Original article

The Impact of Preoperative Endovascular Embolization of Intracranial Meningiomas on Surgical Outcome

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Abstract

Background: Preoperative embolization of highly vascular intracranial meningiomas facilitates their surgical resection. The timing of preoperative embolization stays debatable. In our study, the effect of preoperative embolization of intracranial meningioma on surgical outcomes is assessed. **Aim** is to evaluate the impact of preoperative embolization of intracranial meningiomas on surgical outcome. **Patients and methods:** a planned report was done to assess the effect of preoperative endovascular embolization on surgical outcome of intracranial meningiomas worked from May 2018 to May 2020. In this study, twenty patients with intracranial meningioma went through preoperative embolization followed by surgical resection following 1-5 days. These patients included 12 Female and 8 Males and age went from 35years to 68years with mean age 51.5years. Most frequent locations are Sphenoid wing meningioma and parasagittal meningioma. **Results**: Total and near total disappearance of tumor blush achieved in eighteen patients, while partial obliteration of tumor blush was achieved in two patients. No permanent morbidity or mortality in all patients. Fifteen patients were operated in the 2nd post-embolization day. Significant reduction of operative time that ranged from 3h to 6h with a mean of 4.5 hours and the intraoperative blood loss was reduced in eighteen patients and there was no need for transfusion in tow patients with mean amount of blood transfusion of 300 cc. **Conclusion**: Preoperative embolization was shown to be safe and effective technique as a preoperative procedure that facilitated meningioma surgical resection with marked reduction of blood loss.

Key words: preoperative embolization, intracranial meningioma, tumor blush

Introduction

Numerous years ago, it was a challenge task to do a brain tumor surgery. Recently, with an advanced operating rooms and profoundly qualified neurosurgeons, it became one of the commonest procedures in our everyday practice. Preoperative trans-arterial endovascular embolization of highly vascular intracranial neoplasms begins another transformation in brain tumor surgeries. Meningiomas are hyper-vascular neoplasms that emerge from the connecting leptomeninges. The expression "meningioma" was first reported in 1922 by Harvey Cushing, who distributed his initial practice on meningioma surgical procedure. These tumors most normally emerge extra-axially from arachnoid cap cell degeneration and connecting dural fibroblasts, given their starting point from arachnoid cap cells.[1]

Meningiomas establish 13-18% of all intracranial neoplasms that happen at whatever stage in life between ages 20 to 60 years with a pinnacle frequency at 45 years. In grown-ups, intracranial meningiomas are more prevalent in ladies with female to male proportion of 2:1. They are solitary lesions however might be various. Multiple lesions occur commonly in neurofibromatosis type II. [2]

Meningiomas are well-circumscribed extra-axial masses which are well demarcated from the nearby brain parenchyma. They may compress neural tissues but do not infiltrate them, they may invade dura and dural sinuses, may erode bone and may sometimes extend through skull base into extra-cranial compartments. [3]

Involvements of nearby structures lead to main neurological symptoms. Raised intracranial pressure causes non localizing symptoms and signs, such as headache, visual disturbances, and dementia.[4]

The preoperative transarterial embolization of intracranial meningiomas involve selective catheterization of the feeding arteries to the tumor bed with infusion of embolic particles to saturate the tumor bed to induce necrosis, reducing operative time and blood loss. [5]

Many embolic agents were used. The start was with different types and shapes of particles. Gel foam and silicon rubber particles were previously widely used. Late in 1970s, glue “N-Butyl cyanoacrylate” (NBCA) led to obvious changes in intracranial embolization techniques. In 1980, with poly vinyl alcohol (PVA) particles application, preoperative trans-arterial embolization of many hypervascular brain tumors became popular in many centers. This was followed by application of onyx in 1990, a trade name for Ethylene Vinyl Alcohol Copolymer (EVOH), soluted in Dimethyl-Sulfoxide (DMSO) which had FDA approval in 2003. [6]

There is a great controversy regarding the time interval between the embolization technique and subsequent resective surgery. Currently, the average time interval to operate after embolization ranges from 1.9 to 6.3 days.[7]

