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Endoscopic Endonasal Approach Limitations and Evolutions for Tuberculum Sellae Meningiomas: Data from Single-Center Experience of Sixty Patients

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ABSTRACT

AIM: New detailed scoring systems have been introduced for surgical technique selection. These are greatly helpful and detailed but complex classifications. Despite developments and advances in the endoscopic technique, there are still debates on which of the methods used in surgery in tuberculum sellae meningiomas. Limitations of approaches are not clearly defined.

MATERIAL and METHODS: We reviewed the medical data, radiological images, and surgical videos of the patients with pathologically confirmed meningiomas originating from the tuberculum sellae and they were operated via endoscopic endonasal approach between August 1997 and December 2020. We used our endoscopic classification based on infrachiasmatic corridor. In this classification, tumors were divided into those within the infrachiasmatic corridor and proximity of the optic nerve, internal carotid artery, and anterior artery complex and those outside the infrachiasmatic corridor.

RESULTS: Gross total resection was achieved in 45/60 (75%) patients. We found that tumor consistency was statistically significant on resection rates. Simultaneously, tumor median diameters on the anteroposterior (≤21.15 mm), transverse (≤19.75 mm), and superoinferior (≤15 mm) axes were statistically significant on resection rates.

CONCLUSION: In summary, the most important factor in selecting the surgical technique is the tumor size. Infrachiasmatic corridor boundaries are the limitations of endoscopic approach. These limitations can change based on surgeon's experience. Also, tumor consistency is a factor that affecting degree of tumor resection rates.

KEYWORDS: Endoscopic, Tuberculum sellae, Meningioma, Infrachiasmatic, Classification

ABBREVIATIONS: TS: Tuberculum sellae, **PS:** Planum sphenoidale, **EEA:** Endoscopic endonasal approach, **CSF:** Cerebrospinal fluid, **MR:** Magnetic resonance, **EOR:** Extent of resection, **STR:** Subtotal resection, **NTR:** Near total resection, **GTR:** Gross total resection, **MRI:** Magnetic resonance imaging, **ICA:** Internal carotid artery, **DI:** Diabetes insipidus

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INTRODUCTION

Tuberculum sellae (TS) meningiomas constitute 5%–10% of all intracranial meningiomas (1,7,31). Patients with TS meningiomas often present with progressive vision disturbance because of the adjacent relationship between TS and optic apparatus. The optimal goal of surgery is complete removal of the tumor for preservation or improvement in vision.

TS meningiomas have been customarily evaluated among suprasellar meningiomas (15). They spread to the posterior infrachiasmatic area. Moreover, they can spread into the sella. TS meningiomas lift the optic apparatus up, while planum sphenoidale (PS) meningiomas push the optic apparatus down and backward (22). Due to the proximity of TS meningiomas, this localization feature increases the necessity of dissecting vessels, especially the superior hypophyseal artery, which supplies the inferior aspect of the optic apparatus (12).

For a few decades, transcranial approaches have been the standard methods in surgery of TS meningiomas (7,11,13,20,21,23). There have been developments in the endoscopic endonasal approach (EEA) for anterior skull base meningiomas in the past two decades (8–10,27). The endoscopic technique has well-known advantages and disadvantages (5,6,12).

New detailed scoring systems have been introduced for surgical technique selection (16,29). We previously established a classification based on volume (6). Despite these developments and advances in the endoscopic technique, there are still debates on which of the methods used in surgery is superior (19). Both techniques have their own advantages and disadvantages. Consistency and size of the tumor, presence of pial invasion, and invasion of neurovascular structures have an effect on resection rates.

The main problems in endoscopic technique are high sinonasal morbidity rate and cerebrospinal fluid (CSF) leakage due to the surgical route (2). However, the development of an endoscopic technique and effect of high surgical experience also reduce these morbidity rates.

This study analyzed our evolving surgical experience with TS meningiomas operated via EEA, with the aim of determining the limits of this technique. However, another aim is to show the effect of tumor consistency on resection rates and present that sinonasal morbidity rate decreases over time in endoscopic technique.

MATERIAL and METHODS

Study Design and Participants

With approval from the institutional review board, the authors retrospectively reviewed the medical data, radiological images, and surgical videos. This study was conducted in the Pituitary Research Center and Neurosurgery Department of Kocaeli University Faculty of Medicine. Patients with pathologically confirmed meningiomas originating from the TS were operated via EEA between August 1997 and December 2020 and aged ≥ 18 years were included in the study. Patients who underwent transcranial surgery, were lost to follow-up, and had tumors located in other anterior skull base meningiomas (e.g., PS and olfactory groove meningiomas) were excluded from the study.

Studied Variables

Demographic variables included age, sex, and follow-up duration. Clinical variables, including presenting symptoms, preoperative and postoperative visual deficits, resection rates, tumor recurrence, and postoperative complications, were collected.

