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Original Article

Preoperative Embolization of Skull Base Meningiomas: Impact on Surgical Results

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BACKGROUND: Skull base meningiomas are considered among the most common occurring meningiomas. Because of their rich blood supply, safe and total resection represents a challenge for neurosurgeons. Preoperative embolization is one of the lines that are used to control the tumor bleeding during resection.

OBJECT: This study aims to evaluate the safety and efficacy of preoperative embolization on the skull base meningiomas surgeries.

METHODS: This retrospective study included 20 patients with various types of skull base meningiomas who had undergone preoperative embolization of the feeding arteries to achieve the angiographic absence of tumor blush. Within two days after embolization, each patient underwent surgical resection of the tumor. Intraoperative findings, operative time, operative blood loss, extent of resection, and postoperative events were documented and analyzed.

RESULTS: Average blood loss was 262±62.79 ml and the mean operative time was 254.5±32.03 minutes. Simpson grade 1 was achieved in 5 cases (25%), grade 2 in 9 cases (45%), and grade 3 in 6 cases (30%). There were no embolization-related or surgery-related morbidities or mortalities.

CONCLUSION: Preoperative embolization is a safe option for selected skull base meningiomas to minimize the operative blood loss and facilitate tumor resection.

KEYWORDS: Embolization, endovascular, meningioma, skull base.

INTRODUCTION

Meningiomas are considered the most common benign brain tumors.[1] One of the most challenging anatomical locations are the skull base meningiomas. Special considerations are encountered, such as the rich blood supply, the nearby vital neurovascular structures and the narrow surgical corridor.[2-4] Early devascularization of the lesion is considered the cornerstone step in meningioma surgery, aiming to facilitate tumor dissection from the surroundings and to minimize intraoperative blood loss.[5,6]

In 1973, Manelfe et al. have established preoperative embolization (POE) of highly vascular meningiomas.[7] The aim of POE is to facilitate the tumor resection and to minimize the intraoperative blood loss and the operative time.[8-10] Despite its benefits, POE still carries some risks of causing neurological deficits from occlusion of a feeding artery to a vital neurological structure such as the optic nerve or brain parenchyma. Other potential risks may result from hemorrhage or vasogenic edema.[11-14]

There is still controversy regarding the implication of POE in meningioma surgery. In our study, we will evaluate the safety and efficacy of POE in skull base meningioma surgery and try to define if the benefits outweigh the potential risks and hazards.

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METHODS

This retrospective study was conducted at the neurosurgery department at Tanta University hospitals, within the period from January 2015 to March 2020. Local institution ethical approval was obtained. The study included 20 patients who were diagnosed with skull base meningiomas. We excluded patients who presented with neurological deficits such as aphasia or weakness, and those with lesions exerting significant mass effect on adjacent brain parenchyma or ventricles. An informed consent was obtained from every patient. All patients were managed by POE of the feeding arteries followed by surgical resection within 48 hours.

Complete neurological evaluation was performed for every patient. All preoperative data were recorded including gender, age, and presenting symptoms. All preoperative radiological investigations were carefully examined to detect the tumor location, tumor volume, and the exerted mass effect. There were 2 different neurosurgical teams involved in the study; one for endovascular preoperative embolization, and the other for surgical resection of the tumor.

Under general anesthesia, the standard trans-femoral approach was applied. Using 5 F multipurpose diagnostic catheter, diagnostic angiography was done in all cases to check tumor feeders and to define dangerous anastomosis with the internal carotid artery (ICA) and the vertebral arteries, in addition to evaluation of venous drainage and venous sinuses if invaded. Balloon occlusion test to assess the collateral supply was performed if the ICA was encased and there was a possibility for its injury or sacrifice.

Replacement with 6 F guiding catheter was done in all cases. Combination of different microcatheters and microwires was done according to diameter of feeders, target point of injection (selective or super-selective) and the size of the particles intended for injection (45-350 microns). The used embolizing material in all cases was Polyvinyl Alcohol (PVA) particles (Contour, Boston Scientific). Particles starting from 45-microns were injected in pulsed manner targeting tumor bed until the disappearance of the tumor blush, while digital subtraction angiography (DSA) was repeated to check for the presence of dangerous anastomosis. Control DSA was performed at the end to evaluate the extent of embolization. Surgical resection was planned within 48 hours after embolization. Enhanced computed tomography (CT) or magnetic resonance imaging (MRI) after embolization shows the degree of post embolization tumor necrosis.