Meningiomas receive their blood supply from extracranial or intracranial circulation or both. Either meningeal, pial or both. Meningeal blood supply from external carotid artery as Middle meningeal artery (MMA), ascending pharyngeal artery (APA) and neuromeningeal trunk (NMT). Meningeal blood supply from internal carotid artery as Inferolateral trunk (ILT) and meningeohypophyseal trunk (MHT). Average intraoperative blood loss may be from 200 ml to 2.2 L and so, patients may therefore require transfusion.[8]

During meningioma resection, blood loss is a significant risk and is important to be considered when evaluating the treatment options. To make meningioma resection easier and with less complications, preoperative embolization was accepted as an adjuvant therapy.[9]

It is suggested that not all meningiomas need preoperative embolization. The value of embolization is determined by the source and degree of blood flow to the tumor. Additionally, certain “challenging” meningiomas are of higher risk of embolization due to associated dangerous vascular anastomosis e.g. their anastomotic connections with brain stem blood supply and therefore may be not amenable for preoperative embolization. [10]

Patients and Methods

This is a non-randomized prospective study that was done from May 2018 to May 2020 at Neurosurgery department, Benha University Hospitals and Neurosurgery department, Tanta University Hospitals, EGYPT. All included patients **(20 patients)** had hypervascular intracranial meningiomas and were agreeable for preoperative embolization. This study has given approval by Research Ethics Committee (REC) of Benha faculty of medicine, Benha University. A written informed consent was obtained from each patient after explaining all steps of the procedure. All procedures performed involving human participants were in accordance with the ethical standards of the institutional and/or national research committee, all selected patients were exposed to point by point history taking, general assessment, neurological assessments and full research facility assessment. Full radiological assessment was finished including CT Brain, MRI Brain with contrast and digital subtraction angiography (DSA) for all cases.

Under general anesthesia, standard trans-femoral approach was applied in all cases. 5F multipurpose diagnostic catheter angiography was used in all cases to check tumor feeders and to define dangerous anastomosis with internal carotid and vertebral arteries. Evaluation of venous drainage and venous sinuses was done to check if any of the venous sinuses was invaded.

Replacement with 6F guiding catheter was done in all cases. Combination of different micro-catheters and micro-wires was used according to diameter of feeders, target point of injection. Size of PVA particles injected 45-250 micron, starting with 45 micron particles injected in pulsed manner, tumor bed was targeted until disappearance of the tumor blush while repeated control DSA was done to check opening of dangerous anastomosis. Control DSA, enhanced CT Brain and/or MRI Brain was done at the end of the procedure to evaluate the degree of embolization and degree of central necrosis in MRI images. Surgical excision was done 1-5 days post-embolization. Operative details including amount of blood loss and duration of surgery were documented. Postoperative follow-up of patients was done by doing CT Brain 2nd day postoperative to evaluate the extent of surgical resection and then after 3 months and clinically for neurological outcome and appearance of techniques related complications.

Statistical analysis

The collected data were summarized as mean ± Standard Deviation (SD) and range for quantitative data and frequency and percentage for qualitative data. Comparisons between the different study groups were carried out using the Fisher Exact Test (FET) to compare categorical data, the Mann-Whitney test (MW) and the Kruskal Wallis test (KW) to compare numerical data of two and more than two groups, respectively. All tests of significance were carried out two-tailed and a P-value <0.05 was considered statistically significant. Data management was carried out using STATA/SE version 11.2 for Windows (STATA corporation, College Station, Texas). ***Table 1*** showing relations between surgical outcomes and potential risk factors

Results

Illustrative Cases

Case1

A forty-eight years old male patient presented with headache, vomiting and right sided weakness. CT brain with contrast was done and showed left parasagittal extr-axial lesion, the patient was advised for preoperative embolization, which was done one day before surgery with complete disappearance of tumor blush and central necrosis in post-embolization CT Brain, surgery was done one day after trans-arterial embolization. Mild skin necrosis was noted that healed with frequent dressings, with marked decrease in intraoperative blood loss that was 350cc, operative time was 4 hours, with easy resection. As shown in illustrated figures 1, 2, 3,4and 5.

