The use of preoperative embolization before resection of meningiomas is widely practiced, but is also widely debated. Only a few controlled studies have been conducted to investigate the safety and efficacy of this procedure, and they have produced contradictory results. We performed a retrospective study comparing patients with and without preoperative embolization for intracranial meningiomas. We reviewed the records of 87 patients, 55 who received preoperative embolization and 32 who did not. The mean tumor size was 49.8 mm, range between 20-90 mm. In the embolization and non-embolization groups median blood loss was 650 ml and 700 ml, respectively (P=0.595) and mean surgical time was 382.5 min and 432 min, respectively (P=0.125). We found correlations between tumor size and embolization suggesting that larger tumors benefit from embolization whereas smaller tumors do not. The direction of correlation suggested that embolization was less correlated with reduction of blood loss and reduction of surgical time as tumor size decreased. There was no significant difference of the correlation based on the tumor location (convexity vs parasagittal). Only one adverse event (hemiplegia) was recorded; this did not provide enough data to draw conclusions about safety. We concluded that preoperative embolization is not efficacious for small meningiomas. This study is clinically relevant because it shows that there is a size of meningioma below which embolization is not efficacious for reducing blood loss and surgical time. Future studies should be carried out to more accurately define the cut-off value for tumor size to obtain the benefits of embolization.

The use of preoperative embolization of meningioma was first described in 1973 [1]. Subsequently, preoperative embolization of meningioma has been widely used; however, it has remained controversial. Using preoperative embolization can reduce the tumor mass and make the tumor softer and less bloody, which should permit easier operative manipulation and removal [2]. In theory, the result should be reduced operating time, less blood loss, and reduced risk of brain injury from manipulation of the brain [2].

In general, preoperative embolization is indicated for hypervascular tumors when a large amount of blood loss is predicted during surgery and/or when reduction in tumor size is desired to facilitate removal. It is also indicated when it is expected that the blood supply to the tumor will only be reached toward the end of surgery [2]. Embolization must be used with caution and is contraindicated when the artery feeding the tumor also feeds a critical part of the brain. Thus, preoperative embolization of meningioma always is associated with some risk.

Although preoperative embolization of meningioma has been widely used for many years there have been only a few studies that have evaluated...
the effectiveness of this approach [3-7]. Therefore, we performed a retrospective comparison study to assess the effects of preoperative embolization of meningioma on surgery. We included patients with parasagittal and convexity meningiomas who were treated at our center. These patients were included because parasagittal and convexity meningiomas usually have very obvious external carotid artery (EAC)/dural feeders making embolization feasible and relatively safe. No patients with skull base meningiomas were included because these tumors often have small dural and/or pial feeders which makes embolization difficult and risky. We focused our investigation on whether embolization reduces operative blood loss and surgical time, and whether it is worth the risk of complications. Our working hypothesis was that the benefit of preoperative embolization is only marginal for small meningiomas.

**MATERIALS AND METHODS**

**Patients and surgery**

We retrospectively studied the records of consecutive patients who underwent preoperative angiography and surgical intervention for parasagittal or convexity meningiomas at our institution between 2003 and 2007. A total of 87 patients were identified. Fifty-five patients received preoperative embolization and 32 patients underwent surgery without preoperative embolization. The following data were collected from each patient’s record: tumor size (maximal diameter); tumor vascularity with regard to dural branches from the ECA, pial branches from the internal carotid artery (ICA), and bilateral blood supply; surgical blood loss (ml); surgical time (min); surgical timing (interval between embolization and surgery); and post-embolization complications.

