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Original Article

Comparative anatomical analysis between lateral supraorbital and minipterional approaches

Ricardo Marques Lopes de Araujo[1,2], Dan Zimelewicz Oberman[3], Leonardo Christiaan Welling[4], Bipin Chaurasia[5], Alexander I. Evins[2], Antonio Bernardo[2], Gustavo Rassier Isolan[6], Jose Paulo Dourado[7], Nicollas Nunes Rabelo[1], Eberval G. Figueiredo[8]

[1]Department of Neurosurgery, University of Sao Paulo School of Medicine, Sao Paulo, Brazil, [2]Department of Neurological Surgery, Weill Cornell Medicine/New York-Presbyterian Hospital, New York, United States, [3]Department of Neurosurgery, Air Force Galeão Hospital, Rio de Janeiro, [4]Department of Neurological Surgery, State University of Ponta Grossa, Ponta Grossa, Brazil, [5]Department of Neurosurgery, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh, [6]The Center for Advanced Neurology and Neurosurgery, Porto Alegre, [7]Department of Neurosurgery, Presidente Antonio Carlos Institute of Tocantins, Porto Nacional, Tocantins, [8]Department of Neurosurgery, University of Sao Paulo, Facultade das Clinicas, Sao Paulo, Brazil.

E-mail: *Ricardo Marques Lopes de Araujo - ricmla@gmail.com; Dan Zimelewicz Oberman - danzoberman@gmail.com; Leonardo Christiaan Welling - lcwelling9@gmail.com; Bipin Chaurasia - trozexa@gmail.com; Alexander I. Evins - ale2009@med.cornell.edu; Antonio Bernardo - antonio@antonbernardo.com; Gustavo Rassier Isolan - gisolan@yahoo.com.br; Jose Paulo Dourado - josepaulo18a@gmail.com; Nicollas Nunes Rabelo - nicollasrabelo@hotmail.com; Eberval G. Figueiredo - ebgadelha@yahoo.com

***Corresponding author:**
Ricardo Marques Lopes de Araujo, Department of Neurosurgery, University of São Paulo School of Medicine, São Paulo, Brazil.

ricmla@gmail.com

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ABSTRACT

Background: The pterional craniotomy, described by Yasargil and Fox in 1975, constitutes the most traditional and important surgical access in vascular neurosurgery. Minimally invasive alternatives include the minipterional (MP) and lateral supraorbital (LSO) craniotomies, which avoid complications such as injury to the frontal branch of the facial nerve, temporal muscle dysfunction, depression of the craniotomy site, frontal sinus opening, and cosmetically unacceptable outcomes. We evaluated and compared the exposures provided by MP and LSO craniotomies through quantitative measurements of the surgical exposure area around the circle of Willis and parasellar regions, as well as angular and linear exposures of the internal carotid artery (ICA) bifurcation, middle cerebral artery (MCA), midpoint of the anterior communicating artery, and tip of the basilar artery (BA).

Methods: Seven fresh cadavers were dissected at the São Paulo Medical Examiner's Office, SP, and three at the skull base laboratory of Weill Cornell Medical College, New York, USA. The craniotomies were performed sequentially, initially with the LSO craniotomy followed by the MP. After the craniotomy, the surgical exposure area, craniotomy area, and angular exposures in the horizontal and vertical axes were determined.

Results: The MP craniotomy provided better angular exposure for the ipsilateral MCA, while the LSO craniotomy and BA provided better vertical axis exposures. The LSO craniotomy provided better angular exposure in the vertical axis for the midpoint of the anterior communicating artery and contralateral ICA bifurcation. Regarding surgical exposure and craniotomy area, there were no statistically significant differences.

Conclusion: The MP craniotomy offers a significantly larger surgical exposure compared to the LSO craniotomy, with specific advantages regarding angular exposure to important neurovascular structures. This study provides important quantitative data to guide the choice between these minimally invasive access techniques in vascular neurosurgery.