Case 2:

A forty-eight years old female patient presented with headache and disorientation. MRI brain Showed right sphenoid ridge meningioma. The patient was advised for preoperative trans-arterial embolization, preoperative trans-arterial embolization was done 3 days before major surgery with complete obliteration of tumor blush in post-embolization DSA, intraoperative blood loss was decreased that was 450cc with no permanent complications regarding embolization or the surgery. As shown in illustrated figures 6, 7, 8 and 9.

Case 3:

A fifty-one years old female patient presented with headache and left sided weakness with motor power 3/5. MRI brain showed right convexity meningioma. The patient was advised for preoperative trans-arterial embolization that done with complete obliteration of tumor blush and was operated one day post-embolization, intraoperative blood loss was 300cc, with no permanent morbidity related to either embolization or surgical resection. As shown in illustrated figures 10, 11 and 12.

Case 4:

A thirty-seven years old male patient presented with disturbed level of consciousness, MRI brain showed right medial sphenoid ridge meningioma. The patient was advised for preoperative embolization which was done one day before surgery**,** and all stages of meningioma resection were facilitated with Simpson grade III**,** no permanent morbidity related to either embolization procedure or surgery were noted. As shown in illustrated figures 13, 14,15 and 16.

A total of 20 patients with intracranial meningiomas underwent a preoperative super-selective arterial embolization. Twelve patients are females and eight are males with age ranged from 35 years to 68 years with a mean age 51.5 years. Headache, vomiting, seizures, hemiparesis and blurring of vision were the most common clinical presentations at time of diagnosis. The most common intracranial sites are sphenoid ridge 45%, parasagittal 15%, convexity 10%, olfactory groove 10%, tentorial 10%, cerebellopontine angel 5% and petro-clival 5% as listed in Table (1).

Blood supply of intracranial meningiomas and detailed arterial feeders are listed in Table (2).

Total and subtotal disappearance of tumor blush was achieved in 18 patients (90%) while incomplete disappearance of tumor blush was achieved in the remaining two patients (10%). Necrosis was evaluated by absent enhancement in post-embolization enhanced CT or MRI. Surgical reports of operated cases showed that the amount of intraoperative blood loss ranged from 250cc to 500cc with a mean 300cc , the operative time ranged from 3 hours to 6 hours with a mean of 4.5 hours. In cases of total and subtotal disappearance of tumor blush, three steps of meningioma surgical resection; devascularization, debulking and dissection were facilitated. Tumor softening lead to easy debulking and dissection of tumor capsule. The amount of intraoperative blood loss that ranged from less than 250cc to more than 500cc with a mean 300cc. Table 3 showing Simpson grading evaluated on the postoperative CT scans. Postoperative complications were delayed wound healing in one case of parasagittal meningioma due to mild skin necrosis that healed by frequent dressings. One case of surgical site infection and worsening of preoperative motor power state from Grade 4/5 to Grade 2/5 which was transient. No permanent morbidity or mortality occurred with endovascular procedure. Most of patients had transient mild post-embolization groin pain and headache that resolve with steroids and analgesics. Transient groin localized subcutaneous hematoma occurred in 2 patient, motor deficit in two cases (10%) as shown in table 4 and table 5.

Table 1 showing Relations between surgical outcomes and potential risk factors

		Intraoperative Bl. Loss				Test	P
		250-500 cc (no.=18)		>500 cc (no.=2)			
		No.	%	No.	%		
Age (years)	30-	6	33.33	0	0.0	FET	0.30
	40-	4	22.22	2	100.0		
	50-	5	27.78	0	0.0		
	60-70	3	16.67	0	0.00		
	Mean ± SD; (range)	48.44±10.42; (35-68)		46.5±2.12; (45-48)		MW=0.06	0.95
Gender	Female	6	33.33	2	100.0	FET	0.15
	Male	12	66.67	0	0.0		
Tumor size	< 30 cm^3	3	16.67	0	0.00	FET	**0.032 (S)**
	30-60 cm^3	14	77.78	0	0.00		
	>60 cm^3	1	5.56	2	100.00		
Complication of embolization	None	16	88.89	1	50.0	FET	0.28
	Yes	2	11.11	1	50.0		
Time before surgery (days)	1	13	72.22	2	100.00	FET	1.00
	2	3	16.67	0	0.00		
	3	1	5.56	0	0.00		
	5	1	5.56	0	0.00		
	Mean ± SD; (range)	1.5±1.04; (1-5)		1±0; (1)		MW=0.83	0.41

FET: Fisher Exact Test; MW: Mann Whitney test; S: significant difference (P<0.05)

Table 2 Intracranial meningioma location.

