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Individualized Cerebral Artery Protection Strategies for the Surgical Treatment of Parasellar Meningiomas Based on Preoperative Imaging

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Research Article

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Abstract

OBJECTIVE Parasellar meningiomas represent a cohort of skull base tumors localize to parasellar region. Those meningiomas tend to compress, encase or even invade cerebral arteries and their perforating branches. Surgical resection of PMs is a challenging operation without damaging perforating arteries. The study aimed to analyze functional outcomes in a series of patients who underwent surgery with individualized cerebral arteries protection strategy based on preoperative imaging. METHODS A retrospective review of a single surgeon's experience with microsurgical removal of PMs in 163 patients between January 2012 to March 2020. Individualized approaches with bidirectional dissection strategy were used. Cerebral Artery invasion classification, neurological outcomes, MRC Scale Muscle Strength Grading, and Karnofsky Performance Scale were used to assess the tumor vascular invasion, functional outcome, and patient quality-of-life outcomes, respectively. RESULTS Total resection (Simpson Grade I or II) was achieved in 114 (69.9%) patients in our series. Vision improved in 44.7% of patients with consecutive follow-up, was stable in 51.1% and deteriorated in 3.8%. Improvement in cranial nerve IIII, IV, and VI was observed in 41.1%, 36.2%, and 44.8%, respectively. The mean follow-up time was (38.8±27.9) months and KPS at the last follow-up was (89.6±8.5). Recurrence was observed in 8 (13.8%) patients with CSMs while the rate was only 3.8% and 2.8% in ACMs and MSWMs. CONCLUSIONS Preoperative imaging is of great significance in the selection of surgical approach. Maximum tumor resection and cerebral artery protection can be achieved concurrently utilizing bidirectional dissection. Those Individualized cerebral artery protection strategies not only are of great utility to neurosurgeons but also can improve patient's quality of life.

Background

Parasellar meningiomas (PMs) meningiomas are a heterogeneous group of tumors that origin from the parasellar region. They are frequently compress, encase or even invade adjacent neurovascular of the anterior and middle skull base, making their surgical management still a challenge for skull base surgeons. However, a clear definition of parasellar meningiomas as a distinct entity is lacking result from their multiple definition and classification. They were first described by Stirling in 1896[21]. According to their site of origin, Ugrumov[22] divided PMs into three subgroups: Anterior clinoid meningiomas(ACMs), medial sphenoid wing meningioma(MSWMs), and cavernous sinus(CSMs) meningiomas. Recent advances in skull base microsurgery and microanatomy renew the cognition about PMs and contribute to the development of detailed definitions and classifications. Dolenc, Risi[17; 9] enlarge the definition of PMs and classified them into more subtypes. Concurrently, individualized surgical strategies were developed and applied to the treatment of PMs based on those classifications, which making gross total resection and preserve neurofunction became a possible goal. Nevertheless, the morbidity and mortality of patients with PMs after surgery were still relatively unsatisfied compared with other skull base meningiomas.

After reviewing the history of surgical treatments of PMs, one can easily realize two notable surgical treatment strategies, both of which had a significant impact on patient outcomes. Initially, the parasellar

region was deemed as a “no man’s land”. In the latest 20 centuries, the widespread of the operation microscope to skull base neurosurgery enables neurosurgeons to attempt to remove tumors aggressively. However, owing to their naturality, PMs often compress, encase or even invade cranial nerves, skull base bones, cerebral dura mater, cerebral arteries, and their perforating branches, making the consequences of tumor total resection unsatisfactory. The past few years witnessed the development of stereotactic radiotherapy and molecular targeted therapy of meningiomas, which temper the enthusiasm for aggressive total resection and turn surgical strategy into a more conservative way. To protect neurovascular structures during operation, the purpose of PMs microsurgery shifts to maximal surgical resection, followed by adjuvant therapy. Even though, dissection of cerebral arteries and their perforating branches encased or invaded by PMs is still a great challenge for neurosurgeons.

With the advances in preoperative neuroimaging, we were able to employ Ugrumov’s classification and classified PMs into ACMs, CMSs and MSWMs. Those subtypes originate from adjacent regions and were pretty hard to distinguish from each other when they invade surrounding structures extensively. However, identification of the tumor base of PMs before surgery is of great significance in individualized surgical strategy making. In this study, we present a method to distinguish three PMs based on preoperative imaging and through which we can apply the individualized surgical approach to every patient. And then, a bidirectional dissection technique was performed to achieving maximum tumor resection while preserving cerebral arteries and their perforating branches.

