtual reality technology, 3D CE-MRV

Introduction

The substrate of parasagittal meningioma (PSM) attaches to the superior sagittal sinus (SSS) and nearby dura. Sometimes PSM even invades into SSS, leading to the interruption of blood flow in SSS. Surgery is the preferred method for treatment of PSM, however, due to injuries to venous circulation pathway, it is difficult for surgeons to make surgical plans [1]. Meanwhile, the recurrence and the complications of PSM are relatively high [1-3]. To this end, Sindou [1] pointed a tumor classification method and expounded the method of surgical treatment. This provides a theoretical basis for the surgeons and brings good curative effects.

After removal of PSM and sagittal sinus, recurrence appears in some of the patients and serious complications can even lead to death. The most common complications are cerebral venous sinus thrombosis [4, 5], venous infarction and hemorrhage [6]. Recurrence rate of PSM, the incidence of complications and the mortality rate depends on the processing methods of venous sinus during operation. Tomasello et al [7] reported that after following up for 9 years, the tumor recurrence rate of 63 PSM patients was 10.4%. And, the incidence of complications was 10.4% and the mortality rate was 4.5%.

Preoperative accurate assessment of venous circulation system and tumor can greatly improve the prognosis of PSM patients. With the development of science and technology, computer-assisted imaging methods such as virtual reality (VR) technology are widely used. With VR technology, 2D image is converted into a virtual image of 4D, which can clearly show different tumor anatomic structures, the surrounding brain tissues and the blood vessels [8-10]. In this study, intracranial venous system of the patients was observed and measured

Table 1. General condition of 44 cases of PSM patients

Items		Cases	Items		Cases
Sex	Male	17	Pathological type	Fiber type	12
	Female	27		Endothelial type	8
Primary or recurrence	Primary	33		Atypical	6
	Recurrence	11		Hybrids	5
Preoperative symptoms	Headache and dizziness	19		Transitional type	3
	Limbs spasm	4		Epithelial type	2
	Limb weakness	7		Anaplastic type	2
	Visual impairment	1		Syncytial cells type	2
	No symptoms	13		Angiomatous type	1
Modified Rankin scale	≤ 2	38		Psammomabody type	1
	> 2	6		Fiber type merged secreting type	1
WHO pathological grades	Level I	34		Fiber type merged psammomabody type	1
	Level II	9			
	Level III	1			

Table 2. Imaging features of 44 cases of PSM patients

		Cases
Collateral circulation	Level 0	19
	Level 1	9
	Level 2	0
	Level 3	16
Tumor invasiveness	Level 1-2	21
	Level 3-4	12
	Level 5-6	11
Tumor location	SSS anterior 1/3 segment	6
	SSS mid 1/3 segment	28
	SSS posterior 1/3 segment	10
Peritumoral edema	No	29
	Yes	15

with VR technology preoperatively and the patients were followed up postoperatively. Prognosis and influence of different processing methods of venous sinus were analyzed.

Materials and methods

Clinical data

A total of 44 cases of patients who were diagnosed as PSM and were admitted to our hospital from October 2011 to March 2014 were enrolled in this study. Among them, 17 were male and 27 were female. They aged from 27-85 years old, with an average of 54 years old. Detailed information of the patients was shown in **Table 1**. The inclusion criteria were defined as follows: PSM patients with tumor base attached to the SSS as confirmed by MRI; patients those were confirmed as meningioma by postoperative pathology; patients those were followed up regularly after operation. The exclusion criteria were described as follows: patients those with a history of previous radiotherapy for treatment of PSM; patients with incomplete information or loss of follow-up.

Follow-up was performed at 1 month after the discharge. The follow-up lasted for 2-46 months, with a median of 19 months. The follow-up included: regular re-examination, postoperative radiation therapy and the main symptoms of patients. According to the modified grading system on the prognosis of the patients by Rankin [11], patients those with grades less than or equal to grade 2 were considered as good prognosis while patients those with grades more than grade 2 were taken as poor prognosis.

Prior written and informed consent were obtained from every patient and the study was approved by the ethics review board of Fuzhou General Hospital, Fujian Medical University, China.