Tumor location	Number of cases	Percentage (%)
Sphenoid ridge	9	45%
Parasagittal	3	15%
Convexity	2	10%
Olfactory groove	2	10%
Tentorial	2	10%
Petro-clival	1	5%
CPA	1	5%

Table 3 Pattern of blood supply**.**

Pattern of blood supply	Numberof cases	Percentage (%)
Meningeal from external carotid artery	5	25%
Meningeal from both internal carotid, external carotid arteries and from vertebra-basilar system	10	50%
Mixed supply (meningeal and pial)	5	25%
Dominant pial supply	None	None

Table 4: Simpson grading of meningioma surgical resection.

Simpson grading	Definition	% of patients operated
1	Macroscopic total resection with excision of attatched dura and bone.	10%
2	Macroscopic total resection with coagulation of attatched dura.	45%
3	Macroscopic resection without coagulation of attatched dura.	40%
4	Near total resection.	5%
5	Excisional biopsy.	None

Table 5: Showing complications related to endovascular procedures.

Complication of embolization	**None**	17	85%
	Delayed wound healing	1	5%
	Small femoral hematoma	2	10%

Table 6: Showing complications related to surgery.

Complication of surgery	**None**	17	85%
	Side weakness(Transient hemiparesis G 3/5)	2	10%
	Surgical site infection	1	5%

Fig 1: CT brain, axial cut showing Pre-embolizedleft parasagittal meningioma with marked perilesionaledema.

Fig 2: CT brain, axial cut showing post-embolization left parasagittal meningioma with central necrosis.

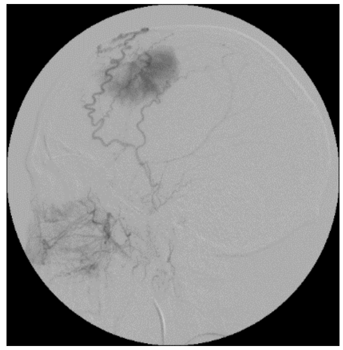

Fig 3: DSA showing tumor Blush (Dominant meningeal supply)

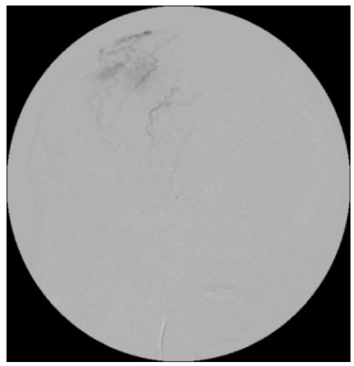

Fig 4: DSA showing complete obliteration of tumor blush

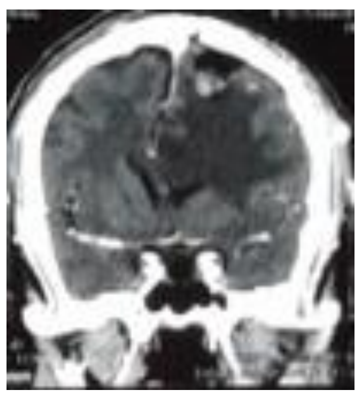

Fig 5: showing postoperative CT brain of operated left parasagittal meningioma.

