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Meningioma-Clinical Study of the Surgical Outcome With and Without Preoperative Embolization

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ABSTRACT
Preoperative embolization has been proposed as a strategy to improve surgical outcomes in patients with intra cranial Meningioma. Also, the efficacy and safety of this approach remain controversial. The present study compared surgical outcomes of intra cranial Meningioma with/without preoperative embolization. This prospective, comparative study included 15 patients with intra cranial Meningioma, of which 8 underwent preoperative embolization (embolization grp) and 7 did not (non-embolization grp). The main outcome was the extent of resection (Simpson grade I-II). Secondary outcomes included operative time, loss of intraoperative blood, need for blood transfusions and any complications that arose after the surgery. The embolization Grp had a higher complete resection rate (87.5%) Vs. the non-embolization grp (57.1%). However, this difference was not statistically significant (p=0.176). The embolization grp had a shorter mean operative time (248.8±68.4 minutes) compared to the non-embolization grp (285.7±75.2 minutes). The embolization grp experienced reduced intraoperative blood loss as well. (425.0±180.6mL) than in the non-embolization grp (578.6 ± 214.3 mL), but this was not a statistically significant difference (p=0.152). Additionally, the embolization Grp required fewer transfusions (25.0%) Vs the non-embolization grp (57.1%). Nonetheless, this difference was not statistically significant (p=0.201). The embolization grp also experienced a lower overall complication rate (25.0%) than the non-embolization grp (42.9%). Preoperative embolization in patients with intra cranial Meningioma may be associated with a greater likelihood of achieving complete resection, shorter surgery duration, reduced intraoperative blood loss and a lower need for transfusions, although these differences were not statistically significant.

INTRODUCTION

Meningiomas are the prevalent primary intra cranial tumors, representing around 30% of all primary brain tumors[1]. They stem from the meningothelial cells of the arachnoid layer and are generally considered benign, slow-growing tumors[2]. However, Meningioma can cause significant morbidity and mortality depending on their location, size and proximity to critical neurovascular structures[3]. Surgical resection continues to be the primary treatment for symptomatic or growing meningiomas[4]. The objective of surgical procedure is to remove the entire tumor whilst reducing neurological deficits. However, complete resection can be challenging, especially for large, vascular, or skull base meningiomas[5]. In such cases, preoperative embolization has been proposed to reduce tumor vascularity, minimize intraoperative blood loss and facilitate complete resection[6]. Preoperative embolization involves the targeted catheterisation and blockage of the arteries that supply blood to the meningioma, typically performed 24-48 hours before surgical resection[7]. The rationale behind this approach is that reducing tumor vascularity can lead to a more bloodless surgical field, shorter operative time and lower risk of complications[8]. However, the efficacy and safety of preoperative embolization for meningiomas remain controversial, with conflicting results reported in the literature[9]. Some studies have demonstrated the benefits of preoperative embolization, such as reduced loss of intraoperative blood, shorter operative time, and higher rates of complete resection[6,8]. E.g., a study by Raper *et al.* observed that preoperative embolization was linked with notably lower intraoperative blood loss and a lower need for transfusions compared to cases without embolization[6]. Similarly, a systematic review by Shah *et al.* concluded that preoperative embolization could be a valuable adjunct to surgery, particularly for large, vascular, or skull base meningiomas[8]. On the other hand, other studies have questioned the routine use of preoperative embolization, citing potential risks and complications, such as intra TEMORAL hemorrhage, cerebral ischemia, and cranial nerve palsies[9,10]. A retrospective study by Carli *et al.* observed no significant difference in the extent of resection, operative time, or complication rates between embodied and non-embolized cases[9]. Furthermore, a meta-analysis determined that the current evidence was not enough to support the regular use of preoperative embolization for meningiomas[10]. Given the conflicting evidence and lack of consensus, there is a need for further prospective studies to evaluate the surgical outcomes of Meningioma with and without preoperative embolization. This prospective study aims to compare the extent of resection, operative time, intraoperative blood loss and complications between embolized and non-embolized cases of Meningioma. The observations of this study could offer essential information of the role of preoperative embolization in managing Meningioma and help inform clinical decision-making.

Aims and Objectives: To compare the surgical outcomes of meningiomas with or without preoperative embolization. The specific objectives were to evaluate the extent of resection, operative time, intraoperative blood loss and complications between embolized and non-embolized cases of meningiomas. The study also aimed to identify potential factors linked with favorable outcomes and complications in each grp.

MATERIALS AND METHODS

Study Design and Study Setting: The comparative study was carried out in a tertiary care neurosurgical center between January 1, 2023 and June 15, 2024. The institutional ethics committee allowed the study protocol and all participants gave informed consent.