The treating physician determined the method of treatment for each patient (whether the patient underwent embolization was determined by the preference of the surgeon). Standard embolization procedures were used. Briefly, each patient was first evaluated by preoperative conventional angiography. If preoperative embolization was chosen, superselective embolization of ECA branches via coaxial microcatheters was performed. A 5-5.5 Fr guiding catheter was inserted into the ECA and a 2.5-1.9 Fr microcatheter was used for superselection of the feeding arteries. Arteries were embolized by using particulate embolizers (45-150 µm polyvinyl alcohol (PVA), >150 µm PVA, or 100-300 µm EmboGold™ Microspheres) or the liquid embolizer n-butyl cyanoacrylate (NBCA). Generally, if the more distal tip of the microcatheter was placed beyond the potentially dangerous arterial branch (i.e., the petrous branch of the middle meningeal artery), either a smaller size particle (45-150 µm PVA) or the liquid embolizer was used. Embolization was considered complete when obliteration of tumor stain and flow stasis were observed. Subsequent surgery was performed within 1-4 days and the tumor was grossly or totally resected.

**Statistical analysis**

Continuous data are expressed as mean with standard deviation (SD), or median with quartiles (Q1 and Q3). Categorical data are expressed as number (percent). A two-sample t-test was performed to compare the differences between patients who did and did not undergo preoperative embolization. One-way analysis of variance (ANOVA) was also performed to analyze the differences among embolizers. If data were far from normally distributed, non-parametric tests, the Mann-Whitney U test, or the Kruskal-Wallis test were used for the comparison. All the statistical assessments were considered under the level of significance 0.05. Statistical analyses were performed using SPSS 15.0 statistics software (SPSS Inc., Chicago, IL, USA).

**RESULTS**

The demographic and clinical characteristics of the patients are shown in Table 1. The total sample was biased by having more patients who underwent preoperative embolization (55 of 87), and by having fewer men (n = 24) than women (n = 63). Nevertheless, there were no significant differences in the distribution of demographic variables between the embolization and non-embolization groups. Also, there was no significant difference in the mean tumor size between the embolization group (49.2 mm) and non-embolization group (51.0 mm). Regarding tumor vascularity, all of the tumors were hypervascular with dural blood supplies. A few of the tumors also had a secondary pial blood supply (there were 16 (29.1%) in embolization group, and 10 (31.3%) in non-embolization group). The pial blood supplies were not embolized. No examples of obvious arteriovenous shunting were observed.
Median blood loss was less in the embolization group (650.0 vs 700 ml) and median surgical time was shorter in the embolization group (382.5 vs 432 min); however, the differences between the groups were not significant.

Table 2 summarizes the correlation among clinical characteristics (tumor size, blood loss, and surgical time) for all patients, the embolization group, and the non-embolization group. (N=87)
Preoperative embolization of meningiomas

Blood loss was significantly positively correlated with tumor size in all patients (P=0.031), the embolization group (P=0.001), and the non-embolization group (P=0.006). Surgical time was significantly positively correlated with tumor size in the non-embolization group (P=0.029). Surgical time was also significantly positively correlated with blood loss for all patients (P=0.005) and the non-embolization group (P=0.003).

Because a variety of embolization agents were used, we compared three measures (tumor sizes; surgical time; and blood loss) between groups based on type of embolization (Table 3). Both large and small PVA particles were combined into a single group. No significant differences were found resulting from the type of embolizer used.

We also compared surgical time and blood loss between groups based on tumor size (1 cm to ≤ 2 cm, 2 cm to ≤ 3 cm, 3 cm to ≤ 4 cm, 4 cm to ≤ 5 cm, ≥ 5 cm) and location (parasagittal vs convexity) (Table 4). The convexity group has less mean blood loss and shorter mean surgical time than the parasagittal group.

Statistical analysis could not be performed for post-embolization complications because only one patient with a complication was reported. The patient, a 49-year-old woman, had a right parasagittal tumor (4 cm) with bilateral MMA vascularization (Fig. 1). After the right MMA was embolized with 45-150 μm PVA (Figs. 1, 2), the patient developed a deteriorated neurological deficit (left hemiplegia). Computed tomography showed increased peritumoral hypodensity, which was presumably due to inadvertent embolization with ischemic damage or post-embolized tumor swelling with increased mass effect compressing the adjacent motor area (Fig. 2). The hemiplegia partially resolved following intravenous steroid therapy and emergent surgical tumor resection.