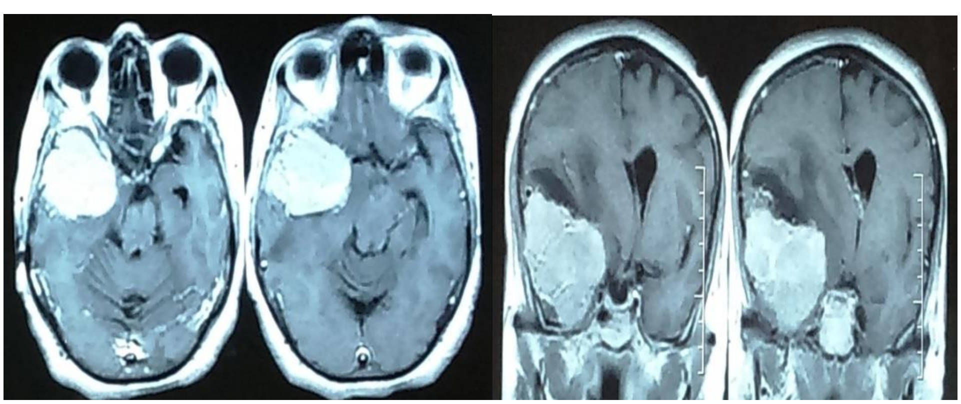

Fig 6: MRI brain with contrast axial cuts (left) and coronal cuts(right) showing right sphenoid ridge meningioma with marked perifocal edema

Fig 7: DSA of external carotid artery showing a highly vascular tumor blush.

Fig 8: DSA of external carotid artery showing complete obliteration of tumor blush.

Fig 9: Showing CT brain axial cuts after tumor resection showing adequate gross total resection.

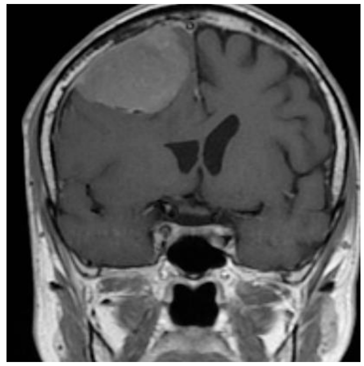

Fig 10: MRI brain, coronal cut showing right convexity meningioma

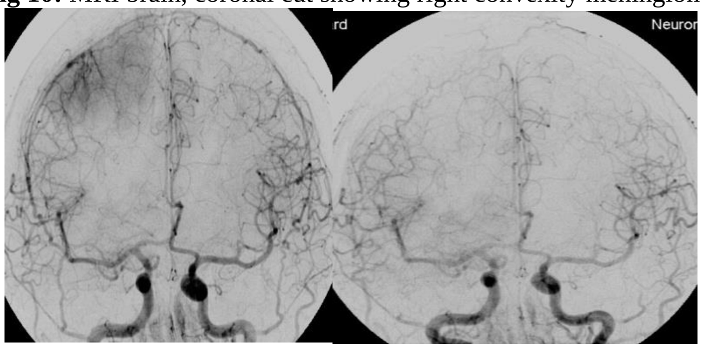

Fig 11: Angiographic pictures showing, pre-embolization tumor blush on the left and post-embolization disappearance of tumor blush on the right

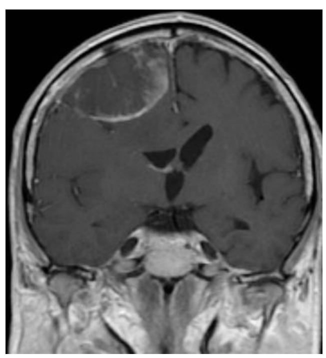

Fig 12: showing MRI brain coronal cut with Post-embolization central necrosis

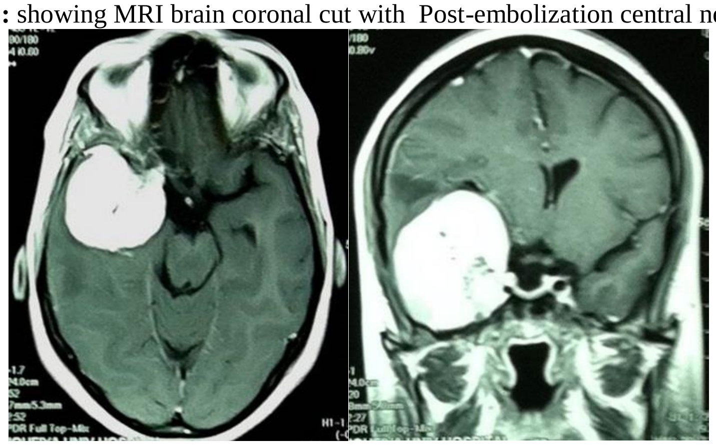

Fig 13: MRI brain axial (lef) and coronal (right)cuts showing pre-embolized right medial sphenoid ridge meningioma