Within 48 hours following embolization, under general anesthesia, the second team has performed the surgical resection of the embolized tumor. They planned the surgical approach according to the anatomical location of the lesion. They recorded intraoperative events, operative blood loss, Simpson grade for the extent of surgical resection, and the operative time.

According to the surgeons and depending on the control of intraoperative bleeding, the lesions were divided into dry, intermediate, and bloody. Lesions were divided according to the easiness of dissection and resection into easy, intermediate, and difficult.

After recovery from the anesthesia, the patients were observed and examined for any adverse effects. All complications were recorded and divided into POE-related and surgery-related complications.

RESULTS

Preoperative Data

Our study included 20 patients with different types of skull base meningiomas. The mean age of participants at the time of surgery was 46.3±8.3 years with a range of 27-58 years. According to gender, there were 12 males and 8 females. According to the affected side, 11 lesions were located on the right side, 6 lesions were on the left side, and 3 olfactory groove lesions were in the midline. The exact locations of the meningiomas are shown in **Table 1.**

Table 1: Anatomical locations of the meningiomas

Location	Patients Number
Olfactory groove meningioma	3
Lateral Sphenoid wing meningioma	6
Medial Sphenoid wing meningioma	4
Petroclival meningioma	2
Tentorial meningioma	3
Posterior fossa meningioma	2
Total	20

The main presenting symptoms were headache in 12 patients (60%), seizures in 5 patients (25%), ataxia in 2 patients (10%), and cognitive impairment in one patient (5%). The mean tumor volume calculated on preoperative MRI was 47±10 cm3 (Range: 30-64 cm3).

Endovascular Embolization

After proper evaluation of the preoperative imaging, all patients were subjected to endovascular angiographic evaluation of the feeding arteries. The feeders included branches from the external carotid artery (ECA) in 90% of the cases, most commonly the middle meningeal, the accessory meningeal, and the neuromeningeal trunk of the ascending pharyngeal artery.

Meningeal feeders from the internal carotid artery were detected in 60% of the cases including the inferolateral trunk, the meningohypophyseal trunk, and the anterior meningeal artery from the ophthalmic artery. Meningeal feeders from the vertebral artery were reported in 30% of the cases including the posterior meningeal artery. Pial feeders from the internal carotid and vertebral arteries were reported in 20% of the cases always supplying variable portions on the pial surface of the tumor **(Table 2).**

Control DSA at the end of embolization revealed total and near-total disappearance of blush in 17 patients (85%) and partial disappearance of blush in 3 patients (15%) **(Figs. 1,2).** No embolization-related morbidity or mortality was reported in any patient.

Table 2: Arterial feeders

Arterial Feeder	No. of Patients
External carotid artery	18
Middle meningeal	15
Accessory meningeal	5
Deep temporal	2
Neuromeningeal trunk of ascending pharyngeal artery	8
Stylomastoid branch from occipital artery	4
Transosseous branch of posterior auricular artery	2
Internal carotid artery	12
Meningohypophyseal trunk	8
Inferolateral trunk	6
Anterior meningeal from ophthalmic artery	2
Vertebral artery	6
Posterior meningeal artery	
Pial feeders	4

Surgical Findings

All cases were operated upon within 48 hours from the embolization. According to the observation of the operating surgeons regarding the vascularity of the lesions, tumors were dry in 11 cases (55%), intermediate in 8 cases (40%), and bloody in one case (5%). The mean intraoperative blood loss was 262±62.79 ml (range 200-450 ml).

According to the easiness of dissection, the surgeons found that it was easy in 11 cases (55%), intermediate in 6 cases (30%), and difficult in 3 cases (15%). The mean operative time was 254.5±32.03 minutes (range 200-300 minutes).

According to the extent of resection, Simpson grade 1 was achieved in 5 cases (25%), grade 2 in 9 cases (45%), and grade 3 in 6 cases (30%). After histopathological examination of the resected lesions, all of them were proved to be meningioma grade 1. There was no surgery-related complications.