Methods

Patient Population

We retrospectively analyzed the neuroimaging, intraoperative video, and follow-up data in a consecutive series of 163 patients with PMs. Between January 2012 to March 2020, patients included in this study were underwent microsurgery by the senior author Qing Liu in the department of neurosurgery, XiangYa Hospital Central South University. All patients underwent MRI, computed tomography angiography (CTA), KPS, Muscle Strength Grading, and neurological examination before and after surgery. PMs were confirmed again by pathological examination and dural origin observed in operation. Meningiomas originate from the petroclival region, middle skull base, sellar, and suprasellar regions secondary involvement of the parasellar region were excluded.

Imaging and Tumor classification

All patients underwent routine MRI before surgery, which includes T1- and T2-weighted MRI images with and without Gd. Through our experience over the years, T2-weighted images allow the surgeon to evaluate tumor texture and edema while T1-weighted and T1-weighted contrast-enhanced images exhibit tumor size, tumor infiltration, tumor growth directions, and cerebral artery involvement. Based on preoperative imaging, we can easily classify PMs into three subtypes according to their growth directions and involved structures (Fig.1).

Computed tomography angiography (CTA) was performed to estimates the relationship between cerebral arteries and tumors. Based on preoperative imaging and intraoperative observation, we divided their relationship into 3 groups: Group A: tumor compressed artery or their perforating branches but the intervening arachnoid plane was intact. Group B: tumor displaced or encased artery or their perforating branches but the intervening arachnoid plane was intact.; Group C: tumor invaded, encased, or displaced artery or their perforating branches, tumor invaded the adventitia caused the absence of the intervening arachnoid plane. High-resolution computed tomography (HRCT) was conducted to evaluate hyperostosis or bone erosion.

Surgical Approach

The classic pterional approach (frontotemporal approach) has been widely applied to PMs surgery several decades ago. Our individualized surgical strategies were based on this approach and its modified approach. 105 (64.4%) of 163 craniotomies were performed via pterional approach and the rest 58 were performed by pretemporal transcavernous approach. A brief overview of our tailored surgical approach based on preoperative imaging is described below.

When surgery was performed by the pterional subdural approach, the patient was placed in supine position with the head fixed and rotated 30-40 degrees to the contralateral side of the tumor. The incision was initiated above the palpated zygoma, extending superiorly then curving anteriorly from the superior temporal line to the limit of the contralateral hairline. Then a standard frontotemporal craniotomy was performed. Drilling the outer and middle portion of the sphenoid wing was followed the craniotomy. After the meningoorbital band was transected, drilling is continued to remove the anterior clinoid or optic canal if the tumor invaded those structures. Pterional intradural approach was required to open dura mater after extradural steps were finished. The dura was opened in a semicircular incision centered on the Sylvian fissure and extended inferior to the floor of the anterior and middle skull base. The arachnoid membrane over the sphenoid wing is opened, allowing drainage of cerebrospinal fluid and elevation of the temporal lobe. Through the operation microscope, the dissection plane is established and the tumor was removed by bipolar coagulation and suction in small parts. Tumor compressed or encased cerebral arteries and their branches were removed by bidirectional dissection technology. The tumor was left and followed by postoperative stereotactic radiotherapy when invaded into the cavernous or adventitia of arteries.

Pretemporal transcavernous approach required the same incision and craniotomy as the pterional subdural approach, but it didn’t enter into the subdural space in most cases. The approach begins by dissecting the meningoorbital band with a micro-dissector through which we can peel off the outer layer of the lateral wall of the cavernous sinus. An incision parallel to the oculomotor or trochlear nerve was made in the inner layer of the lateral wall to enter into the cavernous sinus. The tumor within the cavernous sinus was removed by suction or sharp dissection. Residual tumor encasing ICA or its branches also removed through bidirectional dissection technology. When the tumor extended to the medial part of the cavernous sinus or petroclival region,

we combined the pterional intradural approach and dissection of the Sylvian fissure. Dura mater of the superior wall of the cavernous sinus was opened and through the Dolenc triangle, we were able to access the residual tumor localized to the inner space of the ICA. Following the superior wall, proceeding posteriorly along the tentorial incisura, the tumor extended to the upper part of the petroclival region can be removed.

Bidirectional dissection

Injury to cerebral arteries, their trunk, and perforating branches would cause hemiparesis, neurological dysfunction, or even death. However, the residual tumor which encased or invaded cerebral arteries is one of the main risk factors responsible for tumor recurrence. To achieve maximal surgical resection yet preservation of cerebral arteries and their perforating branches is the most difficult step in the surgical treatment. Here, we present a bidirectional dissection technique to overcome the problem.