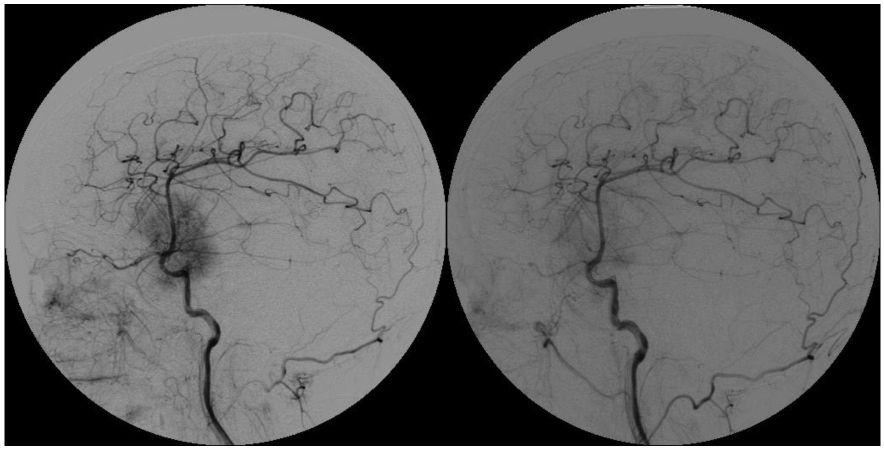

Fig 14: Showing angiographic pictures with the tumor blush (left) and near total disappearance of tumor blush post-embolization

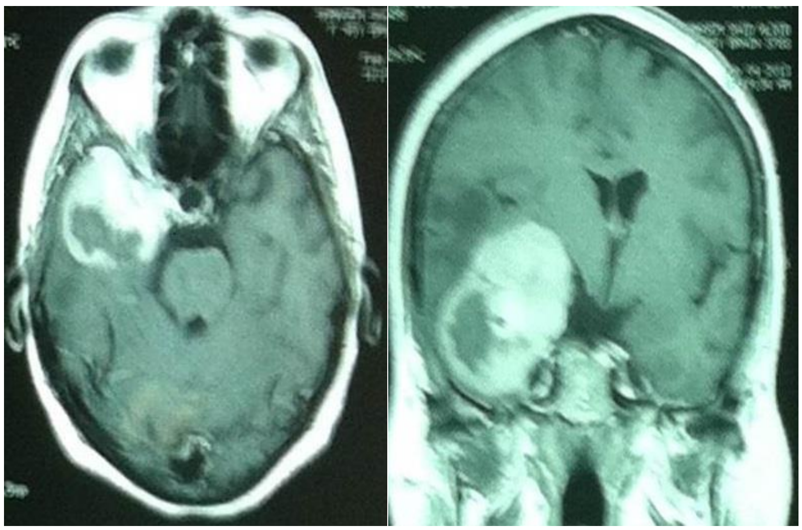

Fig 15: MRI brain axial (lef) and coronal (righ)cuts showing post-embolization central necrosis.

Fig 16: Postoperative CT brain axial cut showing near total surgical removal of preoperative embolized right sphenoid meningioma**.**

Discussion

Although early described in 1970s, preoperative trans-arterial embolization of intracranial meningiomas has generally been reserved for some lesions. With significant advances in endovascular procedures over the last decade, however, preoperative embolization has become possible for a wider variety of meningiomas[11]. Techniques that devascularize intracranial meningiomas leading to their softening are becoming increasingly important as a therapeutic option for treating such tumors. Although controversial, preoperative trans-arterial embolization of intracranial meningiomas has been shown to be efficacious in meningioma surgical resection.[12]