Keywords: Cerebral aneurysm, Lateral supraorbital, Minimally invasive approach, Minipterional craniotomy

INTRODUCTION

The fronto-temporo-sphenoidal craniotomy, conventionally known as the pterional (PT) craniotomy, established by Yasargil and Fox in 1975 [5,20,22] marks a significant milestone in modern neurosurgery following the advent of the microscope. Enhancing anatomical visualization and neurosurgical access to the frontotemporal operculum, Sylvian fissure, circle of Willis, and anterior cranial base cisterns, the PT craniotomy stands out as a cornerstone in contemporary cranial neurosurgery.[6,8] However, its main limitation lies in the manipulation and retraction of the temporal muscle, often leading to considerable atrophy and damage to branches of the facial nerve. The visible temporal depression following PT craniotomy is attributed to the disruption of ligamentous connections between soft tissues and compromised vascularization to the temporoparietal fascia and superficial temporal fascia during the approach.[12,13]

Since its initial proposal by Yasargil and Fox [22], various technique modifications have been suggested over the years, primarily focusing on alternative dissections and reconstruction techniques, such as interfascial and subfascial dissections and the use of retrograde dissection. Among these, new craniotomy proposals have emerged as alternatives to the PT craniotomy, notably the lateral supraorbital (LSO) craniotomy[11] and the mini-pterional (MP) craniotomies.[18]

In the age of minimally invasive techniques, the supraorbital approach was initially proposed by Reisch and Perneczky[17] and modified by Hernesniemi *et al.*[11] into the LSO craniotomy. This approach serves as an alternative to the PT craniotomy, omitting extension to the temporal muscle while providing adequate access to the sellar, para-sellar, supra-sellar, and retro-sellar regions, as well as the vascular structures of the circle of Willis.[15] In the LSO approach, the musculocutaneous flap is opened in a single layer, with dissection limited to the anterior portion of the temporal muscle. Partial dissection of the temporal muscle reduces the risk of temporomandibular joint problems, chewing difficulties, mouth opening limitations, and late disfiguring muscle atrophy. The branch of the facial nerve to the temporal muscle remains unaffected as it is neither exposed, dissected, nor sectioned. Due to its relatively short incision and small bone flap, closure is simplified.[1]

The MP craniotomy, described by Figueiredo *et al*. in 2007, was proposed as an alternative to the classical PT craniotomy to offer similar surgical corridors but with smaller incisions, leading to improved cosmetic and functional outcomes without compromising neurosurgical exposure.[4,10]

Our objective was to assess the surgical exposures provided by both the LSO and MP approaches. This was accomplished through measurements of surgical exposure areas surrounding the circle of Willis, as well as angular exposures in both the horizontal and vertical axes, to provide robust anatomical data that might clarify the distinctions between these approaches.

MATERIALS AND METHODS

Anatomical fresh cadaveric dissections were used within 24 h after death, and pertinent measurements were performed after institutionally approved by the Research Ethics Committee, under number 4640664 de 09 de abril de 2021(University of São Paulo). In addition, three formalin-fixed and injected with red and blue colored silicone rubber were carefully dissected at Weill Cornell University, New York, USA.

The approach was performed unilaterally in four specimens and bilaterally in three specimens, totaling ten sides. Cadavers were positioned in a supine position, with the head securely immobilized using a *Mayfield* headrest, simulating the typical neurosurgical positioning. A brain retractor (*Codman Greenberg, Phoenix, Arizona, USA*) was employed with minimal pressure on the cerebral tissue. The measurements were performed using a neuronavigation system (*Artis Eximus, São Paulo, Brazil*).

To mitigate bias resulting from individual anatomical differences, the craniotomies were systematically conducted in the same cadaver, beginning with the MP craniotomy and subsequently proceeding to the LSO approach [Figure 1]. Measurements were taken for each of the two approaches.

The MP technique was performed initially as described by Figueiredo *et al*.[4] Extensive microsurgical dissection of the Sylvian fissure and basal cisterns was performed [Figure 2a]. Following this, the LSO approach was implemented in accordance with the technique outlined by Hernesniemi *et al*.[11] [Figure 2b].

Quantification

Area of exposure

After each craniotomy, a data point was acquired by touching the tip of the digitizing probe to the anatomic points of interest while its position was recorded with cameras. The computer connected to the system recorded the x, y, and z data to locate each point of interest. The retractor was secured firmly to prevent measurement errors while the points were located spatially.