In patients with ACMs and large MSWMs, bidirectional dissection began with debulking tumor extended to the surface of Sylvian fissure and finding the dissection plane between tumor and neurovascular structures (Fig.2). The distal MCA branches can be located after spilt the Sylvian fissure. Tumor dissection was started from the MCA toward the ICA by microdissector, micros scissor, and suction in small pieces. When tumor invaded into the adventitia or too hard for suction, sharp dissection by 11 blade scalpel was used to remove tumor covered in the arteries. However, reverse dissection may hinder by meningioma calcification or perforating branches, forward dissection was applied to remove the residual tumor. The first step of reverse dissection was to elevate the temporal lobe and identified the distal dural ring of ICA which is localized to the medial of anterior clinoid. Dissection proceeded from the distal dura ring of the ICA to its bifurcations. Special care has to be taken to identify the perforating branches of ICA and MCA embedded in the tumor.

For patients with CSMs, forward dissection started with the identification of the meningoorbital band, followed by peeling off the outer layer of the lateral wall and incising the inner layer of the cavernous sinus. Opening the space between the trochlear nerve and ophthalmic division can expose the posterior bend and horizontal segment of the intracavernous ICA. The abducent nerve coursing through the lateral surface of the ICA should be protected. The posterior bend is a landmark of reverse dissection from which gives of the meningohypophyseal trunk. The trunk is the most important perforating branch of the intracavernous ICA and should be preserved using the bidirectional dissection technique. Dissection proceeded from posterior bend forward to the horizontal segment of ICA through suction and microdissection. However, limited by ICA and trochlear nerve, forward dissection can’t be applied to the resection of the tumor in the inner part of ICA. Reverse dissection was initiated from opening the Dolenc triangle of cavernous sinus superior wall through intradural approach, localizing the proximal dura ring of ICA then dissecting tumor reversely from anterior ascending segment to the anterior bend of ICA.

Results

Patient Population

From January 2012 to March 2020, a total of 163 PMs (63 ACMs, 58 CSMs, and 42 MSWMs) were surgically removed by the senior authors. Among them, 113 were female (69%) and 50 (31%) were male, with a median age of 52.5 years. The most common presenting symptoms were headache (53.2%), visual impairment (42.8%), visual field defect (26.6%), diplopia (17.2%), hemiparesis (6.8%), seizures (5.0%), oculomotor paralysis (14.3%), abducent paralysis (18.1%) and trochlear nerve palsy (12.5%). The mean follow-up time in our study was 38.8 months.

Imaging and Intraoperative Findings

The PMs classification was based on preoperative radiological characteristics and intraoperative inspection. 63 patients with meningioma epicenter of anterior clinoid and grow toward the direction which anterior clinoid extended were classified into ACMs. 42 patients with meningioma originate from the dura of the inner medial sphenoid wing and grow perpendicular to the long axis of the sphenoid wing to compress the medial temporal lobe were grouped into MSWMs. The rest 58 tumors originated within the cavernous sinus or the lateral wall and grow perpendicular to the long axis of the cavernous sinus were grouped into CSMs.

The prominent imaging and intraoperative findings were the tumor's involvement with ICA, MCA, ACA, ACHA (Anterior choroidal artery), and PcomA (posterior communicating artery). According to our preoperative or intraoperative observation, ICA and its branches were encased or invaded in the most of patients with PMs, while ACHA and PcomA only involved in large PMs (Table 1).

Important structures of parasellar region were also found involved by tumors. The optic nerve (ON) impressment or encasement and optic canal involvement were founded in most of ACMs, while CSMs and MSWMs seldom invaded them. Cavernous sinus involvement was founded in almost all of CSMs and some ACMs which invaded into the cavernous sinus through the oculomotor triangle or invading the wall of cavernous sinus directly. Hardly can MSWMs invaded into cavernous sinus while they tend to compress the lateral wall of it. The superior orbital fissure was involved mainly by MSMWs.

Surgical Results

Tailored approaches were applied according to the preoperative imaging classification. Pterional intradural approach was the most frequently performed approach of 63 ACMs and 42 MSWMs. Pretemporal transcavernous approach was only performed in 58 patients with CSMs.

Total resection (Simpson Grade I or II) was achieved in 50 patients (79.3%) with ACMs, 38 patients with MSWMs (90.5%), and 26 patients (44.8%) with CSMs, while subtotal resection (Simpson Grade III) and partial resection (Simpson Grade IV) were achieved in 13(20.7%), 4(9.5%) and 32 (55.2%) patients respectively (Table 2). The tumor invaded into the cavernous sinus or the adventitia of the artery,*tumor calcification andtumor adherent to the epineurium tightly were the three main reasones responsible for subtotal or partial resection.*

Postoperative CT scan was applied to all of the patients after recovery from anesthesia to evaluate the extent of tumor resection and postoperative complications. Postoperative cerebral hemorrhage and severe encephaledema were seldom founded owing to our vascular protection strategy. Patients were required for contrast-enhanced MRI to confirm the extent of resection again before discharge. We suggested patients with residual tumor initiated stereotactic radiotherapy after three months.