3D CE-MRV image sequential scanning and VR image reconstruction

3D CE-MRV image sequential scanning was performed with 3.0T magnetic resonance imaging machine (Tim Trio; Siemens Medical Solutions, Erlangen, Germany) at 1-3 days

Table 3. Operation condition and prognosis of 44 cases of PSM patients

		Cases	Rate (%)
Simpson grading	Level I-II	41	93.18
	Level III-IV	3	6.82
	Level V	0	0
Postoperative complications	Venous sinus thrombosis	3	6.82
	Permanent neurological dysfunction	6	13.64
Died		1	2.27
Recurrence		1	2.27

Table 4. Different venous sinus treatment methods and prognosis of the 44 cases of PSM patients

Venous sinus processing method	Good	Poor	Total	P
Transection	6	3	9	0.054
Reconstruction	2	1	3	
Electric coagulation	30	2	32	
Total	38	6	44	

before operation. The scanning data was transferred to VR image workstation and processed with Radio Dexter TM1.0 software system (Dextroscope, Volume Interaction, Singapore). Re-construction of tumor, intracranial venous and cerebral tissue structure was carried out in the VR workstation. Meanwhile, operation simulation was performed in the VR workstation. The location and size of the bone window was selected.

The analyzed image indexes were shown in **Table 2**. In this study, we mainly analyzed the three indexes of venous collateral circulation, location of the tumor and tumor invasion degree. The classification methods of the three indexes were employed as previously reported [1, 12, 13].

Microneurosurgery

After opening the dura, the tumor was exposed and removed with microneurosurgery. The veins were protected carefully and all tumor resection reached Simpson grade I/II stage. The processing method of SSS was formulated according to the degree and specific situation of SSS invasion and collateral circulation revealed by preoperative imaging. For patients those were with invasion of Sindou classification of I/II types, after tumor resection, electric coagulation was carried to the sinus wall that was attached by the tumor. For III/IV type tumors those were in good collateral circulation condition and without tumor involving the central cortex, after resection of tumor tissue outside the sinus, venous sinus was gradually opened and stitched after excision of the inner sinus tumor. As for the patients those were in poor collateral circulation or with tumor involving the cerebral central region, only the vein sinus walls were electric coagulated and integrity of the sinus was preserved. For V/VI type tumors those were in good collateral circulation, the tumor was removed with the attached venous sinus or the tumor was removed after opening the venous sinus. If the collateral circulation was poor, only electric coagulation to sinus wall was carried and postoperative radiation therapy or intensive follow-up was recommended. Reoperation was performed when there was tumor recurrence. For tumor that blocked the anterior 1/3 segment of SSS, SSS was transected after removal of the tumor. There was no venous bypass reconstruction in this study. During operation, bridging veins was retained as much as possible.

Statistical analysis

All the statistical analyses were performed using SPSS version 17.0 (SPSS Inc, Chicago, IL, USA) for Windows. Measurement data was analyzed using Fisher's exact probability calculation method. A *P* value less than 0.05 was considered as statistically significant.

Results

Tumor resection grade, complications, mortality rate and recurrence rate

To find out PSM operation resection extent and adverse reaction, postoperative situation was observed. As shown in **Table 3**, among the 44 cases of PSM patients, resection of tumor in 41 cases reached Simpson grade I/II (93.18%) and the remaining 3 cases were Simpson grade