The exposure area was determined by a hexagon bounded by the points of interest (POI) around the circle of Willis. Anatomical targets were defined according to the surgical experience of the authors (EBF and RMLA) and based on relevant structures that could be reached with these craniotomies. Six points were used: (1) lateral aspect of the superior orbital fissure in the ipsilateral sphenoid wing; (2) bifurcation of the middle cerebral artery (MCA); (3) the most posterior point of the ipsilateral posterior cerebral artery;

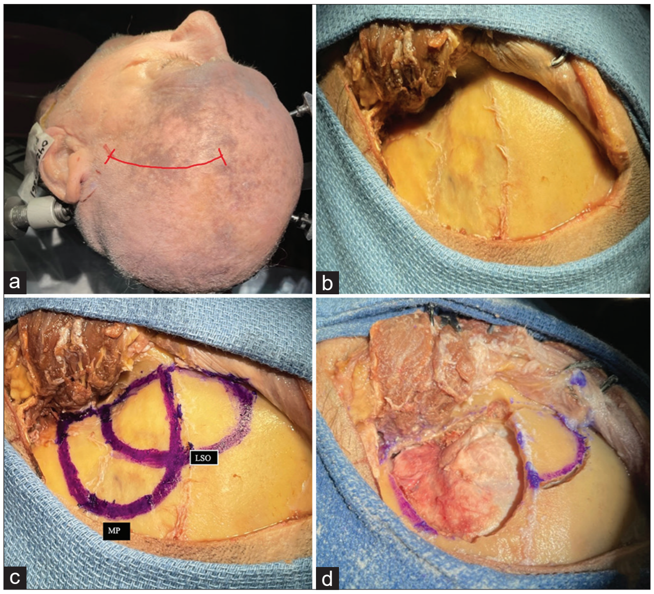

Figure 1: Stepwise dissection in the lateral supraorbital and minipterional approach. (a) Positioning and marking of the incision for performing LSO and MP craniotomies on the left side; The curve define the skin incision made for the approach (b) after retracting the musculocutaneous flap, revealing the anatomical landmarks and reference points for the LSO and MP craniotomies; (c) marking of the LSO and MP craniotomies; and (d) exposition after performing the MP approach and the visualization before opening the dura mater. LSO: Lateral supraorbital, MP: Minipterional.

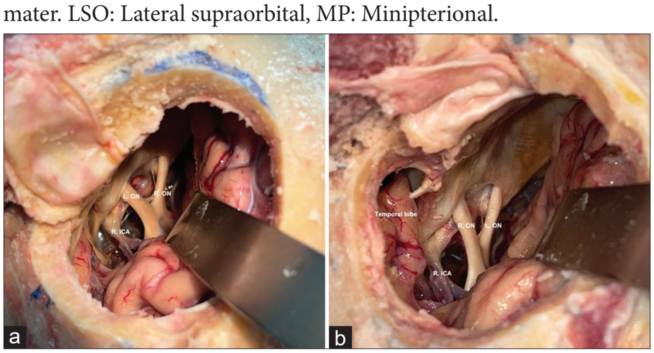

Figure 2: Surgical view of the intradural space provided by the lateral supraorbital craniotomy (a) and the minipterional craniotomy (b) of the left side. ICA: Internal carotid artery, L: Left, ON: Optic nerve, R: Right.

(4) the most posterior point of the contralateral posterior cerebral artery; (5) the most distal point of the contralateral MCA; and (6) the farthest lateral point of the contralateral lesser wing of the sphenoid [Figure 3].

Angular exposure

The angles of approach in the vertical and horizontal planes were utilized to assess angular exposure. The angular exposure area was determined for the six most relevant structures in vascular neurosurgery, including (1) ipsilateral MCA bifurcation; (2) ipsilateral internal carotid artery (ICA) bifurcation; (3)

