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Original Article

Surgical treatment of tuberculum sellae meningioma: A retrospective review of single institutional experience

Roland Sidabutar[1#], Yulius Hermanto[1#], Agung Budi Sutiono[1], Guata Naibaho[1], Ahmad Faried[1]

[1]Department of Neurosurgery, Dr. Hasan Sadikin Hospital, Padjadjaran University, Bandung, West Java, Indonesia.

E-mail: Roland Sidabutar - rolandsidabutar@yahoo.com; *Yulius Hermanto - hermanto_yulius@yahoo.com; Agung Budi Sutiono - agungbudis@gmail.com; Guata Naibaho - guata81ynwa@gmail.com; Ahmad Faried - faried.fkup@gmail.com

[#]: These authors have equally contributed to this work

***Corresponding author:**
Yulius Hermanto,
Department of Neurosurgery,
Dr. Hasan Sadikin Hospital,
Padjadjaran University,
Bandung, West Java, Indonesia.

hermanto_yulius@yahoo.com

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ABSTRACT

Background: Tuberculum sellae meningiomas (TSMs) represent a distinct entity among intracranial meningiomas. Both transcranial approaches (TCAs) and endoscopic endonasal approaches (EEAs) have provided neurosurgeons with options for managing these difficult tumors. Still, controversies persist regarding the selection criteria for the most optimal approach.

Methods: The authors retrospectively reviewed 45 patients treated surgically for TSM between 2018 and 2023. The clinical reports of all subjects were assessed pre-and post-operatively, encompassing demographic information, clinical symptoms, imaging results, ophthalmological evaluations, operative details, and any complications.

Results: A total of 45 patients were included in this study, with 21 patients undergoing EEAs and 24 TCAs. TSMs treated with EEA are smaller than TCA ($P = 0.0014$), less prevalent in optic canal invasion ($P = 0.0291$) and in arterial encasement ($P = 0.0050$), and have no lateral extension ($P < 0.0001$). The majority of patients (36/45) had visual improvement or stabilization following the surgery, with the rate of achieving gross total resection (GTR) was higher in the EEA group (17/21) than in the TCA group (9/24) ($P = 0.0032$). The mortality tends to be higher in the TCA group and is related to arterial encasement, although statistically insignificant.

Conclusion: Both traditional TCAs and EEAs offer options for the surgical management of TSM, each with its advantages and limitations. Based on our experiences, several factors (lateral extension and arterial encasement) may guide the suitable approach, and multidisciplinary considerations, with the overarching goals of achieving maximal tumor resection and minimizing postoperative complications.

Keywords: Endoscopic endonasal, Meningioma, Skull base, Trans sphenoidal, Tuberculum sellae

INTRODUCTION

Tuberculum sellae meningiomas (TSMs) represent a distinct clinical entity among intracranial meningiomas. TSMs arise near the sella turcica, a bony-saddle-shaped structure at the center of the skull base.[8,19] The sellar region is densely populated with critical neurovascular structures; TSMs can impact these structures due to their location.[8,15] The proximity of TSMs to the optic canal is significant due to the potential for compression or encasement of the optic nerve.[15] The majority of patients with TSMs have visual impairment, which becomes the primary indication for surgical treatment.[15,17,21]

The primary goal of TSM surgery is to achieve maximal tumor removal and improve visual function while preserving critical neurovascular structures.[8,15,17,18,21] The surgery for TSM is challenging mainly due to its intricate location. Large TSMs not only cause significant mass-effect or neurological deficits but also comprise surgical access to the tumor. Large tumors carry a higher risk of complications and may require staged or multi-modal therapy to control tumor growth and alleviate symptoms.[18,22]

The emergence of both traditional transcranial approaches (TCAs) and endoscopic endonasal approaches (EEAs) in the surgical management of TSMs has provided neurosurgeons with valuable options for approaching these challenging tumors.[2,5,15-18,22] Each approach offers distinct advantages and limitations, and the choice between them depends on various factors, including tumor size, location, extension, patient anatomy, surgeon expertise, and patient preferences. While both TCAs and EEAs have demonstrated efficacy and safety in the surgical management of TS meningiomas, controversies persist regarding the selection criteria for the most optimal approach.[2,5,6,14-18]

This retrospective study aimed to describe our institutional experiences in surgically managing TSMs in 45 consecutive patients. The emphasis was placed on preoperative evaluation, particularly considering tumor characteristics and anatomical factors that play pivotal roles in determining the most suitable surgical approach and subsequent postoperative outcomes.