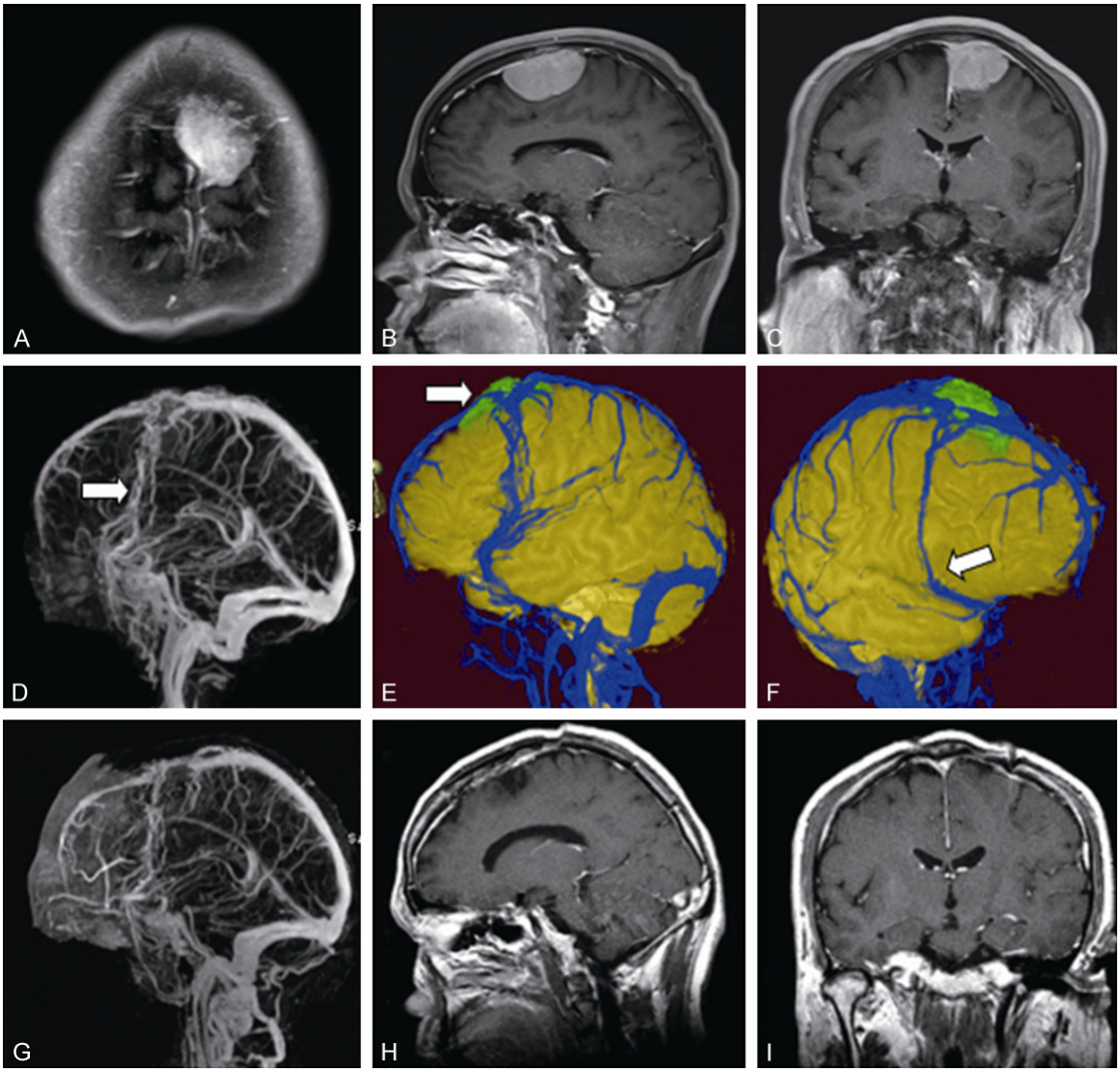

Figure 1. A series of images of typical case one. A. Preoperative axial contrast-enhanced MRI. The tumor was located in the left frontoparietal with obvious enhancement and apparent dural tail sign. B. Preoperative sagittal enhanced MRI. The tumor located in the anterior 1/3 segment of superior sagittal sinus. C. Preoperative coronal enhanced MRI. The superior sagittal sinus was basically occluded. D. 3D CE-MRV. The superior sagittal sinus was invaded by tumor and was basically occluded. The draining veins around the tumor were rich and a large vein (arrow) to lower SSV was seen. E. VR diagram of left side view. The yellow color represents the normal brain tissue, the blue color represents normal intracranial venous system and the green color represents the tumor tissue. The tumor invaded the superior sagittal sinus and the sinus was basically occluded (arrow). The left venous drainage flowed into the SSV and finally flowed to extracranial through the cavernous sinus and pterygoid plexus. F. VR map from right side view. The tumor invaded the superior sagittal sinus and the sinus was basically occluded. The right venous drainage flowed into the SSV (arrow) and finally flowed to extracranial through the cavernous sinus and pterygoid plexus. G. Sagittal 3D CE-MRV 2 days postoperative. The operation area of superior sagittal sinus seemed to be developing visible thin. H. Sagittal enhancement MRI 13 months after surgery. I. Coronal enhancement MRI 13 months after surgery.