Outcome variables included visual function, extent of resection (EOR), tumor consistency in relation to EOR, and recurrence. The EOR was calculated by comparing postoperative MR images with preoperative ones. Moreover, the EOR was classified radiologically as subtotal resection (STR;<95%), near total resection (NTR; 95%–99%), and gross total resection (GTR), which was deemed as the absence of residual tumor.

Magnetic Resonance Imaging (MRI)

MRI studies were performed via a 1,5T or 3T scanner (Achieve Intera Release, Philips, Eindhoven, the Netherlands) on preoperative and postoperative (postop first day and postop third month and one year) periods. MRI sequences included precontrast and postcontrast T1-weighted images in the sagittal and coronal planes; T2-weighted images; and dynamic, contrast-enhanced, T1-weighted images in the coronal plane and 3D volumetric neuronavigation studies. An independent radiologist blinded to the patient data reviewed the MRI scans.

Tumor was measured on three axes: anteroposterior, superoinferior, and transverse. Measurement was based on the thickest part of the tumor in each axis.

Surgical Technique

As previously described, an extended approach was performed in all cases (4,5,8,9,14). Herein, some basic steps and changes in surgery were explained. Our first endoscopic case for tuberculum sella meningiomas was in 2007. We divided our cases into two groups: first group underwent surgery between 2007 and 2013 and second group underwent surgery between 2013 and 2020. The reason for the formation of these two groups is our changing surgical strategies.

In all cases, surgical approaches were performed through both nostrils. In the first group, the middle turbinate of appropriate nasion (mostly right nasion) was totally or partially removed. However, a wide resection was made in the posterior nasal septum. After removing the posterior nasal septum, the mucosa of the nasal septum was prepared to form a flap for closure. The contralateral middle turbinate was pushed laterally, providing wider access. In the second group, both middle turbinates were not removed. For wider access, both of them were only pushed laterally. A more minimal resection was performed in the posterior nasal septum compared to the first group.

Wider anterior sphenoidotomy has been performed to reach the suprasellar area. The upper half of the sella and the bone of the TS, which was thinned with a diamond drill, were removed. The lateral limits of the opening were the protuberances of the optic nerves.

The anterior intercavernous sinus should be controlled and coagulated before the dura is opened. Dural incision was performed horizontally. After dural opening, two different methods were followed, depending on the consistency of the tumor. While tumors with soft content were evacuated more easily with an aspirator (Video 1), an ultrasonic aspirator was used to decrease the volume in tumors with firm and calcified contents. Thus, while removing the tumor, damage to surrounding structures was prevented. Tumor removal has been performed by gentle and careful dissection from the chiasm, superior hypophyseal arteries, and stalk. The anterior communicating artery complex was located above the chiasm (Figure 1). However, total removal of firm and fibrotic tumors is difficult. In this type of tumors, after internal debulking is attempted, if the tumor volume is appropriate, extracapsular dissection can be performed to completely remove the tumor (Video 2). The surgical cavity was inspected with an endoscope, after tumor removal. In firm tumors, extracapsular dissection is often not possible due to adhesions to the surrounding tissues. Moreover, this reduces GTR rates.

Tumor dissections were performed in two different surgical techniques. The first is the anterior extracapsular dissection technique. After internal debulking in tumors extending up to half of the tuberculum sella anteriorly, the tumor capsule is dissected firstly from the frontal base, anterior communicating artery, optic chiasm, and supraclinoid arteries (Video 3). The second technique is the posterior extracapsular method, which we commonly use. In this method, after internal debulking, the tumor capsule is separated firstly with the diaphragma sellae, supraclinoid arteries, infundibulum, and optic chiasm.

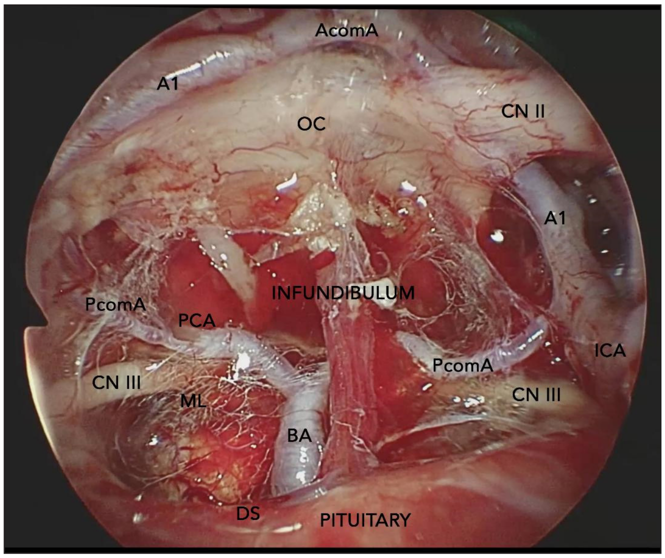

Figure 1: Endoscopic view of infrachiasmatic corridor. **OC:** Optic chiasm, **A1:** Anterior cerebral artery A1 segment, **AcomA:** Anterior communicating artery, **PcomA:** Posterior communicating artery, **CN:** Cranial nerve, **ML:** Mesencephalic leaf, **BA:** Basilar artery, **DS:** Diaphragma sellae, **ICA:** Internal carotid artery.