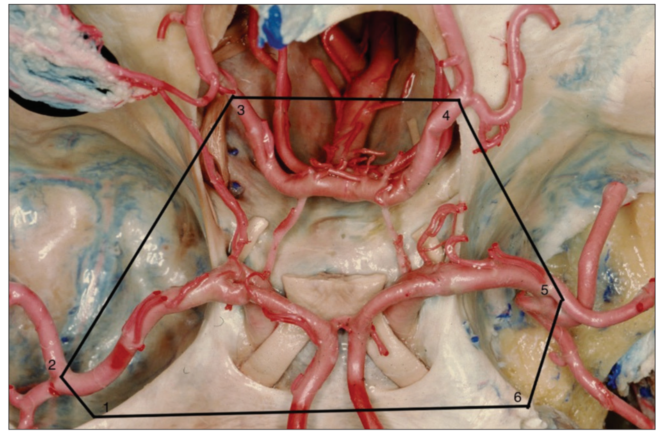

Figure 3: Photograph in superior view of the base of the skull of an anatomical specimen with an illustrative drawing of the six anatomical points used in the calculation of the exposure area for each craniotomy. (1) Most lateral point of the superior orbital fissure in the lesser wing of the ipsilateral sphenoid bone; (2) bifurcation of the ipsilateral middle cerebral artery; (3) most distal point of the ipsilateral posterior cerebral artery; (4) most distal point of the contralateral posterior cerebral artery; (5) most distal point of the contralateral middle cerebral artery; and (6) most lateral point in the lesser wing of the contralateral sphenoid bone. Courtesy of the Rhoton Collection, American Association of Neurological Surgeons/Neurosurgical Research and Education Foundation.

apex of the basilar artery (BA); (4) midpoint of the anterior communicating artery; (5) contralateral carotid bifurcation; and (6) most distal point of the contralateral MCA. Angular exposure was attained by calculating the relationship of these structures with the boundaries of the craniotomy along the horizontal and vertical axes, as defined by the neuronavigation mapping system. The horizontal axis is parallel to the skull base, and the vertical axis is perpendicular to the horizontal axis.

After acquiring values for each predetermined point of interest, a 3D spatial calculator (*GeoGebra*) was employed to compute areas and obtain data on surgical exposure, craniotomy area, and angular exposure [Figure 4].

Statistical analysis

The data were analyzed as two different groups, LSO and MP. For descriptive purposes, the data were presented as means and standard deviations. Statistically relevant results were analyzed using parametric tests (Student *t*-test). $P < 0.05$ was considered significant. All tests were calculated using the software Prism 10 (Macbook- Osx).

RESULTS

Area of exposure

The total surface area of surgical exposure for LSO craniotomy was 1355.70 ± 174 mm^2 and 1371.70 ± 251 mm^2

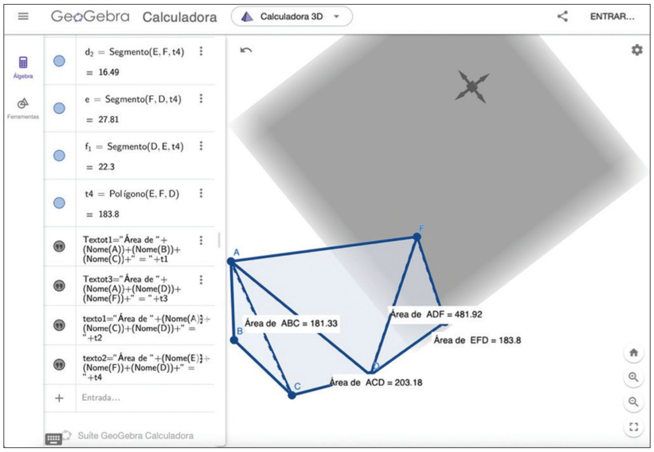

Figure 4: Image of the hexagon and areas obtained in GeoGebra with the surgical exposure, including respective points of interest and obtained areas.

for MP ($P > 0.05$). The results for ipsilateral areas were 227.2 ± 118.40 mm² for LSO craniotomy and 238.80 ± 94.3 mm² for MP ($P > 0.05$). Contralateral areas were 191.70 ± 55.3 mm² for LSO and 185.4 ± 35.6 mm² for MP ($P > 0.05$). Intermediate areas were 623.60 ± 123.30 mm² for LSO and 641.60 ± 106.50 mm² for MP craniotomy ($P > 0.05$). The results are presented in Tables 1 and 2. Therefore, there were no statistically significant differences between the total area and its components in the two craniotomies.

Horizontal angle of exposure

The angles for the ipsilateral MCA bifurcation were 40.47 ± 7.37° for LSO craniotomy and 47.28 ± 7.29° for MP ($P > 0.05$); for the ICA bifurcation, they were 41.64 ± 5.92 for LSO and 38.36 ± 3.79 for MP ($P > 0.05$); for the apex of the BA, they were 33.76 ± 2.59° for LSO and 30.64 ± 3.21° for MP ($P > 0.05$); for the midpoint of the anterior communicating artery, they were 37.58 ± 2.75° for LSO and 33.85 ± 2.35 for MP ($P = 0.0019$); for the contralateral ICA, they were 35.52 ± 3.30 for LSO craniotomy and 30.60 ± 2.86 for MP craniotomy ($P = 0.0014$); and for the contralateral MCA bifurcation, they were 30.58 ± 3.98° for LSO craniotomy and 27.10 ± 3.20 for MP ($P > 0.05$). The results are summarized in Table 3. Therefore, there was a statistically significant difference between the midpoint of the anterior communicating artery and the contralateral ICA, favoring the LSO approach.