III/IV (6.82%). Among the 41 cases with Simpson grade I/II, 6 cases (13.64%) had permanent neurological dysfunction and were with decrease in muscle strength. Venous sinus thrombosis occurred in 3 patients (6.82%). Among them, venous sinus was transected in 2 cases and venous sinus openning with suture ligation in the broken ends was carried in the broken end in 1 case. Standardized anticoagulation therapy was applied postoperatively and

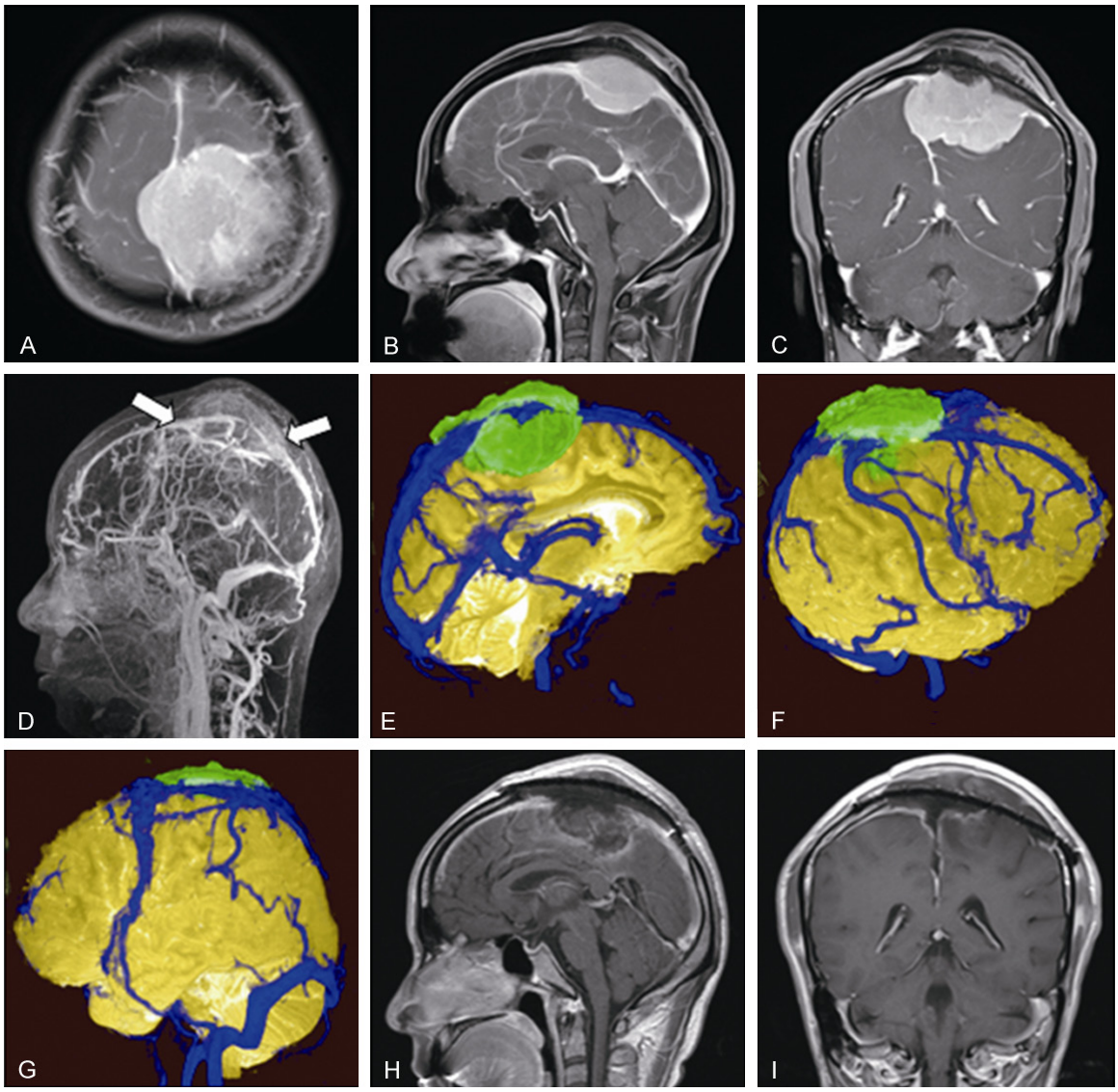

Figure 2. A series of images of typical case two. A. Preoperative axial contrast-enhanced MRI. The tumor was located in the left parietal with obvious enhancement and apparent occupying effect. The midline structures moved to left. B. Preoperative sagittal enhanced MRI. The tumor located in the mid 1/3 segment of superior sagittal sinus and was with visible dural tail sign. C. Preoperative coronal enhanced MRI. The superior sagittal sinus was basically occluded and moved to right. D. 3D CE-MRV. The superior sagittal sinus was interrupted and the draining veins surrounding the tumor formed into compensatory collateral loop (arrow). E. VR diagram. The yellow color represents the normal brain tissue, the blue color represents normal intracranial venous system and the green color represents the tumor tissue. The superior sagittal sinus was basically invaded by the tumor. F. VR map from right side view. The right hemisphere cortical vein was rich and veins draining into the SSV. The draining vein surrounding the tumor was relatively rich. G. VR map from left side view. The left cortical vein draining into the SSV and the draining vein surrounding the tumor was relatively rich forming a loop like shape. H. Sagittal enhancement MRI 1 month after surgery. No tumor was seen in the operation area and only a small amount of effusion was seen under local scalp. I. Coronal enhancement MRI at 1 month after surgery. No tumor was seen in the operation area and only a small amount of effusion was seen under local scalp.

delayed intracranial hematoma did not occur. Two cases were improved greatly and discharged. After operation, the muscle strength in the right lower limb in 1 case was grade 2. In one case, postoperative general condition was good. However, at day 10 after operation, brain CT showed a little brain swelling. At day 13 after operation, the patient died of sudden cardiac respiratory arrest. Because that autopsy was not performed, the specific cause of death was