In the first group, a multilayer technique has been used for dural closure to avoid postoperative CSF fistula using fat graft, bone graft, duragen, fascia lata, and nasoseptal flap with its pedicle. Surgical glues have been used to fill the sphenoid cavity and hold the repair in place. Lumbar drainage was not routinely performed in all cases. In the second group, differently, no bone graft was used. Moreover, lumbar drainage was performed in all cases.

Limits of Endoscopic Technique

Although there are many new classifications related to TS meningiomas, these new classifications also have computational difficulties (16,29). We used our endoscopic classification based on infrachiasmatic corridor as determined in our previous study (6). In this classification, tumors were divided into [1] those within the infrachiasmatic corridor and proximity of the optic nerve, internal carotid artery (ICA), and anterior artery complex and [2] those outside the infrachiasmatic corridor, which surround the optic nerve and carotid arteries (Figure 2). These are the tumors within the infrachiasmatic corridor that may touch the optic nerve, optic chiasm, and supraclinoid carotid arteries but not touch the anterior communicating artery complex (Figure 3) and tumors outside the infrachiasmatic corridor that are ≥ 180° around the anterior artery complex or expand lateral to the optic nerve (Figure 4). They were basically divided into those within the infrachiasmatic corridor and those extending outside the corridor. Since the infrachiasmatic corridor provides a safe way for the endoscopic technique, the endoscopic method is the first choice for tumors within the infrachiasmatic corridor. If the tumor extends out of the infrachiasmatic corridor, it is more appropriate to perform the pure endoscopic technique in departments with high surgical experience.

Optic canal invasions were seen in two ways as inferomedial and superior extensions (Figure 5). In cases with optic canal invasion where there is only inferomedial extension, it is possible to see the optic nerve as crushed (Figure 6).

Statistical Analysis

All statistical analyses were performed using IBM SPSS for Windows version 18.0 (SPSS, Chicago, IL, USA). Kolmogorov–Smirnov's and Shapiro–Wilk's tests were used to assess the assumption of normality. Continuous variables were presented depending on a normal distribution with either mean ± standard deviation or (in case of no normal distribution) median (25^{th}–75^{th} percentile). Categorical variables were summarized as counts (percentages). The association between two categorical variables was examined using the chi-square test. All statistical analyses were conducted with 5% significance, and a two-sided p-value < 0.05 was considered statistically significant.

RESULTS

Demographic and Clinical Data

We identified 60 patients (49 women and 11 men) who under-

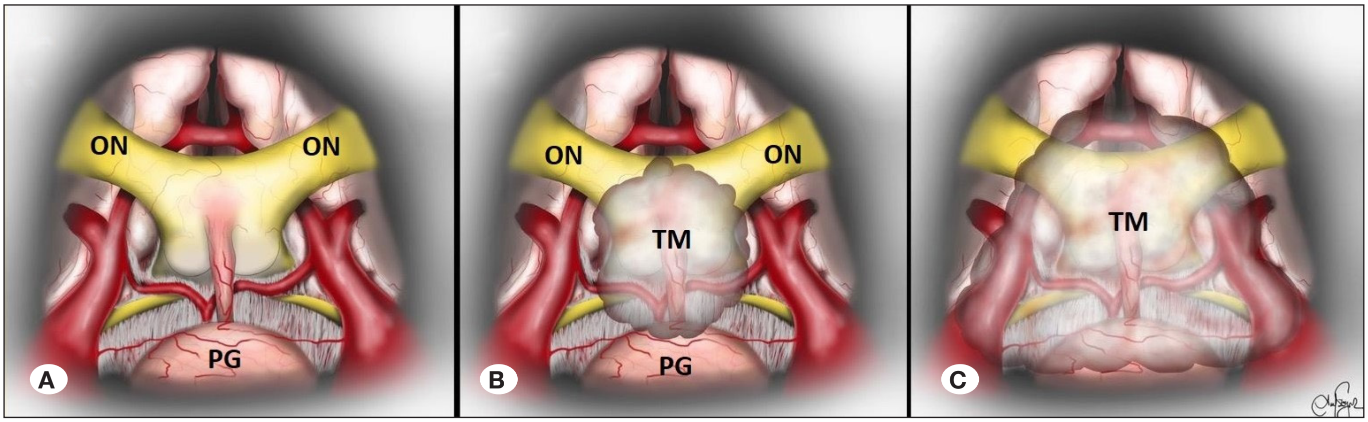

Figure 2: Tumor extension. **A)** There is no tumor, Grade 0. **B)** Tumors within the infrachiasmatic corridor that may touch the optic nerve, optic chiasm, and supraclinoid carotid arteries but not touch the anterior communicating artery complex. **C)** Tumors outside the infrachiasmatic corridor that are ≥ 180° around the anterior artery complex or expand lateral to the optic nerve. **TM:** Tumor, **ON:** Optic nerve, **PG:** Pituitary gland.