Vertical angle of exposure

The angles for the ipsilateral MCA bifurcation were 35.18 ± 7.96° for LSO craniotomy and 47.51 ± 9.91 for MP ($P = 0.0156$); for the ICA bifurcation, they were 31.96 ± 2.67 for LSO and 38.92 ± 5.15 for MP ($P > 0.05$); for the apex of the BA, they were 25.60 ± 2.30 for LSO and 28.86 ± 1.75 for MP ($P = 0.0085$); for the midpoint of the anterior communicating artery, they were 28.31 ± 2.61 for LSO and 30.03 ± 3.66 for MP ($P > 0.05$); for the contralateral ICA, they were 25.77 ± 3.37 for LSO craniotomy and 26.61 ± 4.08 for MP craniotomy ($P > 0.05$); and for the contralateral MCA, they were 22.50 ± 2.50 for LSO craniotomy and 23.62 ± 3.39 for MP ($P > 0.05$). The results are summarized in Table 3. Therefore, there was a statistically significant difference between the ipsilateral MCA bifurcation and the apex of the BA, favoring the MP approach.

DISCUSSION

Advancements in microneurosurgery and technology have revolutionized our ability to adopt less invasive techniques, significantly enhancing our surgical capabilities. In both vascular and skull base surgery, the core principles emphasize strategic bone removal to optimize operative exposure while minimizing brain retraction.[7,10] These methodologies are united by a common goal: avoid brain tissue damage while maximizing the surgical field exposure.

Conventionally, the PT craniotomy has been considered the gold standard approach for addressing tumor and vascular pathologies. However, its extensive drilling, potential for esthetic deformity, patient dissatisfaction, and risk of facial nerve damage have prompted a shift toward alternative approaches.[4,19] The aim is to simplify procedures, expedite surgery, and reduce craniotomy-related complications.

The minimally invasive approaches discussed herein provide access to a range of pathologies in the anterior segment of the circle of Willis, Sylvian fissure, and the interpeduncular fossa. These approaches boast several advantages over the standard PT craniotomy, including fast craniotomies, minimized trauma, heightened safety for the facial nerve, favorable cosmetic results, preservation of muscle function, and improved pain management.[3,4,9-11,16]

While several clinical series have demonstrated the feasibility of these minimally invasive approaches, there remains a scarcity of objective quantitative data comparing the working space between the LSO and MP approaches. Further, research in this area is essential to understand the comparative benefits and limitations of each technique.

No statistically significant variances were detected in the surgical exposure areas among the assessed approaches in this study. The anatomical exposure remained consistent irrespective of the extent of the craniotomy performed. It appears that bone removal primarily amplifies the working angles accessible to the surgeon rather than directly expanding the surgical exposure area. Interestingly, a similar extent of visualization and dissection of the subarachnoid space was achieved regardless of the chosen technique.

Table 1: Microsurgical area of exposition in mm^2 of lateral supraorbital and minipterional craniotomies.

Craniotomy	Total area	Ipsilateral area	Intermediate area	Contra-lateral area
Lateral supraorbital	1355.7±174	227.2±118.4	623.6±123.3	191.7±55.3
Minipterional	1371.7±251	238.8±94.3	641.6±106.5	185.4±35.6

Table 2: Area of the lateral supraorbital and minipterional craniotomies in mm^2.

Craniotomy	Total area
Lateral supraorbital	855.8±188.5 mm^2
Minipterional	727.57±89.52 mm^2

Table 3: Angular exposure in H and V degrees.