unknown. We consider that this death may be caused by postoperative venous sinus thrombosis. Thus, the mortality rate was 2.27%. During the follow-up period, adjuvant radiotherapy was carried out in 1 case and recurrence was found in 1 case with regular inspection (recurrence rate 2.27%). These results showed that most of the operations were ideal and the postoperative complications were mainly limb muscle strength decline and venous sinus thrombosis in operation area. And venous sinus thrombosis might be fatal.

Effects of different treatment methods of venous sinus on prognosis

In order to compare the effects of different treatment methods of venous sinus on prognosis, the patients were followed up for post-operation situation. In this study, tumor attached SSS was transected in 9 cases and the poor prognosis rate was 33.33%. SSS was opened in 3 cases and after removal of the tumor the broken end was sutured directly. The poor prognosis occurred in one case (33.33%). Electrocoagulation was carried out to the SSS wall in 32 cases without opening venous sinus and 2 cases were with poor prognosis (6.25%). Calculated by Fisher's exact probability method, the three different venous sinus processing methods had no significantly different effects ($P > 0.05$) on the prognosis of the patients (**Table 4**). These results indicate that it is appropriate to take different approach according to the tumor invasion extent to SSS, meanwhile, the remarkable sequela of venous sinus thrombosis might occur in some cases once venous sinus is opened.

Typical case one

A 48 years old male patient was admitted because of "taking physical examination and was occasionally found intracranial occupying lesions for 17 days". Examination showed no obvious neurological signs. Preoperative imaging suggested that the tumor was located in the anterior 1/3 segment of SSS, venous collateral circulation was level III and invasiveness of the tumor to SSS was type V (**Figure 1**). While performing PSM resection operation, a small part of tumor tissue was seen in the SSS cavity. In order to protect SSS and veins, tumor inside venous sinus was not removed. Electric coagulation was carried out to the affected SSS wall. The patient once was lethargy after operation. Cerebrospinal fluid pressure via lumbar puncture was about 260 mmH_2O and head CT scans showed obvious brain edema. After appropriate treatment, he regained consciousness and his general condition was good. The muscle strength of the limbs was grade 5 with normal muscular tension. Postoperative pathology confirmed that this case was syncytial meningioma (WHO grade 1). At the time he discharged, the modified Rankin scale was improved to level 1. He was regularly followed up. At 20 months of follow-up, he was conscious with no special discomfort. The modified Rankin scale was level 0 and there was no tumor recurrence.