Neurofunctional Outcome

The post-operative neurofunction outcome was defined as improved, unchanged or deteriorated (Table 3). Preoperative and postoperative neurofunction was evaluated through ophthalmologic examination or MRC Scale Muscle Strength Grading at the first follow up after 3 months.

Visual acuity or visual field improvement in patients with three types meningioma were 41.3%, 46.5% and 47.6% for ACMs, CSMs and MSWMs, respectively. However, most patients remain unchanged in vision field and acuity in the follow-up several months postoperatively.

CN III deterioration was the most common in all patients. 4 patients with ACMs and 2 patients with CSMs suffered from transient CN III deterioration and most of them recovered to unchanged status after a few months. CN IV and CN VI deterioration was mainly founded in postoperative 5 patients with CSMs.

Tumor Recurrence

Altogether 155 patients(95%) were underwent long-term follow-up. The actual follow-up time ranges from 11.9-65.7 months. Follow-up was done with contrast-enhanced MRI examination. Tumor recurrence or progression was observed in 8 patients with CSMs, 2 patient with ACMs, and 1 patient with MSWMs. 32 patients with the residual tumor within the cavernous sinus or invaded the artery remain stable. The mean KPS carried out in patients at follow up was 89.6 compared with 81.1 preoperatively.

Discussion

Over the past few decades, advancements in skull base surgery have renewed our understanding of parasellar meningiomas (PMS). The definition of PMs was first invented by String[21] in 1986. Dolenc, Ugrumov, and Risi [21; 17; 9]broadly classified PMs into many subtypes and developed many surgical approaches based on their characteristics. However, we advocate a clear classification of PMs which will help to make individualized surgical strategies and reduce surgical mobilities. We improved Risi's classification and grouped PMs into three subtypes based on preoperative imaging. The classification allowed us to perform individualized surgical approaches and strategies to achieve maximized tumor resection and minimized mobilities.

Preoperative Imaging and Classification

From our experiences of 163 patients with PMs, we classified those patients into ACMs, CSMs, and MSWMs based on the radiological features of preoperative imaging. Consistent with our experience and

other reports[15], ACMs originate from the dura covered in inferior, superior and lateral aspect of the anterior clinoid[1] . On coronal MRI images, ACMs epicenter on anterior clinoid and surround the anterior clinoid form a “v” shape. They often extended to the direction which anterior clinoid projected to (Fig.1A). In contrast, MSWMs tend to grow toward perpendicular to the long axis of sphenoid wing and compress the temporal lobe (Fig.1B). Another important feature of ACMs we can conclude from CTA or HRCT was the anterior clinoid hyperostosis and optic canal involvement. In contrast, MSWMs and CSMs scarcely extended to those structures. CSMs represent a kind of meningiomas that originate from arachnoid granulations localized to the intermembrane space of the lateral wall of the cavernous sinus[12], those originating from the outside of the cavernous and secondary invaded into it were excluded from our study. We observed that the CSMs tend to extended within the cavernous sinus in the early stage due to the dense lateral wall which reflected on the coronal images was CSMs extended along the long axis of the cavernous sinus (Fig.1C). CN III dysfunction in the early stages along with radiological features of CSMs contribute to the diagnosis of it accurately. Besides, large ACMs and MSWMs may also secondary extended to the cavernous sinus in different routes. We observed 20 ACMs invaded into the cavernous sinus through the oculomotor triangle or infiltrating the roof or lateral wall directly. In contrast to ACMs, MSWMs seldom invaded into the cavernous sinus instead of compressing its lateral wall.

Our classification allows surgeon to diagnosis PMs easily and classified them into three subtypes accurately based on preoperative imaging. Concurrently, we can estimate the tumor invading direction, involved neurovascular structures, and arterial supply to perform tailored surgical strategies for every patient.