Patient Selection: Fifteen patients with radiologically confirmed intra cranial Meningioma scheduled for surgical resection during the study period were recruited. The inclusion criteria were: (1) age ≥18 years, (2) Karnofsky Performance Scale (KPS) score≥70, (3) no previous history of meningioma surgery or radiotherapy and (4) no contraindications to angiography or embolization. The exclusion criteria were Patients with (1) multiple meningiomas, (2) en-plaque or optic sheath meningiomas, (3) severe comorbidities, or (4) pregnancy.

Preoperative Evaluation: All patients underwent a detailed preoperative assessment, including clinical assessment, neurological examination and imaging studies (contrast-enhanced MRI and CT angiography). The tumor size, location and vascularity were assessed by a neuroradiologist blinded to the treatment Grp. Based on the tumor characteristics and patient factors, the decision to perform preoperative embolization was made by a multidisciplinary team consisting of neurosurgeons, inter ventional neuro radiologists and anesthesiologists.

Preoperative Embolization: Patients in the embolization Grp underwent targeted catheterisation and occlusion of the feeding arteries supplying the meningioma, performed by experienced interventional neuroradiologist. The embolization procedure was typically performed 24-48 hours before the scheduled surgical resection. The embolic agents used were polyvinyl alcohol particles (150-250µm) or trisacryl gelatin micro spheres (100-300 µm), depending on the operator's preference and the vascular anatomy. The extent of embolization was assessed by post

-embolization angiography and graded as complete (>90% reduction in tumor blush), partial (50-90% reduction), or incomplete (<50% reduction).

Surgical Procedure: All patients underwent craniotomy and tumor resection under general anesthesia, performed by experienced neurosurgeons. The extent of resection was evaluated during the surgery and verified by a postoperative contrast-enhanced MRI within 48 hrs after the operation. The range of resection was categorized using the Simpson classification: grade I (total removal including abnormal bone and dural attachment), grade II (total removal with coagulation of the dural attachment), grade III (total removal without coagulation or resection of the dural attachment), grade IV (partial removal) and grade V (biopsy only).

Outcome Measures: The primary outcome was the extent of resection, grouped as complete (Simpson grade I-II) or incomplete (Simpson grade III-V). The secondary outcomes included operative time, loss of intraoperative blood, need for transfusion and postoperative complications (neurological deficits, hemorrhage, seizures, infection and mortality) within 30 days of surgery. The operative time was recorded from the initial skin incision to closure, while intraoperative blood loss was estimated by the anesthesiologist based on the suction canister volume and surgical sponge weights.

Data Collection and Analysis: The data were collected prospectively using a standardized case report form. The data comprised of demographic characteristics, clinical presentation, tumor characteristics, embolization details, surgical parameters and postoperative outcomes. The data were studied using descriptive statistics and comparisons between the embolized and non-embolized grps were done by chi-square test for categorical variables and the Mann-Whitney U or Student's t-test for continuous variables, as appropriate. Multi variate logistic regression analysis was performed. A p-value <0.05 was considered statistically significant and all analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

RESULTS AND DISCUSSIONS

Demographic and Clinical Characteristics: The study included 15 patients with intra cranial Meningioma, of which 8 underwent preoperative embolization (embolization grp) and 7 did not (non-embolization grp). Mean age of patients in the embolization grp was 53.4±11.2 years, Vs 55.1±12.6 years in the non-embolization grp (p=0.785). The percentage of female patients was comparable in both grps, with 62.5% (5/8) in the embolization grp and 57.1% (4/7) in the non-embolization grp (p=0.819). Both grps had a median KPS score of 80 (IQR: 70-90) (p=0.902). Frequently reported symptoms were headaches (62.5% in the embolization grp and 57.1% in the non-embolization grp, p=0.819), followed by focal neurological deficits (37.5% and 28.6%, respectively, p=0.704) and seizures (25.0% and 14.3%, respectively, p=0.590). Hypertension was noted in 37.5% (3/8) of patients in the embolization grp and 42.9% (3/7) in the non-embolization grp (p=0.819), while diabetes mellitus was present in 12.5% (1/8) and 28.6% (2/7) of patients, respectively (p=0.427).