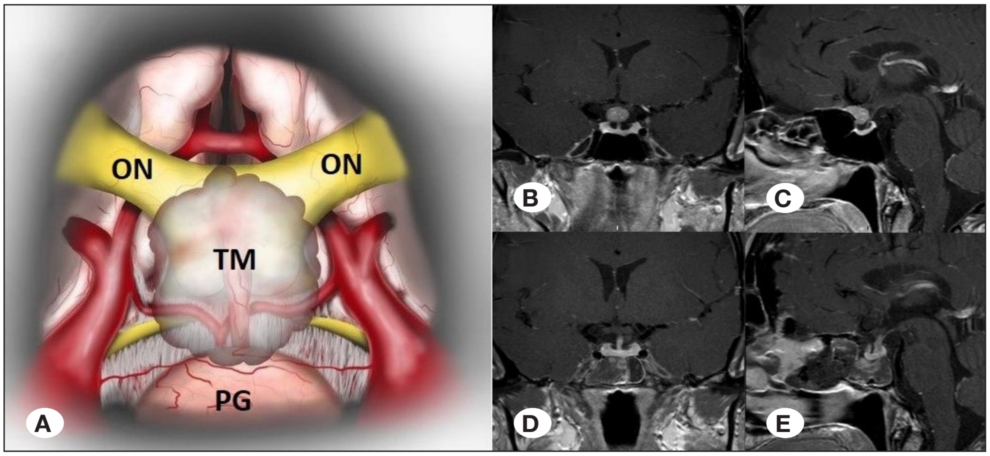

Figure 3: Tumor within the infrachiasmatic corridor and MR images. **A)** Tumor within the infrachiasmatic corridor. **B)** Preoperative coronal T1-contrast-enhanced MR image of patient with tumor within the infrachiasmatic corridor. **C)** Preoperative sagittal T1-contrast-enhanced MR image of patient with tumor within the infrachiasmatic corridor. **D)** Postoperative coronal T1-contrast-enhanced MR image of same patient **E)** Postoperative sagittal T1-contrast-enhanced MR image of same patient. **TM:** tumor, **ON:** Optic nerve, **PG:** Pituitary gland.

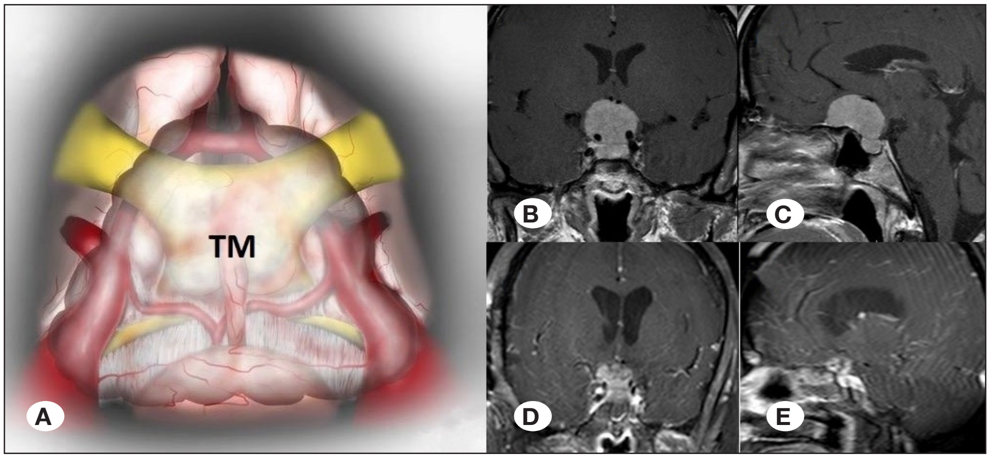

Figure 4: Tumor outside the infrachiasmatic corridor and MR images. **A)** Tumor outside the infrachiasmatic corridor. **B)** Preoperative coronal T1-contrast-enhanced MR image of a patient with tumor which outside the infrachiasmatic corridor. **C)** Preoperative sagittal T1-contrast-enhanced MR image of a patient with tumor which outside the infrachiasmatic corridor. **D)** Postoperative coronal T1-contrast-enhanced MR image of same patient. Residual tumor tissue is seen above the right carotid artery. **E)** Postoperative sagittal T1-contrast-enhanced MR image of same patient. **TM:** Tumor.