MATERIALS AND METHODS

Patients

This study received approval from the Institutional Review Board (IRB) at our institution. This retrospective study enrolled all patients of TSMs who experienced TCA or EEA surgery at Dr Hasan Sadikin Hospital between January 2018 and December 2023 (a total of 45 cases). All patients were pathologically confirmed as meningioma (93.3% of cases were WHO grade I). Meningiomas originating from the clinoid processes, olfactory groove, and planum sphenoidal were excluded from the study. The surgical indications included vision impairment, progressive headache, and intracranial hypertension. Traditional TCAs, such as pterional (16 patients), subfrontal interhemispheric (seven patients), and lateral supraorbital craniotomy (one patient), as well as extended EEA surgeries (21 patients), were performed to resect the tumor. All TCA procedures were conducted by experienced neurosurgeons within our department (A.B.S. and R.S.). For EEA, all surgeries were performed by a single surgeon (RS).

The clinical reports of all subjects were assessed pre-and post-operatively, encompassing demographic information, clinical symptoms, imaging results, ophthalmological evaluations, operative details, and any complications. Both computed tomography (CT) and magnetic resonance imaging (MRI) data were used for preoperative assessment, intraoperative guidance, and postoperative outcomes.

Radiological assessment

The tumor volume was determined using the formula: tumor volume (in cubic centimeters, cm^3) = (anteroposterior × coronal × craniocaudal)/2. This calculation assumes the tumor's shape resembles a rough sphere. The degree of tumor removal was assessed based on surgical records and postoperative MRI scans. Gross total resection (GTR) was defined as the absence of any residual tumor on the postoperative imaging. The presence of tumor remnants characterized subtotal resection.

The refined Magill-McDermott (M-M) scale was used to classify optic canal invasion and arterial encasement

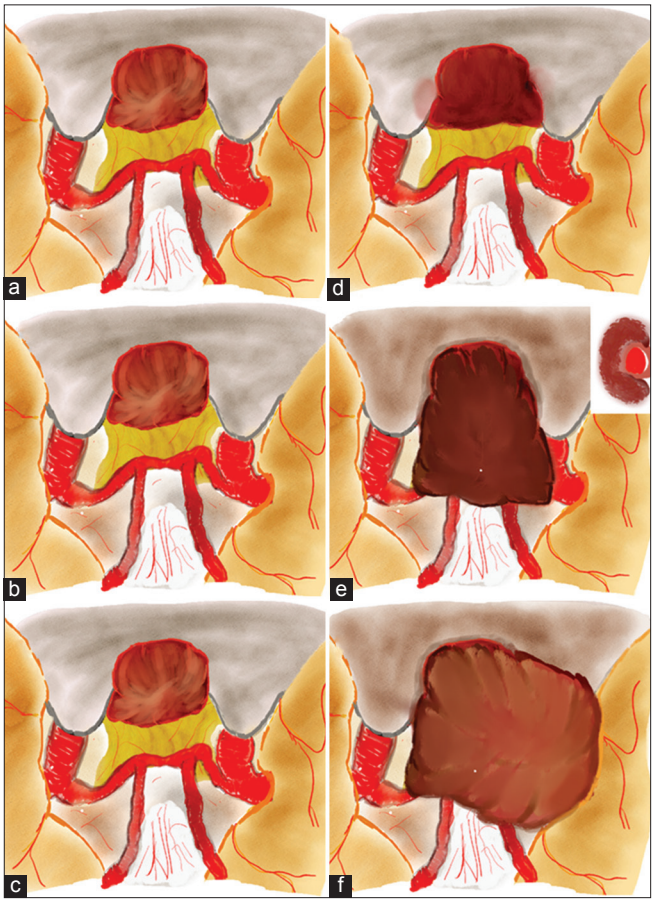

Figure 1: The illustration of classification in our study, adopted from the refined Magill-McDermott scale. (a,b,c) The drawings of tuberculum sellae meningioma without the involvement of optic canal, arterial encasement, and lateral extension. (d) Optic canal invasion. (e) Arterial encasement > 180^0 of either internal carotid artery, middle cerebral artery, or anterior cerebral artery. (f) Lateral extension beyond the anterior clinoid process.