Individualized Surgical Strategies

The surgical approaches to remove PMs have been published in many reports. The traditional approach for PMs surgery was the pterional approach which first described by Dandy in 1942[5]. Dolenc[8] applied it to the surgical treatment of cavernous hemangioma of the cavernous sinus. In the last 20 decades, pterional approach has been widely applied to the surgical treatment of PMs[19; 15; 16; 2; 14; 13], pterional approach and extended pterional approach were centered around the Sylvian fissure with the exposure of temporal and frontal lobes. After removing the bone flap, there are mainly two routes to the parasellar region. Intradural approach was the most widely used. After dura opening and drainage of cerebrospinal fluid, the temporal lobe can be elevated easily to expose the tumor. Another approach is the extradural approach which dura incision is not required. Instead, through removing the sphenoid wing and dissection of meningoorbital band, surgeons can easily enter into the intermembrane space of the lateral wall of the cavernous sinus through which enter into the cavernous sinus to remove tumor. In this series, we present our experience by combing intradural approach and extradural approach to the parasellar region via pterional or extended pterional craniotomy.

For ACMs and MSWMs, we drill the bone constitute of the sphenoid wing and transected the meningoorbital band. And then, we elevated the dura from extradural and conjugated the arterial supply from the ophthalmic artery, the anterior branch of the middle meningeal artery and the meningo-orbital

artery [24; 19]. Those techniques including the following advantages:(1) Bone removal and elevation of dura allow us to identify the optic nerve and ICA from extradural; (2) Interrupting the arterial supply from out dura alleviate the bleeding in the intradural procedures; (3) Bone removal enlarged the operation room and reduction of temporal lobe retraction. To alleviate the tension of the brain, we choose to open dura mater for CSF drainage before tumor resection. Large tumor would be pushed to surgeon after split the Sylvian fissure with the help of high CSF pressure of basal arachnoid cisterns. Tumor debulking was initiated from outside to inside. Through the bidirectional dissection technique, we can remove the residual tumor which encase the ICA or MCA in little pieces. Anterior clinoidectomy was performed only in patients with anterior clinoid hyperostosis or erosion to minimized the intraoperative complications. We prefer extradural clinoidectomy as dura mater act as a protective screen during dissection or drilling. In addition to this advantage, extradural clinoidectomy allow section of falciform ligament to decompress the optic nerve and protect it from the compression of the sharp falciform ligament. Benefit from those procedures, visual function deterioration was observed only in 2.9% patients with ACMs and MSMWs.

For CSMs, the bone of the sphenoid wing was drilled to the base of the middle cranial fossa to enlarge the dissection space. Dissection into the cavernous sinus was initiated from the meningoorbital band which is located in the apex of the superior orbital fissure. Through the sharp dissection, a plane between the temporal tip and cavernous sinus lateral wall was established. The outer layer of the lateral wall was peeled away from the anterior aspect of the cavernous sinus. The tumor invaded into the intermembrane space of the lateral wall can be removed by suction and sharp dissection. Through the enlarged space caused by tumor compression superior or inferior to the CN IV, an incision parasellar to the CN IV was made to enter into the cavernous sinus. Those maneuvers took advantage of the natural space between cranial nerves caused by tumor compression and enable the surgeon to enter into the cavernous sinus in the shortest routes. Sharp dissection along the cleavage planes within the cavernous sinus minimized the injury of cranial nerves and arteries caused by traction or suction. When tumor invading the inner part of the cavernous, we performed the intradural approach and enter into the cavernous through an incision of its roof which making total resection of CSMs possible. Only when the tumor invading the adventitia or epineurium of the cavernous sinus, we leave residual tumor in it and followed by postoperative stereotactic radiotherapy. Benefits from the above surgical techniques, the recurrence and progression rate of CSMs were only 13.7% compared with 7.5-20% [19; 16; 14]in other reports. A few patients exhibit temporary post-operative cranial dysfunction and most of them recovered to preoperative after several months.

Bidirectional Dissection

Encasement of the ICA and its branches was reported in 20-55%[2]. Vessel invasion dealt with aggressively, unintended vessel perforation occurred in 20.8% of patients[1] . Hemiparesis, coma, and death caused by intraoperative injury of PMs was range from 2 to 7%[1; 15; 3]. Sacrifice of the middle cerebral artery branches invaded by ACMs even resulted in 100% mortality[10]. PMs encasing or invading the major cerebral arteries and their perforating branches is still a great challenge for surgical total resection. However, residual tumor along the arteries is one of the risk factors that result in tumor

progression. Achieving maximal tumor resection while preserving the arteries is the desired surgical goal. To achieve the goal, we performed a technique named bidirectional dissection technique based on tailored surgical approach.

Based on individualized preoperative classification and approach, we performed this technique from different directions and only 1 patient suffered from the artery perforation. The postoperative hemiparesis rates were only 3.1% in patients with PMs. This technique facilitates tumor debulking and differentiation of feeding artery or perforators. Sharp dissection combined with mild traction was the core technique of bidirectional dissection. Compared with suction and blunt dissection, sharp dissection along the arachnoid plane prevents traction force from injury the cranial nerve and perforating arteries. While tumor invading adventitia or epineurium and arachnoid membrane were absent, we choose to leave tumor tuft along the arteries and their perforating branches.