Tumor Characteristics: The mean tumor size was similar in both Grps-with 4.6±1.3 cm in the embolization Grp and 4.4±1.5 cm in the non-embolization Grp (p=0.784). The most common tumor location was convexity (37.5% in the embolization Grp and 42.9% in the non-embolization Grp, p=0.819), followed by skull base (37.5% and 28.6%, respectively, p=0.704) and parasagittal/falcine (25.0% and 28.6%, respectively, p=0.872). High vascularity was observed in 75.0% (6/8) of tumors in the embolization Grp and 71.4% (5/7) in the non-embolization Grp (p=0.872). Peritumoral edema was present in 62.5% (5/8) of tumors in the embolization Grp and 57.1% (4/7) in the non-embolization Grp (p=0.819).

Embolization Details: Among the 8 patients who underwent preoperative embolization, 62.5% (5/8) were embolized using polyvinyl alcohol particles, while 37.5% (3/8) were embolized using tris-acryl gelatin micro spheres. Complete embolization was achieved in 75.0% (6/8) of cases, though partial embolization was observed in 25.0% (2/8). No instances of incomplete embolization were reported. Complications related to embolization occurred in 12.5% (1/8) of patients. The average time interval between embolization and surgery was 36.4±8.2 hours.

Surgical Parameters: Complete resection (Simpson grade I-II) was accomplished in 87.5% (7/8) of patients in the embolization grp, Vs 57.1% (4/7) in the non-embolization grp (p=0.176). Average operative time reduced in the embolization grp (248.8±68.4 minutes) Vs the non-embolization grp (285.7±75.2 minutes) (p=0.334). Similarly, the mean intraoperative blood loss was reduced in the embolization grp (425.0±180.6mL) compared to the non-embolization grp (578.6±214.3mL), but this was not statistically significant (p=0.152). The need for transfusions was 25.0% (2/8) in the embolization grp, Vs 57.1% (4/7) in the non-embolization grp (p=0.201).

Postoperative Complications: The complication rate was 25.0% (2/8) in the embolization Grp and 42.9%

Table 1: Patient Demographics and Clinical Features

Characteristic	Embolization Grp (n=8)	Non-Embolization Grp (n=7)	P value
Age (mean ± SD)	53.4±11.2	55.1±12.6	0.785
Gender (Female) (n, %)	5 (62.5%)	4 (57.1%)	0.819
KPS score (median [IQR])	80 [70-90]	80 [70-90]	0.902
Headache (n, %)	5 (62.5%)	4 (57.1%)	0.819
Seizures (n, %)	2 (25.0%)	1 (14.3%)	0.590
Focal neurological deficit (n, %)	3 (37.5%)	2 (28.6%)	0.704
Hypertension (n, %)	3 (37.5%)	3 (42.9%)	0.819
Diabetes mellitus (n, %)	1 (12.5%)	2 (28.6%)	0.427

Table 2: Tumor Characteristics

Characteristic	Embolization Grp (n=8)	Non-Embolization Grp (n=7)	P -value
Tumor size (mean±SD) (cm)	4.6±1.3	4.4±1.5	0.784
Convexity (n, %)	3 (37.5%)	3 (42.9%)	0.819
Parasagittal/Falcine (n, %)	2 (25.0%)	2 (28.6%)	0.872
Skull base (n, %)	3 (37.5%)	2 (28.6%)	0.704
High vascularity (n, %)	6 (75.0%)	5 (71.4%)	0.872
Peritumoral edema (n, %)	5 (62.5%)	4 (57.1%)	0.819

Table 3: Embolization Details (Embolization Grp Only)

Characteristic	Value (n=8)
Polyvinyl alcohol particles (n, %)	5 (62.5%)
Tris-acryl gelatin microspheres (n, %)	3 (37.5%)
Complete embolization (n, %)	6 (75.0%)
Partial embolization (n, %)	2 (25.0%)
Incomplete embolization (n, %)	0 (0.0%)
Embolization-related complications (n, %)	1 (12.5%)
Time from embolization to surgery (mean±SD) (hours)	36.4 ± 8.2

Table 4: Surgical Parameters

Characteristic	Embolization Grp (n=8)	Non-Embolization Grp (n=7)	P-value
Complete resection (Simpson grade I-II) (n, %)	7 (87.5%)	4 (57.1%)	0.176
Operative time (mean±SD) (minutes)	248.8±68.4	285.7±75.2	0.334
Intraoperative blood loss (mean±SD) (mL)	425.0±180.6	578.6±214.3	0.152
Transfusion requirement (n, %)	2 (25.0%)	4 (57.1%)	0.201