[Figures 1a-f].[16,17] The optic canal invasion is assigned if the tumor extends >3 mm into the either optic canal.[15] Measurement of optic canal invasion can be performed in the coronal plane of a standard preoperative MR image.[15-17] In addition, the arterial encasement score is assigned minimal or extensive. Minimal is assigned if the tumor either does not touch or surround the internal carotid artery (ICA) or the anterior wall of the anterior cerebral artery (ACA) or middle cerebral artery (MCA). However, if the tumor completely encircles the ICA or ACA or MCA, extending 180° or more around the artery, it is assigned extensive. All tumors that extend beyond the clinoid process laterally are assigned to have a lateral extension. All radiological assessments were evaluated by senior authors (A.B.S. and R.S.); representative images are presented in Figure 2.

Study bias

This study is constrained by selection and observer biases. In addition, observer bias is a limitation, as only data documented in the electronic medical records were available for analysis.

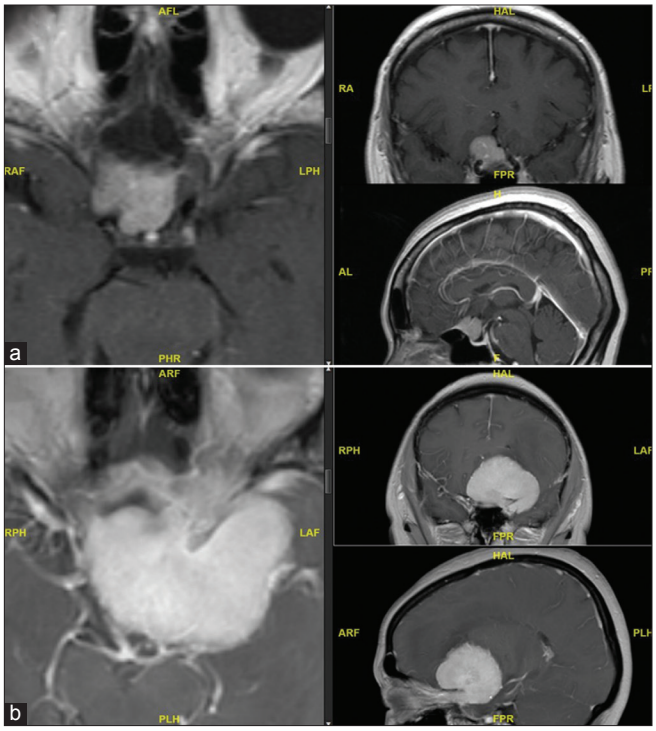

Figure 2: Representative images from patients with tuberculum sellae meningioma. (a) The suitable candidate for an endoscopic endonasal approach – is a small tumor, with minimal arterial encasement and no lateral extension beyond the clinoid process. (b) The suitable candidate for transcranial approach – a large tumor, extensive arterial encasement, and lateral extension beyond the clinoid process.

Statistical analysis

Statistical analysis was conducted using GraphPad Prism 8.0. Descriptive statistics, including patient demographics, were presented in tabular format. Continuous variables were reported as means with standard deviations, while categorical variables were expressed as percentages. Group comparisons were performed using the Student's t-test for continuous variables and the Chi-square test for categorical variables. $P < 0.05$ was considered indicative of a statistically significant difference.

RESULTS

Clinical characteristics

A total of 45 patients were included in this study, with 21 patients undergoing EEA and 24 patients undergoing TCAs. There was no significant difference in age, sex, and presenting symptoms in both groups, with the majority of patients being middle-aged females. The chief complaint in our series was mostly related to vision impairment (n = 37/45), followed by visual field disturbance (7/45), and one patient had decreased consciousness due to intracranial hypertension. All patients were pathologically confirmed as meningioma, with the majority of cases (n = 42/45) being WHO grade I. The clinical data are presented in Table 1.