	LSO	MP	*P*-value
Ipsilateral MCA	H 40.47±7.37	47.28±7.29	0.1058
	V 35.18±7.96	47.51±9.91	0.0156*
Ipsilateral ICA	H 41.64±5.92	38.36±3.79	0.1192
	V 31.96±2.67	33.92±5.15	0.2856
Basilar artery	H 33.76±2.59	30.64±3.21	0.0902
	V 25.6±2.3	28.86±1.75	0.0085*
AcomA	H 37.58±2.75	33.85±2.35	0.0019*
	V 28.31±2.61	30.03±3.66	0.2133
Contralateral ICA	H 35.52±3.3	30.6±2.86	0.0014*
	V 25.77±3.37	26.61±4.08	0.6540
Contralateral MCA	H 30.58±3.98	27.1±3.2	0.0701
	V 22.5±2.5	23.62±3.39	0.6827

*Difference with statistical significance. H: Horizontal, V: Vertical, AcomA: Anterior communicating artery, ICA: Internal carotid artery, MP: Minipterional, MCA: Middle cerebral artery, LSO: Lateral supraorbital

Notably, the dissection of the Sylvian fissure, whether on the same side or opposite side, could be accomplished to a comparable degree in both approaches.

In contrast to the area, angular exposure is enhanced by working within the superficial portion of the craniotomy, achieved through bone removal. Wider angles facilitate multidirectional maneuverability and provide a more accommodating surgical pathway, thereby reducing the necessity for brain retraction. Our findings indicate a statistically significant discrepancy between the horizontal angles at the ipsilateral MCA bifurcation and the apex of the BA. The MP approach offers a superior horizontal working angle compared to the LSO craniotomy.

Similarly, a statistically significant distinction was noted in the vertical angles between the midpoint of the anterior communicating artery and the contralateral ICA. The LSO approach yields a superior vertical working angle compared to the MP craniotomy. Such angular disparities are achieved through bone drilling, emphasizing the trade-off involved.

Our findings are corroborated by previous anatomical studies[4,14,21] and clinical series showing excellent results.[2,9-11] The LSO surgical approach provides a view that exposes the anterior communicating artery complex, optic chiasm, and both optic nerves from the anterior perspective. This is achieved through a subfrontal trajectory combined with dissection of the proximal Sylvian fissure. Conversely, accessing the interpeduncular cistern region may be better facilitated by employing the MP approach. This approach provides a lateral view trajectory and allows for a broader dissection of the Sylvian fissure compared to the LSO, which exposes the fissure only initially. Moreover, the MP approach offers a shorter distance and wider space to the interpeduncular fossa and the carotid-oculomotor corridor. In addition, thanks to its more extensive Sylvian fissure dissection, the MP craniotomy is better suited for lesions in the middle fossa and Sylvian fissure.

A thorough comprehension of the anatomical exposure associated with a particular neurosurgical approach can improve the decision-making process when choosing the appropriate approach. Moreover, tailored techniques exist for both approaches, enabling enhanced local exposure when addressing specific areas. Ultimately, the selection of approach should be guided by the pathology and treatment objectives tailored to the patient's needs.

Finally, both the LSO and MP approaches can be adapted based on the characteristics of the lesion, enabling a lesion-specific surgical strategy rather than employing traditional techniques for various lesions.

Limitations

In this study, cadavers were utilized, acknowledging inherent limitations regarding retraction or structural shrinkage despite efforts to maintain consistency in these variables. Specifically, our investigation employed fresh cadavers, recognized as a more dependable model for anatomical studies. Tissue properties such as consistency and resistance persist even hours after death, providing a more accurate representation of living patient anatomy.

This study primarily focuses on anatomical aspects to refine microsurgical techniques. It's important to note that we could not replicate clinical risks inherent in actual surgical situations, such as bleeding, brain edema, intracranial lesions, temporal contusion, and postoperative cosmetic outcomes for each craniotomy.

CONCLUSION

Our study offers an objective anatomical analysis comparing the LSO and MP approaches by quantifying morphometric parameters for specific targets. The LSO craniotomy offers comparable anatomical exposure to that provided by the MP craniotomy. It provides good maneuverability to lesions in the anterior communicating artery complex and contralateral ICA. However, it features a narrower surgical corridor to the interpeduncular fossa and the MCA and Sylvian fissure, while the MP craniotomy offers superior visibility and maneuverability for lesions in the interpeduncular area and ipsilateral MCA aneurysms.

Ethical approval

The research/study approved by the Institutional Review Board at Universidade de Sao Paulo, number 4640664, dated September 04, 2021.

Declaration of patient consent

Patient's consent was not required as there are no patients in this study.

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Nil.

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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