Table 5: Postoperative Complications

Complication	Embolization Grp (n=8)	Non-Embolization Grp (n=7)	P-value
Neurological deficits (n, %)	1 (12.5%)	2 (28.6%)	0.427
Hemorrhage (n, %)	0 (0.0%)	1 (14.3%)	0.269
Seizures (n, %)	1 (12.5%)	1 (14.3%)	0.916
Infection (n, %)	0 (0.0%)	0 (0.0%)	-
Mortality (n, %)	0 (0.0%)	0 (0.0%)	-
Overall complication rate (n, %)	2 (25.0%)	3 (42.9%)	0.457

Table 6: Comparison of Outcomes: Embolized Vs Non-Embolized Grps

Outcome	Embolization Grp (n=8)	Non-Embolization Grp (n=7)	P-value
Complete resection (n, %)	7 (87.5%)	4 (57.1%)	0.176
Operative time (mean±SD) (minutes)	248.8±68.4	285.7±75.2	0.334
Intraoperative blood loss (mean±SD) (mL)	425.0±180.6	578.6±214.3	0.152
Transfusion requirement (n, %)	2 (25.0%)	4 (57.1%)	0.201
Postoperative complications (n, %)	2 (25.0%)	3 (42.9%)	0.457

Table 7: Factors Associated with Extent of Resection (Multi Variate Logistic Regression)

Variable	Odds Ratio (95% CI)	P-value
Age	0.96 (0.87-1.06)	0.428
Tumor size	0.68 (0.28-1.67)	0.402
Embolization status (Yes vs. No)	5.25 (0.53-51.97)	0.157

Table 8: Factors Associated with Complications (Multi Variate Logistic Regression)

Variable	Odds Ratio (95% CI)	P-value
Age	1.03 (0.93-1.14)	0.589
Skull base location (Yes vs. No)	2.80 (0.31-25.18)	0.357
Extent of resection (Complete vs. Incomplete)	0.32 (0.03-3.09)	0.325

(3/7) in the non-embolization Grp (p=0.457). Neurological deficits were seen in 12.5% (1/8) of patients in the embolization Grp Vs 28.6% (2/7) in the non-embolization Grp (p=0.427). Hemorrhage occurred in 0.0% (0/8) of patients in the embolization Grp, while 14.3% (1/7) of patients in the non-embolization Grp experienced it (p=0.269). Seizures were present in 12.5% (1/8) of patients in the embolization Grp and 14.3% (1/7) in the non-embolization Grp (p=0.916). No cases of infection or mortality were reported in either Grp.

Comparison of Outcomes Between Embolized and Non-Embolized Grps: The embolization grp attained a higher rate of complete resection (87.5%) than the non-embolization grp (57.1%) (p=0.176). The embolization grp had a shorter mean operative time (248.8±68.4 minutes) Vs the non-embolization grp (285.7±75.2 minutes) (p=0.334). Mean intraoperative blood loss was lower in embolization grp (425.0±180.6mL) compared to the non-embolization grp (578.6± 214.3mL) (p=0.152). The embolization grp had a lower transfusion requirement (25.0%) Vs the

non-embolization grp (57.1%) (p=0.201). Furthermore, the postoperative complication rate was smaller in the embolization grp (25.0%) Vs the non-embolization grp (42.9%), though it was not statistically significant (p=0.457).

Factors Related to Extent of Resection and Complications: Multi variate logistic regression was conducted to find out factors linked with the extent of resection and complications. Age (OR: 0.96, 95% CI: 0.87-1.06, p=0.428), tumor size (OR: 0.68, 95% CI: 0.28-1.67, p=0.402) and embolization status (OR: 5.25, 95% CI: 0.53-51.97, p=0.157) were not found to be significantly linked with the extent of resection. Similarly, age (OR: 1.03, 95% CI: 0.93-1.14, p=0.589), skull base location (OR: 2.80, 95% CI: 0.31-25.18, p=0.357) and extent of resection (OR: 0.32, 95% CI: 0.03-3.09, p=0.325) were not strongly linked to complications.