Radiological findings

In this series, the mean volume of the tumor was 10.99 ± 4.51 cm^3 in the EEA group and 18.31 ± 8.87 cm^3 (P = 0.0014) in the TCA group. Similarly, there was a significant difference in tumor diameter, with measurements of 2.86 ± 0.53 cm in the EEA group and 3.48 ± 0.82 cm in

Table 1: Characteristics of subjects in this study

Characteristics	EEA	TCA	*p*
Age	42,86±8,51	46.63±8,56	0.1467'
Sex			
Male	0	1	>0.9999*
Female	21	23	
Chief Complaint			
Vision impairment	16	21	
Visual Field Disturbance	5	2	0.2499^
Decreased consciousness	0	1	
WHO Grade			
Grade I	20	22	
Grade II	0	2	0.2336^
Grade III	1	0	

'Analysis was performed with Mann-whitney U test. *Anaysis was performed with Fisher's exact test. ^Analysis was performed with chi-square. EEA: Endoscopic endonasal approach, TCA: Transcranial approach.

Table 2: Pre-operative radiological assessment in patients with tuberculum sellae meningiomas

Findings	EEA	TCA	*p*
Tumor Volume	10.99±4.51	18.31±8.87	**0.0014***
Maximum Diameter	2.86±0.53	3.48±0.82	**0.0043***
Optic Canal Invasion			
Yes	13	22	**0.0291˜**
No	8	2	
Arterial Encasement			
Minimal	19	11	**0.0018˜**
Extensive	2	13	
Lateral Extension			
Yes	0	13	**<0.0001˜**
No	21	9	

*Analysis was performed with independent t-test. ˜Analysis was peformed with Fisher's exact test. EEA: Endoscopic endonasal approach, TCA: Transcranial approach. Bold value represents $p < 0.05$.

Table 3: Multivariate analysis of pre-operative radiological assessment in association with surgical approach

Findings	β	95% CI	*p*
Tumor Volume	-0.0199	-0.04 - 0.01	0.1167
Maximum Diameter	0.1052	-0.17 - 0.38	0.4432
Optic Canal Invasion	-0.1233	-0.47 - 0.22	0.4767
Arterial Encasement	-0.0544	-0.28 - 0.18	0.6430
Lateral Extension	-0.5211	-0.89 - -0.13	**0.0098**

Analysis was performed with multiple linear regression. CI: Confidence interval, β: Beta coefficient. Bold value represents $p<0.05$.

the TCA group ($P = 0.0043$). Moreover, the patients in the EEA group exhibited a significantly lower rate of optic canal invasion, with 13 out of 21 patients (13/21), compared to patients in the TCA group, where 22 out of 24 patients (22/24) had optic canal invasion ($P = 0.0291$). In addition, the EEA group had a lower rate of arterial encasement, with 19 out of 21 patients showing minimal encasement and two out of 21 patients displaying extensive encasement. On the contrary, the TCA group had 11 out of 24 patients with minimal encasement and 13 out of 24 patients with extensive encasement ($P = 0.0018$). All patients in the EEA group showed no lateral extension beyond the clinoid process. Conversely, in the TCA group, 13 out of 24 had lateral extension ($P < 0.0001$). The radiological assessment is presented in Table 2.

Then, we conducted a multivariate analysis to ascertain which radiological factors are crucial in determining the appropriate surgical approach for patients with TSMs. Our analysis confirmed that lateral extension beyond the clinoid process precludes the utilization of the EEA for treating TSMs in our series [$P = 0.0098$, Table 3].

Table 4: The incidence of complications following the surgery of TSMs

Complications	EEA	TCA	*p*
Surgery - related death	2/21	4/24	0.6695
Transient Diabetes Insipidus	3/21	2/24	0.6251
CSF Leakage	1/21	0/24	0.4667
Subdural hemorrhage	0/21	1/24	>0.9999
Edema	0/22	1/24	>0.9999
Intracerebral hemorrhage	0/22	1/24	>0.9999

All analysis were performed with Fisher's exact test. EEA: Endoscopic endonasal approach, TCA: Transcranial approach, CSF: Cerebrospinal fluid, TSM: Tuberculum sellae meningiomas

Table 5: Subgroup analysis of factors associated with surgery-related death in EEAs

Radiological findings	Surgery-related death		*P*
	Yes	No	
Volume	12.29±5.94	10.85±4.52	0.7714^
Tumor diameter	2.87±0.33	2.85±0.52	0.8524^
Optic canal invasion			
Yes	2	11	0.5408
No	0	8	
Arterial encasement			
Extensive	2	0	**0.0048***
None	0	19	

^Analysis was performed with independent *t*-test. *Analysis was performed with Fisher's exact test, EEA: Endoscopic endonasal approach, Bold value represents $p < 0.05$.