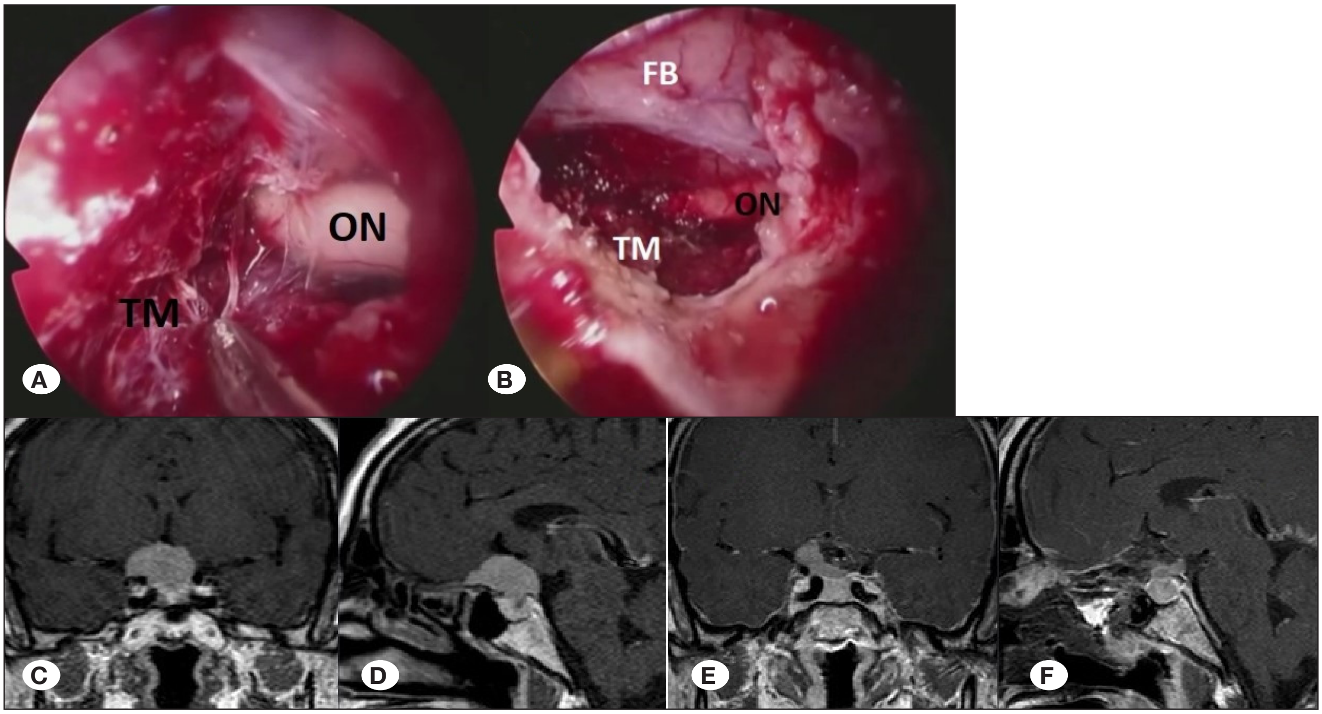

Figure 5: A) Intraoperative view of adherent and firm tumor **B)** Intraoperative view of adherent tumor before closure. Right optic canal invasion superior extension is seen. **C)** Preoperative coronal T1-contrast-enhanced MR image of patient in panel A **D)** Preoperative sagittal T1-contrast-enhanced MR image of patient in panel A **E)** Postoperative coronal T1-contrast-enhanced MR image of patient in panel A. Right optic canal invasion superior extension could not be evacuated. **F)** Postoperative sagittal T1-contrast-enhanced MR image of patient in panel A. **ON:** Optic nerve, **TM:** Tumor, **FB:** Frontal bazis.