A study matched 33 embolized and 193 non-embolized meningiomas to compare both groups for intraoperative blood loss, duration of surgery and complications. Embolization was revealed to be useful since the estimated intraoperative blood loss was significantly less than usual (533 ml versus 836ml), duration of surgery was shorter (305.8 minutes versus 337.5 minutes) and duration of hospital stay was shorter (10.6 days versus 15.0 days). There were only ten minor complications in embolized group. [13] The results of preoperative embolization of intracranial meningiomas with fibrin glue in 80 patients with intracranial meningioma have been reported, in 65 patients the tumor was supratentorially, and in 15 it was located infratentorially. The outcome of preoperative embolization on the surgical techniques was reported that preoperative embolization with fibrin glue expands the spectrum of intracranial meningiomas that can be operated upon safely; intraoperative blood loss and operating time were reduced.[14]

A retrospective study on patients underwent intracranial meningioma resection at their institution (from March 2001 to December 2012). Comparisons were made between embolized and non-embolized patients, including patient and tumor criterias, embolization techniques, intraoperative blood loss, complications, and extent of surgical resection. Preoperatively, 224 patients were referred for preoperative embolization, of which 177 received embolization, they reported that preoperative embolization is a safe option for selected meningiomas. [15] A study compared a group of 14 patients with meningiomas that embolized with PVA particles (150 to 300 microns), with a group of 20 patients using smaller (50 to 150 microns) particles. The patients were radiologically evaluated by CT, MRI, and MRS and of their tumors, with a conclusion that embolization with (50 to 150 microns) microparticles improved the surgical treatment of intracranial meningiomas, as compared to larger particles embolization. They suggested using this technique in definitive embolization in patients who are not candidates for surgery[16]. Small particles can penetrate deep into the vasculature of meningioma, while particles of larger sizes produced proximal occlusion of feeding arteries. This proximal vascular occlusion results in clot formation which, over time, may be recanalized and so embolization is less efficient.[17] In our study marked decrease of intraoperative blood loss was noted with a mean of 300ml blood loss and also duration of surgery was reduced with a range from 3 hours to 6 hours with a mean of 4.5 hours. In our study we used polyvinyl alcohol "PVA particles" and not fibrin glue.[21]

we used more than one concentration. PVA particles "150 -250 microns "are the main. It represents 75% of our study. We should pay great attention to different dangerous anastomosis at embolization site. We mean that smaller particles will be more dangerous. PVA particles "45 – 150" only used in 25% of our cases, and this coincides with this study.[16] Regarding the timing of surgery post-embolization, one study proved that the greatest degree of tumor softening at surgery was found between 7th and 9th day after embolization.[3] another study compared two groups of patients. In the first group 28 patients were operated within 24 hours from preoperative embolization, while in the second group meningioma was surgically resected later on (2-7 days). The authors found that intraoperative blood loss was significantly decreased in the delayed surgery group.[8]

Another study recommended surgical resection 1-5 days after embolization, while others advocate waiting for 1-2 weeks. With time, embolization-induced necrosis softens and shrinks the tumor, thereby facilitating surgical resection.[18] A study preferred to operate upon embolized meningiomas within 24 hours after trans-arterial embolization before revascularization avoiding problems due to tumor swelling in some cases.[19] This coincides with our study in which 75% of our cases operated 24 hours post embolization and one case (5%) was operated 5 days post-embolization and the three steps of meningioma surgical resection, devascularization, debulking and dissection, were facilitated with tumor softening that leads to easy debulking and easy dissection of tumor capsule. Others reported in their study on 185 consecutive cases underwent microspheres embolization, 12 of them (7%) had complications related to the procedure, 6 of them had ischemia and the other 6 had hemorrhage. They concluded that the individual risk to-benefit ratio of preoperative embolization should be considered.[20] cranial nerve deficits in 2 cases out of 80 patients had preoperative embolization have been reported, temporary in one case and permanent in the other.[21] others reported no permanent neurological complications in 11 patients had preoperative embolization.[22] only 10% of our cases had minor complications. It was a post-procedure complication (transient localized small femoral hematoma). Only one case had a post-operative surgical site skin necrosis which healed within 3 weeks by frequent dressings.

Conclusion

We found that preoperative trans-arterial embolization of highly vascular intracranial meningioma using more than one concentration of PVA particles, is a safe technique and an ideal adjuvant before surgical resection of such lesions, and we recommend surgical resection to be done within 48 post-embolization as it made the surgical resection easier, faster with less intraoperative blood loss.

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