Table 6: Subgroup analysis of factors associated with surgery-related death in TCAs

Radiological findings	Surgery related death		*P*
	Yes	No	
Volume	26.95±8.4	16.58±8.07	**0.0291**^
Tumor diameter	3.75±0.66	3.43±0.85	0.3168^
Optic canal invasion			
Yes	4	18	>0.9999*
No	0	2	
Arterial encasement			
Extensive	2	11	>0.9999*
None	2	9	

^Analysis was performed with independent *t*-test. *Analysis was performed with Fisher's exact test. Bold value represents $p < 0.05$. TCA: Transcranial approaches, Bold value represents $p < 0.05$.

Postoperative outcomes

In this series, the rate of achieving gross total resection (GTR) was higher in the EEA group (17/21) than in the TCA group (9/24) ($P = 0.0032$). Among the 44 patients with vision impairment, vision restoration or stabilization was reported in 36 (81.82%) patients, including 14 (58.33%) in the TCA group and 17 (80.95%) in the EEA group. There was no statistically significant difference ($P >$

0.05) between TCA and EEA groups in vision restoration or stabilization rates.

In our study, there was 1 patient (4.76%) experienced postoperative cerebrospinal fluid leakage in the EEA group and required secondary surgery to repair the dural leakage. Whereas none of the 24 patients in the TCA group experienced cerebrospinal fluid leakage. Transient diabetes insipidus occurred in three out of 21 patients with EEA and two out of 24 patients with TCA ($P = 0.6521$). There was a lower rate of surgery-related death in the EEA group (2/21) compared to the TCA group (4/24), all of them related to injury to the major arteries. In addition, we also observed other complications, including subdural hemorrhage (one in TCA), edema (one in TCA), and intracerebral hemorrhage (one in TCA). However, there was no significant difference in postoperative complications rate between the EEA and TCA ($P > 0.05$). The data are presented in Table 4.

We subsequently performed an analysis to identify the factors associated with surgery-related death in the EEA group. In the EEA group, extensive arterial encasement was associated with surgery-related death [Table 5, $P < 0.0001$]. Meanwhile, in the TCA group, larger tumor volume was associated with postoperative complications [Table 6, $P = 0.0004$].

DISCUSSION

TSM is a prevalent benign tumor located in the sellae region.[2,15-21] In our series, TSM is highly prevalent in females (44/45), suggesting a hormonal role in meningioma genesis. The expression of progesterone receptors is well-reported in meningioma.[19,21] The female: male ratio in our series (44:1) is higher than reported literature;[2,15,16,18,19] Moreover, all female patients in our series had a history of hormonal contraception for at least 5 years, suggesting a prolonged exposure to high progesterone levels might contribute to meningioma formation, particularly in skull base.[19]

Typically, TSM exhibits slow growth and may not manifest any clinical symptoms in its early stages. In our series, almost all patients presented with visual disturbances, reflecting meningioma's growth pattern and proximity to the optic apparatus. Impaired visual acuity and visual field deficits are often reported as the clinical manifestations of TSM due to its proximity to the optic apparatus. As the tumor compresses the optic nerve or chiasm, patients may experience visual disturbances ranging from blurry vision to partial or complete vision loss or visual field disturbance.[2,5,9,15,18,21,23,26,27]

Surgical intervention is the optimal treatment strategy for TSM, aiming not only to remove the tumor but also to alleviate compression on critical structures and restore vision. In our series, we avoid performing EEA in TCMs with lateral extension. In the context of EEA, lateral extension beyond the clinoid process presents a challenge. This extension can involve critical structures such as the cavernous sinus, optic nerve, and ICA, making complete resection through an endonasal route difficult or impossible without risking damage to these structures. Therefore, in cases where lateral extension beyond the clinoid process is present, EEA surgery for TSM is not advisable due to the increased risk of complications and inadequate tumor resection. Instead, traditional TCAs may be preferred for accessing and resecting tumors with lateral extension beyond the clinoid process.[2,5,10,15-21,25-27]