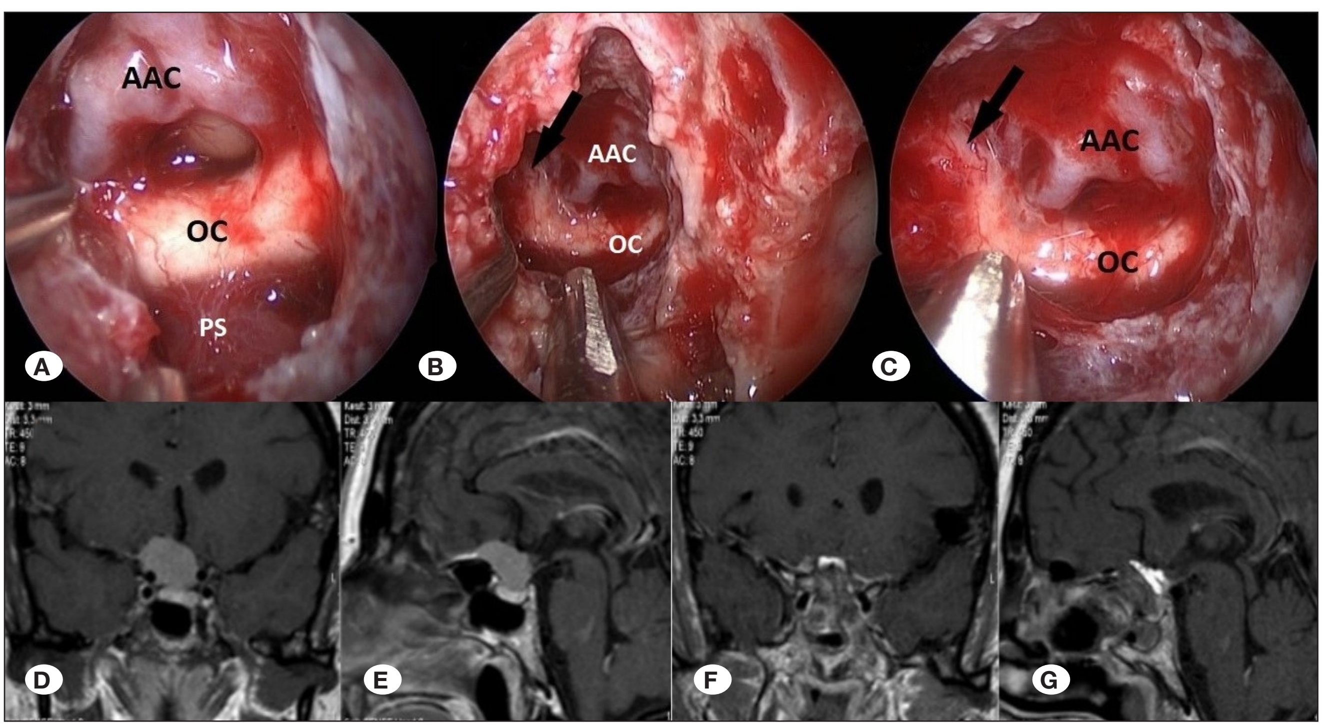

Figure 6: A) Evacuation of the optic canal invasion part of the tumor **B)** Evacuation of the optic canal inferomedial invasion. Black arrow indicates right optic nerve **C)** After evacuation of the optic canal invasion part of the tumor. Right optic nerve appears crushed (black arrow) **D)** Preoperative coronal T1-contrast-enhanced MR image of same patient **E)** Preoperative sagittal T1-contrast-enhanced MR image of same patient **F)** Postoperative coronal T1-contrast-enhanced MR image of same patient **G)** Postoperative sagittal T1-contrast-enhanced MR image of same patient. **OC:** Optic chiasm, **AAC:** Anterior artery complex, **PS:** Pituitary stalk.

Table I: Demographic and Preoperative Characteristics of Patients

		n (%)
Sex	Male	11 (18.3)
	Female	49 (81.7)
	Total	60 (100)
Age range (years)		23-77 (mean age of 50.25 ± 11.96)
Mean Follow-up (months)		45.42 ± 32.09 (range: 3 -105)
Presenting Symptoms	Vision Loss	39 (65)
	Headache	23 (38.3)
	Dizziness	2 (3.3)
	Facial Paralysis	1 (1.7)
	Tinnitus	1 (1.7)
	Hearing Loss	1 (1.7)
	Amnesia	1 (1.7)

Table II: Pathological Subtypes of Tumors

Pathological Subtypes	n (%)
Meningotheliomatous	31 (51.7)
Transitional	13 (21.7)
Psammomatous	8 (13.3)
Syncytial	4 (6.6)
Fibrous	2 (3.3)
Angiomatous	1 (1.7)
Atypical (grade 2)	1 (1.7)
Total	60 (100)

went surgery via endoscopic transnasal approach between August 1997 and December 2020. Their age ranged from 23 to 77 years, with a mean age of 50 years (25 ± 11.96 years). The mean follow-up duration was 45.42 ± 32.09 months (range, 3–105 months). Vision loss and headache were the most common presenting symptoms (Table I). Recurrence was detected in 6 of 60 patients during their follow-up. Moreover, a second surgery was performed. We have performed a total of 66 endoscopic transnasal operations in these 60 patients. Two patients died due to non-surgical reasons (one myocardial infarction, and one stroke) during the follow-up.

Ophthalmologic examinations revealed visual loss in 39 patients. Early postoperative evaluation showed improvement in 18 (46.2%) of them. Nineteen (48.7%) of them remained the same. Moreover, in two (5.1%) patients, vision loss progressed postoperatively. In 16 of 19 patients whose visual loss did not change, improvement was observed in the 3-month follow-up.

Table III: Resection Rates

		n (%)
Resection rates	GTR	45 (75)
	NTR	3 (5)
	STR	12 (20)
	Total	60

Meningotheliomatous and transitional meningiomas were the most common pathological subtype results (Table II).

Intraoperative Data

The consistency of the tumor is a feature that is examined intraoperatively. Tumors that could be easily removed with an aspirator were classified as soft-containing tumors. In contrast, tumors requiring the use of ultrasonic aspirator during evacuation were classified as firm-containing tumors.

In our study, the numbers of tumors with soft and hard contents were 14 (23.3%) and 46 (76.7%), respectively.

MRI and Outcome Data

The diameters of the lesions were between 8 and 68.60 mm, with a median of 21.15 mm on the anteroposterior axis. Measurements were between 6.60 and 39.20 mm, with a median of 15 mm on the superoinferior axis, and between 6.50 and 56.90 mm, with a median of 19.75 mm on the transverse axis.

GTR was achieved in 45/60 (75%) patients. NTR and STR were performed in 3/60 (5%) and 12/60 (20%) patients, respectively (Table III).

We analyzed factors affecting GTR, such as tumor consistency and tumor diameters.