Bidirectional dissection technique not only can apply to the dissection of ICA, MCA, ACA, ACHA, and PcomA (Fig.2) but also can be applied to the dissection of their perforating branches. We take special attention to perforating branches which support the cranial nerves (Fig.3). The arterial supply of the chiasm and optic nerve mainly from the superior hypophyseal arteries which often damaged by intraoperative operation and result in subsequent optic nerve ischemia and visual deficits[23]. In our study, we dissect this branch by finding the entrance point from the posteromedial aspect of the ICA and dissect it from proximal to distal (Fig.3A). The meningohypophyseal trunk and inferolateral trunk are the most important branches of the cavernous ICA which can be located in the posterior band and the horizontal ICA segment. Sacrifice of these arteries may cause the dysfunction of CN III, IV, and VI because of interruption of their blood supply[18]. By following their course and using the bidirectional dissection technique, these can be protected while achieving maximal tumor resection (Fig.3B). The lenticulostriate arteries are the most important perforating branches of MCA whose injury may cause hemiparesis, coma or death[7]. The majority of those perforating branches coursed medially and parallel to the M1 supply the basal ganglia and portions of the internal capsule. Special attention needed to protect this branch when dissection along the MCA trunk. Dissection of lenticulostriate arteries initiated from the MCA trunk, followed by tumor decompression to identified the distal end of lenticulostriate arteries encased in tumors (Fig.3C). Using these bidirectional dissection procedures, maximal tumor resection can be achieved.

Neurofunctional Outcomes at Long-Term Follow-Up

During the past 2 decades, our surgical goal was to achieve maximal tumor resection while protecting the neurofunction of patients and improve their postoperative life quality. Those individualized surgical techniques mentioned above were to minimalize mobility and morbidity. In our series, The KPS of patients with PMs at the last follow-up was elevated to 89.6 compared to 81.1 preoperatively.

The optic nerve was the most often involved in PMs and postoperative visual improvement was present in 10-66.7% of patients according to the previous reports[1; 10; 2]. The visual acuity or visual improvement or unchangeableness in our series were up to 90.3%. We attribute the good outcome not

only to the bidirectional dissection technique but also to the extradural clinoidectomy, the section of the falciform, and preserving the perforating branches which supply the optic nerve and optic chiasm. In our experience, compression of the nerve directly or its feeding artery was the reason to cause the deterioration of visual acuity preoperatively. Even in blind patients, efforts should be made to dissect the optic nerve and its feeding arteries from tumor instead of sacrificing it to achieve maximal tumor resection. 3 patients with the blind eye can recovery the sense of light after several months. Another important procedure that may contribute to the improvement of patients was the dissection of the superior hypophyseal arteries which was the main blood supply of the optic nerve.

Likewise, CN III, IV, and VI are often encased or invaded by CSMs and large ACMs. Injury of those cranial nerves or injury of their blood supply were the two main reasons that result in postoperative cranial nerve dysfunction. According to previous reports, postoperative CN III, IV, and VI dysfunctions was range from 12.9 to 29%[6; 19; 16; 14]. The deteriorated nerve function was observed only in 9.2% of our patients and 66.7% was recovered to unchanged after the following follow-up. We contribute those to the following individualized surgical techniques: (1) pretemporal transcavernous approach allows surgeon identified the plane between the tumor and neurovascular structures within the cavernous sinus; (2) sharp dissection minimized the traction to cranial nerves; (3) bidirectional dissection technique was used to preserve the blood supply of these cranial nerves. The total resection rate of CSMs was only 44.8% and much less than ACMs and MSWMs. The reason was to prevent the intraoperative injury of ICA and cranial nerves when tumor invades their adventitia or epineurium. If we remove the residual tumor in the above cases, the injury of the ICA or cranial nerves was unavoidable. Owing to the slow-growing of the residual tumor[11] and the advances in stereotactic radiotherapy[20; 4], we leave the residual tumor for stereotactic radiotherapy three months after the surgery. The recurrence rate of CSMs was only 3.4% during the follow-up.

Conclusion

Parasellar meningiomas are one of the most challenging skull base meningiomas. We classified it into three subtypes based on the preoperative imaging, according to which we can perform individualized surgical strategies to the patients, including tailored surgical approaches and bidirectional dissection technique. This technique contributes to the total resection of meningioma while preserving the cerebral arteries and cranial nerves.

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Tables

Due to technical limitations, the tables are only available as a download in the supplementary files section.