In our series, the mortality is relatively lower in the EEA group. Our subsequent analysis revealed that arterial encasement is the factor associated with surgery-related death in EEA surgery. Due to the intricate anatomy and limited working space within the narrow corridor of the sphenoid sinus, adequately accessing and safely dissecting tumors that encase major arteries can be difficult through an endonasal route.[2,6,8,15,21,23,24] Arteries such as the ICA and ACA are critical structures supplying blood to the brain, and inadvertent injury during surgery can lead to catastrophic complications such as stroke or hemorrhage. Therefore, for TSMs with significant arterial encasement, the EEA approach may not be the preferred surgical option. Instead, TCA may be considered, as they provide better visualization and access to the tumor and surrounding structures, allowing for safer dissection and resection of tumors encasing major arteries.[2,4,5,8,15,18,21,23,24,29] It is important to preserve and maintain the arachnoidal plane to aid with a good cleavage from arterial vessels, even in vessel encasement.[2,4,5,18,23,24,26,29]

In our series, surgery-related deaths in TCAs were associated with large tumor sizes. A large tumor (>25 cm^3) often distorts the normal architecture of the surrounding structures, which poses a significant challenge for TCA surgery in treating TSMs. The distorted anatomy complicates the surgical approach and increases the risk of damaging critical structures such as blood vessels and nerves.[7,8,10,11,21,29] In such cases, performing a single-stage complete resection through TCA may be difficult or unsafe due to limited visibility and maneuverability within the surgical field. Therefore, a staged procedure may be considered as a safer alternative. This approach minimizes the risk of complications associated with extensive manipulation of vital structures during a single surgery.[24] The difficulty in achieving a complete resection in TSMs is also influenced by the close adherent of the tumor to perforating or main arteries.[2,4,5,8,15,18,21,23,24,29]

Studies have shown that early surgical intervention in TSMs can result in significant improvement or stabilization of visual deficits in a considerable number of patients.[3,4,12,13,15,18,21] In our series, most patients had some degree of improvement following surgery. However, the degree of improvement can vary, and complete vision restoration may not always be achievable, especially in cases where there has been

significant optic nerve damage before surgery; in addition, the duration and severity of compression determine the prognosis of visual outcome.[1,3,12,13,28]

Recent International TSM study has reported that optic canal invasion and arterial encasement are associated with difficulty in achieving GTR either with EEA or TCAs.[16,17] Our studies also confirmed that visual improvement is higher in EEA than in TCAs, which might reflect the higher M-M scale or more complex meningiomas in TCAs.[16,17] Despite the shifting trend in TSM surgery from TCA to EEA,[16] several anatomical factors remained critical to consider for determining the suitable approach.

The strength of our study is the first report from a single institution with the experience of performing >20 cases for both EEA and TCA in the surgical treatment of TSM. In our study, we confirm that among all factors in the M-M scale, the arterial encasement is an important guidance for the approach. Overall, surgery may improve visual outcomes in many cases of TSM; it is important to consider individual patient factors and tailor treatment strategies based on surgical expertise, radiological assessment, and postoperative care. Several radiological parameters (lateral extension and arterial encasement) were associated as guidance for neurosurgeons in awareness of potential challenges during the surgery. Patient and surgical approach selection is crucial to minimize complications while achieving the treatment goal.

Limitation

This study is limited by observation bias and a single center. The surgeon preference bias is well reflected in our series, as all cases with lateral extension were performed transcranially. However, this situation is a common precaution for the EEA approach. In addition, the limited duration of follow-up makes it difficult to obtain the recurrence rate.

CONCLUSION

Both traditional TCAs and EEAs offer valuable options for the surgical management of TSM, each with its advantages and limitations. Based on our experiences, lateral extension and arterial encasement may guide the suitable approach, in addition to surgeon expertise and multidisciplinary considerations, with the overarching goals of achieving maximal tumor resection, preserving neurological function, and minimizing postoperative complications.

Authors' contributions

RS, YH: Conceptualization, data curation, formal analysis, methodology, and writing; ABS, GN: Review and editing; AF: Final approval of the manuscript.

Ethical approval

The research/study was approved by the IRB at Dr. Hasan Sadikin Hospital Ethical Committee, number DP.04.03/D. XIV.2.2.1/1221/2023, dated December 20, 2023.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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