**DISCUSSION**

In our study, all three analyses of correlations (blood loss vs. surgical time, surgical time vs. tumor size, and tumor size vs. blood loss) showed that the correlation coefficients for the non-embolization
Figure 1. A 49-year-old woman who experienced hemiplegia following preoperative embolization. Post-contrast MRI showed a strongly enhanced, extra-axial mass in the right frontal parasagittal area (a, b). Digital subtraction angiography demonstrated hypervascularity, with feeders from the bilateral middle meningeal artery (c, d). The tumor blood supply was successfully eliminated (e, f).

Figure 2. No peritumoral brain edema was seen on pre-embolization MRI/FLAIR a. After total arterial embolization with 45-150 μm PVA particles, the follow-up CT showed abnormal hypodensity of the brain parenchyma around the embolized tumor b, presumably due to increased mass effect upon and/or inadvertent embolization of the brain.
group were greater than for the embolization group. The correlation coefficients for the non-embolization group were all statistically significant, whereas all but one (tumor size vs. blood loss) were not statistically significant for the embolization group. Thus, this suggests that embolization has a trend toward having an effect on surgical time and blood loss as the tumor size increases. This conclusion agrees with simple logic, and also agrees with the findings of Dean et al that large meningioma tumors benefit from preoperative embolization [5]. The clinical implication of this finding is that small meningiomas should not be embolized preoperatively but large meningiomas should. The fact that there was some significant correlation between tumor size and blood loss in the embolization group implies that the cut-off size between the large tumors which would benefit from embolization and the small tumors which would not benefit from embolization exists within the range of tumor sizes in our data set. For subgroup analysis based on tumor size (Table 4), there is a paradoxical decrease of average blood loss in the nonembolized subgroups with 30mm< tumor ≤40 mm and 40mm< tumor ≤50 mm. This unexpected result may be explained by small case number (only four and five cases in these nonembolized subgroups, respectively) with inherent bias. In the future, larger data sets could be used to calculate an estimation of a cut-off size for meningioma tumors which could then be used as guidance for proceeding with preoperative embolization. Using a size cut-off standard may improve the accuracy of future studies of preoperative embolization of meningiomas.

Regarding the safety of embolization, we were not able to statistically test whether any benefit was worth the risk of potential complications. However, we were able to draw some conclusions. First, the efficacy data presented in Table 2 suggests that there was no benefit derived from preoperative embolization of the smaller-sized tumors in our sample. Thus, for small tumors, there is no justification in risking the safety of the patient with preoperative embolization. Second, since we only found one reported complication in our data set we did not have enough data to perform any analysis. A previous study of complications during preoperative embolization of intracranial meningiomas found that 6 of 185 patients (3.2%) had adverse ischemic events (including hemiparesis which we found in this study) and 6 of 185 patients (3.2%) had adverse hemorrhagic events [8]. This suggests that the expected rate of adverse events is probably lower than the power of our study could meaningfully detect. Because we did not include skull base meningiomas in our study the complication rate may be lower than in studies that included these tumors.

Our findings on the efficacy of preoperative embolization differed somewhat from those of previous studies comparing embolization and non-embolization groups. Macpherson, who used a personal series to retrospectively compare patients with meningioma who did or did not undergo embolization, found that there was less bleeding in the embolization group than in the non-embolization group (25% vs. 62%); however, this finding was based on subjective assessment by the surgeons and no statistical analysis was performed to determine whether the difference between the groups was statistically significant [4]. Also, there may have been selection bias because the non-embolization group consisted of patients for whom embolization was not possible because of technical reasons or there was little blood supply from the EAC (0 to <40%). Dean et al also retrospectively compared an embolization and non-embolization group [5]. The patients had large meningiomas (mean, 5.7 cm). It was found that the embolization group had significantly less estimated blood loss and number of transfusions. In a study by Lee et al, the patients were stratified on the basis of tumor location [6]. It was found that embolization compared with non-embolization reduced blood loss and shortened surgical time for patients with parasagittal and sphenoid wing meningiomas but provided no benefits for patients with convexity meningiomas. In contrast, there was no significant difference of the correlation based on the tumor location (convexity vs parasagittal) in our study (Table 4). A prospective study by Bendszus et al included 60 patients with intracranial meningioma who were equally divided into embolization and non-embolization groups [7]. A comparison of the two groups showed that embolization did not provide any benefit in reducing blood loss. However, subgroup analysis showed that those embolized patients who had >90% of the tumor devascularized did have significantly less bleeding than the non-embolized patients. The authors concluded that only complete embolization reduces blood loss. Unlike in our study in which all the patients were treated at one center, the patients who were embolized in the study by Bendszus et al were treated at a different center than those that were not embolized which could have affected the results.