In our study, we found that tumor consistency was statistically significant on resection rates (p=0.048) (Table IV). Simultaneously, tumor median diameters on the anteroposterior (≤21.15 mm), transverse (≤19.75 mm), and superoinferior (≤15 mm) axes were statistically significant on resection rates (p=0.001; p=0.001; and p=0.006, respectively) (Table V).

However, we found that optic canal invasion did not significantly differ on resection rates (Table VI).

Sinonasal Morbidity and Surgical Complications

We compared patients in the first and second groups under sinonasal morbidity. Cacosmia, nasal congestion (synechia, difficulty in breathing), and postoperative sinusitis were considered sinonasal morbidities. As previously mentioned, the difference between the two groups is whether the middle turbinate was removed. Although removal of the middle turbinate will especially decrease the incidence of sinusitis (26), a statistically significant difference was found between the first and second groups in our study (p<0.001) (Table VII).

Table IV: Effect of Tumor Consistency on Resection Rates

		Tumor consistency			
		SOFT	**FIRM**	**Total**	
Resection rates	GTR	14	31	45	**p=0.048***
	NTR	0	3	3	
	STR	0	12	12	
	Total	14	46	60	

**Statistically significant.*

Table V: Effect of Tumor Diameters on Resection Rates

		≤21.15 mm	**>21.15 mm**	**Total**	
Anteroposterior	GTR	29	16	45	**p=0.001***
	NTR	0	3	3	
	STR	1	11	12	
	Total	30	30	60	
		≤19.75 mm	>19.75 mm	Total	
Transverse	GTR	29	16	45	**p=0.001***
	NTR	0	3	3	
	STR	1	11	12	
	Total	30	30	60	
		≤15 mm	>15 mm	Total	
Superinferior	GTR	27	18	45	**p=0.006***
	NTR	0	3	3	
	STR	2	10	12	
	Total	29	31	60	

**Statistically significant.*

Table VI: Effect of Optic Canal Invasion on Resection Rates

	Optic canal invasion +	**Optic canal invasion -**	**Total**	
GTR	19	26	45	p=0.113
NTR	1	2	3	
STR	9	3	12	
Total	29	31	60	

Table VII: Sinonasal Morbidity in Two Groups

	Cacosmia, sinusitis, nasal congestion	No active complaints	Total	
First group (2007-2013)[a]	15	8	23	p<0.001*
Second group (2013-2020)[b]	6	31	37	
Total	21	39	60	

*[a]Middle turbinate totally or partially was removed in this group, [b]Middle turbinate was not removed in this group, *Statistically significant.*

Table VIII: Complications in the Study

		CSF leakage +	CSF leakage -	Total	
CSF leakage	First group (2007-2013)[a]	4	19	23	p=0.009*
	Second group (2013-2020)[b]	0	37	37	
	Total	4 (6,6%)	56	60	
			n (%)		
Other complications	Transient DI		2 (3.3)		
	Hydrocephalus		2 (3.3)		
	Hemorrhage		1 (1.7)		
	Epistaxis		1 (1.7)		
	Vision loss progression		2 (3.3)		

*[a]Bone graft was used and lumbar drainage was not performed routinely, [b]Bone graft was not used and lumbar drainage was performed routinely. *Statistically significant*

CSF leakage was observed in 4/60 (6.6%) patients, all of whom underwent reoperation. These four patients were in our first group. Different from second group, we used bone graft and did not routinely use lumbar drainage in this group. In the second group, CSF leakage was not observed in any patients. Moreover, this difference was statistically significant (p=0.009) (Table VIII).

Transient diabetes insipidus (DI) was noted in 2/60 (3.3%) patients postoperatively. Hydrocephalus was observed in 2/60 (3.3%) patients postoperatively. These two patients underwent surgery to implant a ventriculoperitoneal shunt. Operative site hemorrhage and epistaxis were observed in 1/60 (1.7%) and 1/60 (1.7%) patients, respectively. All of them underwent reoperation. No new vision loss was noted, but vision loss of two patients progressed (Table VIII).

DISCUSSION

In this study, we have presented criteria that can help determine for cases where endoscopic technique may be more effective. Critical factors for TS meningioma surgery have been defined over time (29), but it is clear that simpler predictive values are needed. These simple predictive factors will greatly facilitate the selection of the surgical route. Particularly, the cutoff values in all axis lengths that we calculated and presented are the values that will greatly contribute to the choice of surgical method. We also demonstrated the effect of tumor consistency on resection rates and results of experience and changes in surgical strategies.

The endoscopic technique continues to develop exponentially, especially in the last two decades. With this development, especially in skull base surgical interventions, it is preferred over transcranial techniques, considering that it has lower mortality and morbidity values, and higher patient comfort.

There are studies indicating that both techniques are superior when surgical techniques for TS meningiomas are compared (3,17–19). This is due to the fact that patient selection is not based on the objective criteria and at least as important as the surgeon's experience. There are no clear criteria accepted objectively for surgical technique selection.