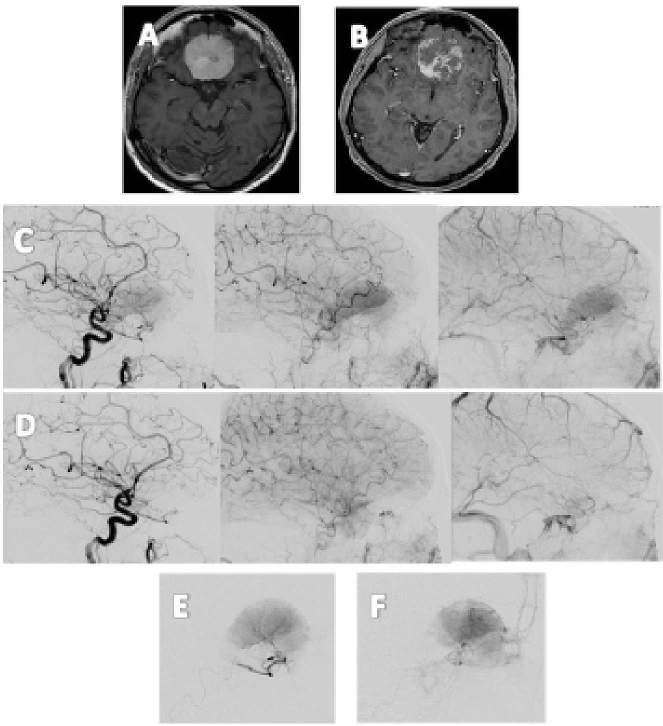

Fig 1: A case with olfactory groove meningioma A) Pre-embolization MRI axial T1 with contrast shows homogenous tumor enhancement, B) Post-embolization MRI axial T1 with contrast shows tumor necrosis with capsular enhancement, C) Pre-embolization common carotid artery (CCA) angiogram in different phases shows tumor blush, D) Post-embolization CCA angiogram in different phases shows disappearance of tumor blush, E) Selective catheterization of the ophthalmic artery shows retinal blush, F) Super-selective catheterization of the posterior ethmoidal artery with no retinal blush seen.

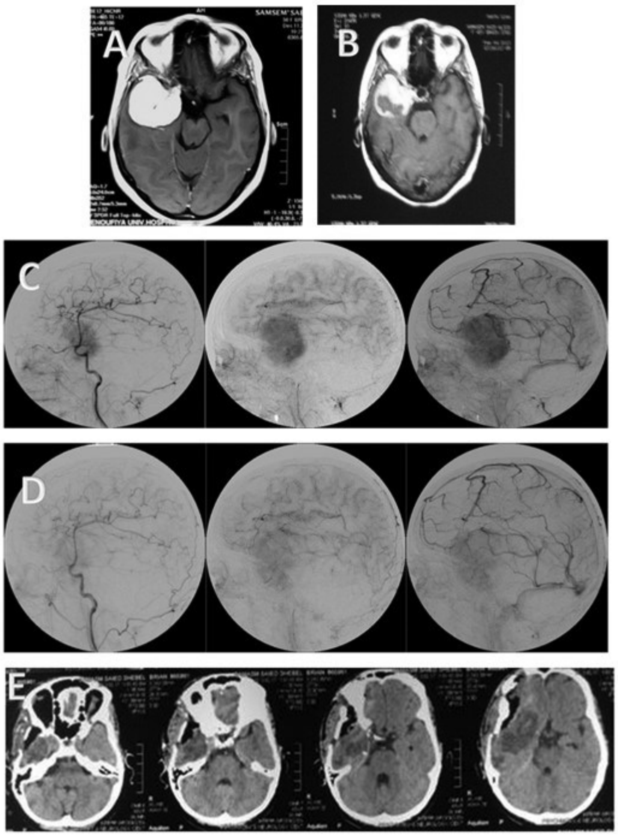

Fig 2: A case with right sphenoid wing meningioma A) Pre-embolization MRI axial T1 with contrast shows homogenous tumor enhancement, B) Post-embolization MRI axial T1 with contrast shows tumor necrosis and shrinkage with capsular enhancement, C) Pre-embolization ECA angiogram in different phases shows tumor blush, D) Post-embolization ECA angiogram in different phases shows disappearance of tumor blush, E) Post-operative axial CT brain shows total tumor resection.