Figures

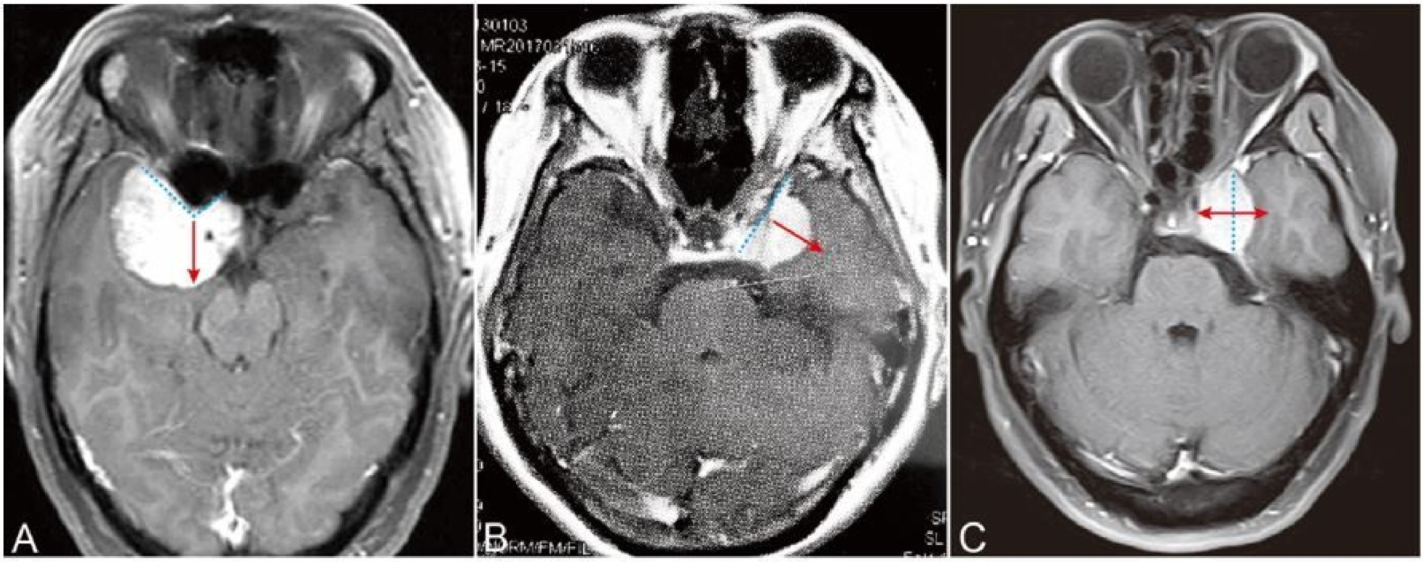

Figure 1

Extension directions of three typical PCMs. Cyan dash line: the base of the tumor. Red arrow: tumor extension directions.