Likewise, new scoring systems have been recently described for surgical technique selection (16,29). These are greatly helpful and detailed classifications. Our MR based endoscopic classification also defines the limitations of this technique (6). Although these limitations may change with the surgeon's experience, it is the MR based endoscopic classification that shows the limitations based on the boundaries of the infrachiasmatic corridor.

Over the years, optic nerve (optic canal invasion) and ICA encasement have been shown to be the most important factors affecting resection rates. Although it is true, we believe that it is deficient for surgical technique selection. Because the presence of these conditions also affects the results of transcranial surgery. Especially in tumors within the infrachiasmatic corridor, since the invasion of the optic canal begins inferomedially, it is easier to remove endoscopically. GTR rates are satisfactory. In tumors which outside the infrachiasmatic corridor, it is difficult because the optic nerve can be completely wrapped. In our study, it was found that optic canal invasion did not have a significant effect on resection rates (p=0.113). The relatively high number of patients without optic canal invasion affects this. Moreover, endoscopic removal of tumors extending below the optic chiasm is easier than the transcranial approach. Because in the transcranial approach, it is more difficult to observe under the ipsilateral optic nerve.

The most important factor in selecting the surgical technique is the tumor size. Previously, TS meningiomas were classified according to their size (28). However, these classifications were made on a single axis. Although the endoscopic method provides a two-dimensional view, we should consider all three dimensions of the tumor we removed as the factor affecting surgery. We found that the median measurements on the three axes of the tumor (superoinferior, anteroposterior, and transverse axes) contribute to resection rates (p=0,006; p=0.001; and p=0.001, respectively). The reason for this is thought to be multifactorial, such as tumor consistency and surgeon's experience. Furthermore, the endoscopic technique is insufficient in tumors that outside the infrachiasmatic corridor. Because entanglement of neurovascular structures is one of the factors that negatively affect surgery, particularly, it is not possible to remove the parts of the tumor that spread to the superolateral carotid bifurcation behind the optic chiasm. These results also support our previously defined classification (6).

Although it is discussed that, factors such as tumor volume and sizes affect surgery, tumor consistency, which is the most important factor affecting resection rates, has not been sufficiently discussed. Tumor consistency is a factor affecting resection rates and tumor size (p=0.048). In our study, the results we derived based on our intraoperative observations are the factors that facilitate the removal of the tumor, which is softer. This increases the resection rates. Although it is thought that it is not a predictive factor for surgical route selection, it can be considered as the most important factor for good resection rates. In some studies, imaging methods have been investigated to determine the tumor content preoperatively (24,25,30). But there is still no verified method. Moreover, considering that endoscopic technique causes less mortality and morbidity, it is very important to reveal the markers that can provide the tumor consistency in the preoperative period with new studies.

The experience gained by the surgeon over time contributes greatly to further development of the endoscopic technique. Our study has shown that the experience gained and change in surgical techniques reduce the rates of postoperative complications. We statistically show the necessity of lumbar drainage to prevent CSF fistula in extended endoscopic approaches. It seems that the use of bone grafts in the closure is not more meaningful than lumbar drainage (p=0.009). The duration of lumbar drainage should not exceed 3–5 days to prevent other complications related to lumbar drainage.

Although it has been previously stated that removal of the middle turbinate is a good factor in terms of odor and especially sinus function (26), our study showed that removal of the middle turbinate is actually a bad factor especially for the development of sinusitis (p<0.001). Instead, of completely or partially removing the turbinate, lateralizing with gentle manipulations to avoid bleeding and synechia, will provide a better outcome. The result is that, with increasing experience, sinonasal morbidity can be reduced.

Despite these results, there is a need for new studies that can objectively compare transcranial and endoscopic techniques and show the tumor consistency preoperatively.

The limitations of our study can be considered as the absence of transcranial cases. Thus, the two techniques can be compared together. However, our primary goal was to help resolve the confusion in choosing the endoscopic technique. Moreover, another limitation is that working on a numerically larger population may yield better results.

CONCLUSION

The most important factor in selecting the surgical technique is the tumor size. The cutoff values in all axis lengths are the values that will greatly contribute to the choice of surgical method. The endoscopic method can be safely preferred for sizes below the cutoff values. In values above the cutoff values, endoscopic method alone may be insufficient. Therefore, it seems more appropriate to apply transcranial or combined approaches.

Infrachiasmatic corridor boundaries are the limitations of endoscopic approach. These limitations can change based on surgeon's experience. Moreover, these are important factors for choosing the surgical technique. The endoscopic approach seems more appropriate for tumors within this corridor.

Also, tumor consistency is a factor that affecting degree of tumor resection rates. With increasing experience, sinonasal morbidity can be reduced.

AUTHORSHIP CONTRIBUTION

Study conception and design: SC, MC

Data collection: AE, EY, HG

Analysis and interpretation of results: MC

Draft manuscript preparation: MC

Critical revision of the article: BC, IA, SC

Other (study supervision, fundings, materials, etc...): SC

All authors (MC, AE, EY, HG, BC, IA, SC) reviewed the results and approved the final version of the manuscript.

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