DISCUSSION

Surgery of skull base meningiomas is considered challenging because of nearby vital vessels and cranial nerves. Each surgical approach was designed to safely resect the tumor completely with minimal brain retraction.[15-17] Prior to surgical excision, embolization of these tumors may be employed in order to minimize intraoperative blood loss and to enhance total resection.[4,18-20]

Most of the skull base meningiomas have dual blood supply from both ECA and ICA. Embolization of ECA branches is much easier than ICA. The risk of ischemic complications increases on targeting branches from ICA or in the presence of ECA-ICA anastomoses which may also occur within the tumor vascular network itself.[21] The ICA branches may have acute take-off, increasing the risk of arterial perforation.[12,22]

Different materials including liquid embolic such as N-butyl-2-cyanoacrylate (NBCA), Onyx and solid particles such as PVA, and trisacryl gelatin microspheres could be used. Each material has its own advantages and disadvantages. The PVA particles are the most commonly used material as they are considered cheaper, easily controllable, have different sizes and could be used as free flow embolization when proximal access is difficult.[23,24] In our series, PVA was used in all cases. Total occlusion was obtained in 85% of cases. There was no POE-related morbidity or mortality in our series. Possible embolization-related complications include hemorrhage, ischemic deficit, nerve palsy, and brain edema. The incidence of these complications ranges from 0-16.7%.[3,25-27]

Depending on the used empolysate, the use of smaller particles carries a higher risk of complications such as occlusion of the venous outflow causing back pressure and subsequent hemorrhage. Thus, some authors generally do not recommend the use of particles smaller than 100 mm, especially whenever there is a risk for potentially dangerous anastomoses or loss of vascular supply to the cranial nerves.[28,29]

The advances in microcatheter designs, such as wire-directed and flow-directed catheters, enable much safer embolization. The use of wireless flow-directed catheters minimizes the risk of injury to the distal cerebral vasculature and intracerebral hemorrhage.[30]

We achieved total tumor resection (Simpson grade 1 and 2) in 70% of the cases and subtotal resection (Simpson grade 3) in 30% of the cases. The mean operative blood loss was 262±62.79 ml. The mean surgical time was 254.5±32.03 minutes. No surgery-related morbidity or mortality was reported. According to the systematic review conducted by Ilyas et al., the rate of complete skull base meningiomas resection without POE was 47–81%, while in cases with POE, it was 74%.[6]

In their meta-analysis, Chen et al. concluded that the incidence of overall complications between POE plus surgery and surgery alone has no significant difference. They explained that while the POE may increase the risk of embolic-related complications, it reduces the risk of surgical complications.[27] The duration of surgery was significantly shorter in the POE cases than in the non-POE cases.[25,27,31,32] Chen et al. have also shown that the operative blood loss was significantly lower in cases with POE when compared to cases without POE.[27] Previous studies have found that the mean intraoperative blood loss depends mainly on the embolization rate; higher occlusion rate is associated with less blood loss.[25,27,33] Others found that larger tumors get more benefits from POE.[8,27]

There is still controversy regarding the interval between POE and surgical resection. Some authors recommend an interval of 1-7 days due to the potential risk for collaterals development and revascularization of the lesion.[34,35] Others recommend a period of more than 1 week for more softening of the lesion and relative ease of resection, less edema, and less blood loss.[36,37]

According to the literature, one of the common indications for POE of meningiomas was the surgeons' own preferences and institutional practices.[33,38] Other possible indications include large tumor size especially if associated with significant perifocal edema where the surgical plane may be obscured, high vascularity, significant supply from the ECA, arterial supply that may be difficult to be reached intraoperatively such as in skull base meningiomas, tumor involvement of dural sinuses, invasion of the scalp and calvaria, and tumors in proximity to eloquent cortex.[11,29,34,39-41]

The main limitation of the current study is its retrospective nature. Further prospective comparative studies including a larger number of both embolized and non-embolized cases are recommended.

CONCLUSION

Preoperative embolization of skull base meningiomas is considered a safe and effective adjuvant intervention to skull base meningiomas resection. Appropriate selection of the patients for POE is the cornerstone in the success of this maneuver. More randomized studies are needed to confirm these results.

List of abbreviations

CCA: Common carotid artery.
CT: Computerized tomograpghy.
DSA: Digital subtraction angiography.
ECA: External carotid artery.
ICA: Internal carotid Artery.
MRI: Magnetic resonance imagining.
NBCA: N-butyl-2-cyanoacrylate.
POE: Preoperative embolization.
PVA: Polyvinyl alcohol.

Disclosure

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

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