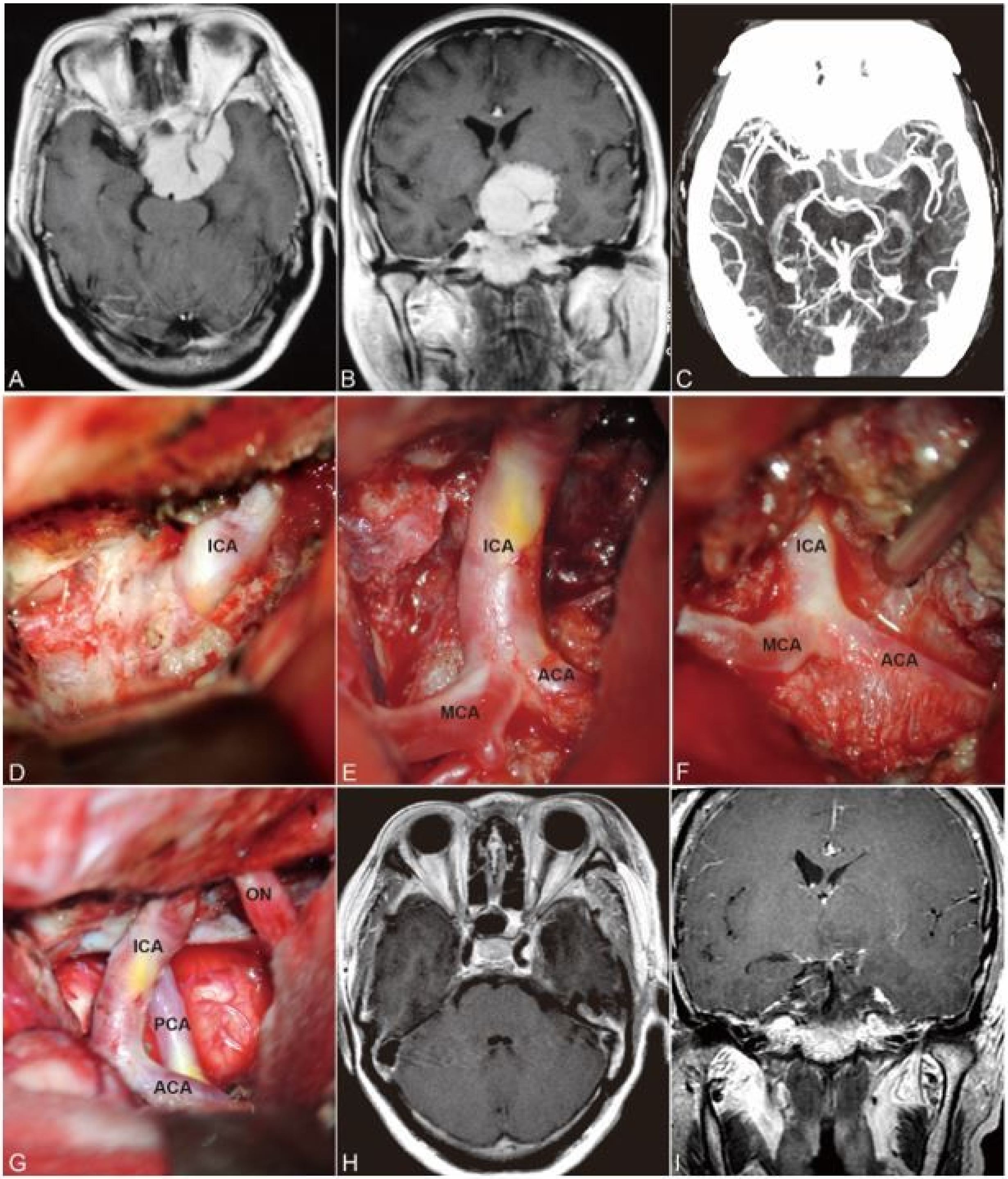

Figure 2

Contrast-enhanced MRI and CTA images of ACM (A, B and C preoperative; H, I postoperative) and steps of bidirectional dissection technique (D, E, F and G). Intradural localization of the ICA (D) and dissection along the course of ICA and its branches (E, F) to achieve total resection while preserved the ICA and its branches(G).

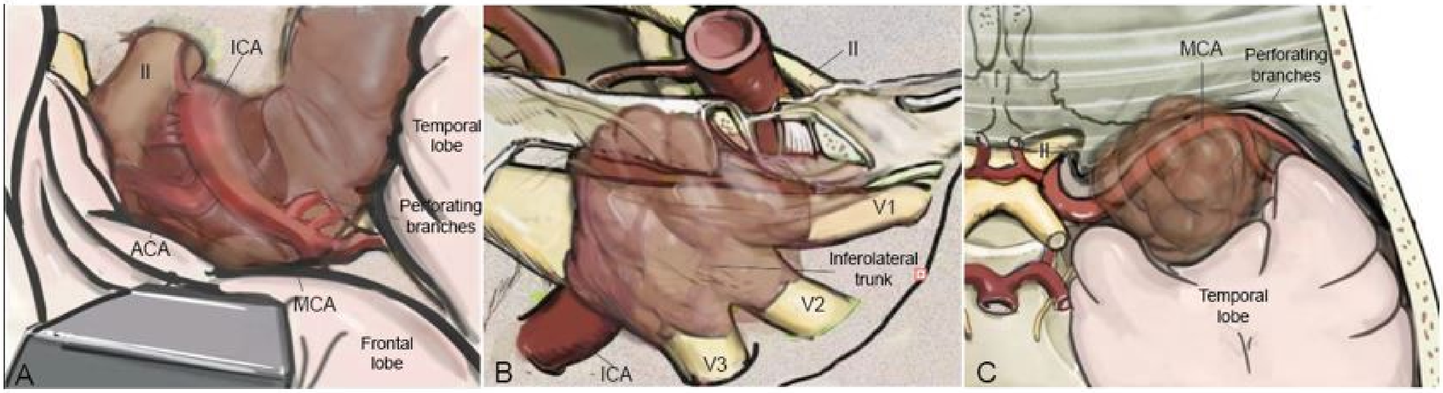

Figure 3

The cranial artery, perforating branches, and cranial nerve involved in the PCMs. The ACA, ICA, MCA, and their perforating branches were involved in ACMs (A) while MCA and its perforating branches was the most involved in MSWMs (C). The inferolateral trunk and the meningohypophyseal trunk of ICA was encased by CSMs (B).

Supplementary Files

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