Typical case two

Another case was a 43 years old male patient who was admitted because of "taking physical examination and was found intracranial occupying lesions for 2 years". No obvious neurological signs were observed by physical examination. Preoperative imaging scan showed that the tumor was in the mid 1/3 segment of SSS. Venous collateral circulation around the tumor was level III and the tumor invasion degree to SSS was type V (**Figure 2**). Tumor totally protruded into the SSS and obstructed SSS. The tumor was totally removed and the SSS broken end was sutured. The extent of tumor resection was Simpson grade 1. After operation, the patient was conscious but quite restless. The muscle strength of the left upper limb was normal, the muscle strength of the right upper limb was grade 1, and the muscle strength of double lower limbs was grade 1. Bilateral pathological reflex was positive, bilateral knee jerk was hyperreflexia and right bicep reflex was hyperreflexia. The modified Rankin scale was level 5. Considering that the tumors were near the central sulcus, there may be damage in the central area of the brain during the operation. Thus, the patient was transferred to physiatry department for rehabilitation treatment. Postoperative pathology confirmed that he had endothelial meningiomas (WHO grade 1). He was conscious when followed up for 19 months. The muscle strength of the left limb was normal, the muscle strength of the right lower limb muscle strength was grade 2, and the right upper limb muscle strength was grade 4. The modified Rankin scale was level 4.

Discussion

In this study, VR technology and 3D CE-MRV were used to observe intracranial venous circulation in patients with PSM. According to the venous collateral degree classification method proposed by Qureshi [13] and grading of the tumors invasion to SSS by Sindou [1], preoperative intracranial venous circulation in the patients with PSM were quantitatively evaluated. Brotchi [14] reported that SSS was transected in 2 cases of PSM patients with incomplete SSS occlusion. The patients had a high life quality after operation with no complications or tumor relapse. Mantovani et al [15] considered that for PSM patients with SSS occlusion and with good venous compensatory circulation, SSS could be transected without reconstruction. In this study, the recurrence rate of tumor and the incidence of complications were comprehensively considered. Priority was given to postoperative quality of the patients' life. According to classification of venous collateral circulation, the location of the tumor and the degree that venous sinus was invaded, different operation strategies were used. In this study, 41 cases of PSM (93.18%) patients achieved level I/II resection according to Simpson grading and the remaining 3 cases reached level III/IV resection.

Different operation strategies can lead to different prognosis. Colli et al [2] reported 53 cases of PSM patients who accepted operation without removing affected venous sinus or tumor inside sinus. The tumor recurrence rate was 17.5%, the complication rate was 7.3%, and the mortality rate was 7.8%. Sughrue et al [3] did not open the venous sinus nor sacrifice the bridging veins during operation; as a result, 19% of the patients had postoperative complications. Removal of the tumor inside sinus and removal of venous sinus were also reported [16, 17]. In this study, the average follow-up was 19 months, the overall postoperative complication rate was 13.64%, and the mortality rate was 2.27%. During the follow-up period, the recurrence rate was 2.27%, which, was consistent with previous reports. For the treatment of venous sinus, three operation strategies were used in this study: transection, venous sinus openning with suture ligation in the broken ends and electrocoagulation. Further analysis found that the effects of these three different treatment methods on the prognosis of patients were not significantly different.

Cerebral venous sinus thrombosis is one of the leading postoperative complications causing death. After PSM operation, changes of blood flow in residual SSS and the complicated local vascular structure are easy to induce local thrombosis. The tumor may invade or wrap around the bridging veins, leading to the damage of the bridging veins during the operation. This is also a factor that induces venous sinus thrombosis formation [4]. Understanding anatomical characteristics of the bridging veins can avoid injuries, thus reducing intraoperative cerebral venous sinus thrombosis as far as possible [5]. Raza et al [18] reported the incidence of venous sinus thrombosis was 7% in 110 cases of PSM patients. Postoperative venous sinus thrombosis was also found in this study and it had great influence to patients' prognosis. Blood flow around venous sinus end slowed down after operation and the injured vascular inner wall was also easy to induce thrombosis. These factors should be seriously considered. According to above mentioned results, we suppose that the intraoperative protection to the venous circulation is very important. Once the surgery may endanger the important or large cortical veins, retention of part of the tumor or sinus wall is recommended so as to preserve important venous collateral circulation. For the patients with sutured sinus, anticoagulant treatment should be applied immediately after surgery and continued for at least 2 weeks to avoid or reduce the venous sinus thrombosis.

Taken together, preoperative evaluation of intracranial venous circulation by VR and 3D CE-MRV can guide the surgical operation in the treatment of venous sinus and tumor individually and improve the prognosis of patients.

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Disclosure of conflict of interest

None.

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References

[1] Sindou M, Auque J and Jouanneau E. Neurosurgery and the intracranial venous system. Acta Neurochir Suppl 2005; 94: 167-175.