The studies of Dean et al and Bendszus et al
used different embolizing agents than we did [5, 7], but within the range of embolizers used in our study we did not find any correlation with the outcome measures (Table 3). We did not consider the cost of embolization as an outcome. Large meningiomas typically more tightly adhere to adjacent structures (presenting a difficult surgical plane) and have more feeder arteries, including pial and contralateral branches than the smaller tumors in our study. These factors should be addressed in future studies of large meningeal tumors.

Our findings support our hypothesis that the benefit of preoperative embolization is only marginal for small tumors. Although with our data set we did not define quantitatively what a small tumor is, we suggest that such a definition is reasonable for the tumors in our study. Our data also did not allow us to assess risks versus benefits. There are theoretical benefits to preoperative embolization that our study did not address. Prevention of tumor recurrence at the site of dural attachment may be an important benefit of preoperative embolization [1]. Future prospective studies of preoperative embolization of intracranial meningiomas should address this possibility. Embolization alone can have beneficial effects in the management of meningioma, and is sometimes performed when surgery is not possible [9]. Future studies may reveal other beneficial effects of preoperative embolization.

Our study had a number of limitations. Because it was a retrospective study selection bias may have occurred. Also, there were many other factors in this complex procedure that were not considered such as whether the tumors were proximally or intratumorally embolized, possible variations among the surgeons involved in the interventions, and the time between embolization and surgery.

In conclusion, for small meningiomas we do not recommend preoperative embolization based on safety and efficacy findings, and for large tumors we believe further research is needed. The evidence from our study and from that of the study by Dean et al [5] suggests that there is significant efficacy for large tumors, but larger data sets that include only tumors over a certain cut-off size that needs to be determined will be required to assess the safety of preoperative embolization.

**REFERENCES**

儘管臨床上常於腦膜瘤切除前進行術前栓塞，但這亦飽受爭議。僅有些許研究分析此步驟的安全性與療效，而分析出的結果也是相當不一致。本研究進行回顧性分析，比較腦膜瘤病患接受術前栓塞與未接受術前栓塞的差異性。共分析八十七名病患資料（平均腫瘤大小 49.8mm，範圍 20-90mm 之間），其中五十五名接受術前栓塞，另外三十二名病患則否。術前栓塞與未接受術前栓塞兩組之平均失血量（中位數）各別為 650ml 與 700ml（p=0.595），兩組之平均手術時間各別為 382 min 與 432 min（p=0.125）。我們發現腫瘤大小與栓塞之間具有相關性，較大的腫瘤進行栓塞可有較好的效益，而較小的腫瘤則否。此相關性結果表示當腫瘤較小時，栓塞與失血量以及手術時間的減少的相關性較低。此相關性不因不同腫瘤位置而有統計學上有意義之差異。本研究僅記錄到一件副作用（半身不遂），不足以提供足夠的數據對於安全性下結論。小結以上，術前栓塞對於較大的腦膜瘤有較高的臨床效益。此研究的臨床重要性在於本實驗結果指出當腦膜瘤的大小小於一定程度時，栓塞對於降低失血量及手術時間是沒有顯著效益的。需要進一步的研究準確定義腫瘤大小的截止值與栓塞效益之間的關係。