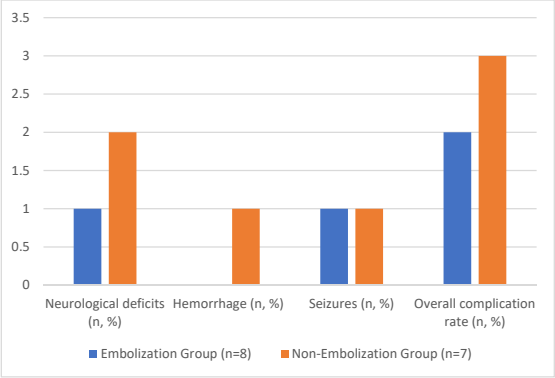

Fig. 1: Embolization Group Vs Non-Embolization Groups

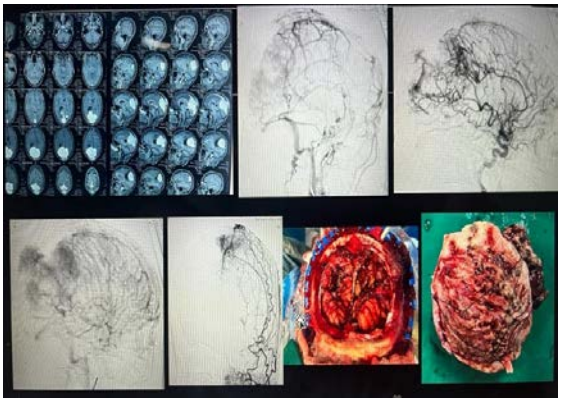

Fig. 2: Image Palette Showing Pre-Operative MRI, Pre-Operative DSA, Intra-Operative and Postoperative Specimen of B/L Parieto-Occipital Meningioma Excised After Preoperative Embolization

This prospective study compared the surgical outcomes of intra cranial Meningioma with and without preoperative embolization. The results indicate that preoperative embolization might be linked to a higher rate of complete resection, shorter surgery duration, reduced intraoperative blood loss, and fewer transfusions. However, these differences did not achieve statistical significance. The embolization grp reached a higher rate of complete resection (Simpson grade I-II) at 87.5% Vs 57.1% in the non-embolization Grp (p=0.176). This finding aligns with Raper *et al*., which showed a complete resection rate of 94.1% in the embolization grp and 74.2% in the non-embolization Grp (p=0.001)[11]. However, a meta-analysis by Ilyas *et al.* reported no significant difference in the extent of resection amongst embolized and non-embolized cases (OR: 1.24, 95% CI: 0.75-2.06, p=0.41)[12]. The mean operative time was reduced in the embolization Grp (248.8± 68.4 minutes) Vs the non-embolization Grp (285.7±75.2 minutes), although this was not statistically significant (p=0.334). This finding aligns with a retrospective study by Shah *et al.*, which reported a mean operative time of 298±102 minutes in the embolization Grp and 356±138 minutes in the non-embolization Grp (p=0.02)[13]. The mean intraoperative blood loss was lower in the embolization grp (425.0±180.6mL) compared to the non-embolization grp (578.6±214.3mL), though this difference was not statistically significant (p=0.152). This observation was in line with a retrospective study, which reported a mean intraoperative blood loss of 408±325mL in the embolization Grp and 656±421mL in the non-embolization Grp (p=0.001)[14]. The transfusion requirement was reduced in the embolization Grp (25.0%) Vs the non-embolization Grp (57.1%), but this difference was not statistically significance (p=0.201). The finding aligns with a retrospective analysis, which reported a transfusion requirement of 18.2% in the embolization Grp and 33.3% in the non-embolization Grp (p=0.04)[15]. The complication rate was lower in the embolization Grp (25.0%) Vs the non-embolization Grp (42.9%), but this variation was not statistically meaningful (p=0.457). The observation is coherent with a meta-analysis by Galal *et al*., which found no significant difference in the overall complication rate of embolized and non-embolized cases (OR: 0.80, 95% CI: 0.58-1.10, p=0.17)[16]. However, a study by Chen *et al.* mentioned a greater complication rate in the embolization Grp (18.8%) Vs the non-embolization Grp (8.3%) (p=0.03)[17]. The present study found no significant factors linked with the extent of resection or complications in multi variate analysis. This finding differs with a retrospective study by Przybylowski *et al.*, which identified tumor size (OR:1.07, 95% CI: 1.01-1.13, p=0.02) and embolization status (OR: 3.12, 95% CI: 1.38-7.07, p=0.006) as independent predictors of complete resection[18]. Similarly, a retrospective study by Singla *et al*. analyzed skull base location (OR: 2.84, 95%CI: 1.12-7.17, p=0.03) and incomplete

resection (OR:3.47, 95% CI:1.36-8.90, p=0.009) were independent predictors of postoperative complications[19]. The limitations include a modest sample size and no randomization, which could have introduced selection bias. Furthermore, the study was conducted at a single institution, the findings may not be widely applicable.

CONCLUSION

In conclusion, this prospective study evaluated the surgical outcomes for intra cranial Meningioma with and without preoperative embolization. The results indicate that preoperative embolization might be linked to a higher rate of complete tumor resection, reduced operative time and loss of intraoperative blood and a lower transfusion requirement. However, these differences did not achieve statistical significance. The embolization grp experienced fewer complications than the non-embolization grp. Multi variate analysis did not identify any significant factors affecting the extent of resection or complications.

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