[2] Colli BO, Carlotti CG, Assirati JA, Dos Santos MB, Neder L and Dos Santos AC. Parasagittal meningiomas: follow-up review. Surg Neurol 2006; 66 Suppl 3: S20-7; discussion S27-28.

[3] Sughrue ME, Rutkowski MJ, Shangari G, Parsa AT, Berger MS and McDermott MW. Results with judicious modern neurosurgical management of parasagittal and falcine meningiomas. Clinical article. J Neurosurg 2011; 114: 731-737.

[4] Murata J, Sawamura Y, Saito H and Abe H. Resection of a recurrent parasagittal meningioma with cortical vein anastomosis: technical note. Surg Neurol 1997; 48: 592-5; discussion 595-597.

[5] Jiang CM, Liu F, Lv SG, Song SX, Zhu JM, Shen XL, Zhu XG and Cheng ZY. Microsurgtcal treatment of large meningiomas in the sagittal sinus and faLx cerebri. Chinese J Neuromedicine 2011; 10: 950-952.

[6] Sakaki T, Kakizaki T, Takeshima T, Miyamoto K and Tsujimoto S. Importance of prevention of intravenous thrombosis and preservation of the venous collateral flow in bridging vein injury during surgery: an experimental study. Surg Neurol 1995; 44: 158-162.

[7] Tomasello F, Conti A, Cardali S and Angileri FF. Venous preservation-guided resection: a changing paradigm in parasagittal meningioma surgery. J Neurosurg 2013; 119: 74-81.

[8] Burtscher J, Kremser C, Seiwald M, Obwegeser A, Wagner M, Aichner F, Twerdy K and Felber S. Three-dimensional computer assisted magnetic resonance imaging for neurosurgical planning in parasagittal and parafalcine central region tumors. Comput Aided Surg 1998; 3: 27-32.

[9] Tang HL, Sun HP, Gong Y, Mao Y, Wu JS, Zhang XL, Xie Q, Xie LQ, Zheng MZ, Wang DJ, Zhu H, Tang WJ, Feng XY, Chen XC and Zhou LF. Preoperative surgical planning for intracranial meningioma resection by virtual reality. Chin Med J (Engl) 2012; 125: 2057-2061.

[10] Low D, Lee CK, Dip LLT, Ng WH, Ang BT and Ng I. Augmented reality neurosurgical planning and navigation for surgical excision of parasagittal, falcine and convexity meningiomas. Br J Neurosurg 2010; 24: 69-74.

[11] Kang J, Park TH, Lee KB, Park JM, Ko Y, Lee SJ, Hong KS, Cho YJ, Lee JS, Lee J, Lee BC, Yu KH, Kim DH, Cha JK, Lee J, Jang MS, Han MK and Bae HJ. Symptomatic steno-occlusion in patients with acute cerebral infarction: prevalence, distribution, and functional outcome. J Stroke 2014; 16: 36-43.

[12] Oka K, Go Y, Kimura H and Tomonaga M. Obstruction of the superior sagittal sinus caused by parasagittal meningiomas: the role of collateral venous pathways. J Neurosurg 1994; 81: 520-524.

[13] Qureshi AI. A Classification Scheme for Assessing Recanalization and Collateral Formation following Cerebral Venous Thrombosis. J Vasc Interv Neurol 2010; 3: 1-2.

[14] Brotchi J. Should we pursue superior sagittal sinus grafting in parasagittal meningiomas in 2013? World Neurosurg 2014; 82: 325-326.

[15] Mantovani A, Di Maio S, Ferreira MJ and Sekhar LN. Management of meningiomas invading the major dural venous sinuses: operative technique, results, and potential benefit for higher grade tumors. World Neurosurg 2014; 82: 455-467.

[16] Giombini S, Solero CL, Lasio G and Morello G. Immediate and late outcome of operations for Parasagittal and falx meningiomas. Report of 342 cases. Surg Neurol 1984; 21: 427-435.

[17] Adegbite AB, Khan MI, Paine KW and Tan LK. The recurrence of intracranial meningiomas after surgical treatment. J Neurosurg 1983; 58: 51-56.

[18] Raza SM, Gallia GL, Brem H, Weingart JD, Long DM and Olivi A. Perioperative and long-term outcomes from the management of parasagittal meningiomas invading the superior sagittal sinus. Neurosurgery 2010; 67: 885-893; discussion 893.