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Microsurgical clipping of multiple cerebral aneurysms in the acute phase of aneurysmal subarachnoid hemorrhage through a minipterional approach: The Chilean experience

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ABSTRACT

Objective: The minipterional craniotomy (MPTc) has been widely accepted as a minimally invasive alternative to the pterional approach for the treatment of certain small non-ruptured anterior circulation aneurysms. The aim of this study was to determine the effectiveness and safety of the MPTc in the context of a complex and potentially harmful scenario: acute onset of subarachnoid hemorrhage (SAH) in patients harboring multiple intracranial aneurysms (MIA).

Methods: Patients harboring MIA clipped through a unilateral MPTc were selected from four retrospective databases of four high-volume neurosurgical centers. Patients with a Hunt & Hess score 4 or 5 were not considered candidates for clipping through a MPTc. Medical records and radiological images were retrospectively reviewed. Epidemiological, clinical and radiological data, as well as short-term outcome (modified Rankin scale at 6 month-follow-up) were analyzed.

Results: 16 patients harboring 33 aneurysms (16 ruptured, 17 non ruptured) met the inclusion criteria. Each aneurysm size was 5.7 ± 2.1 mm (range 3–11). 12 out of 33 aneurysms were located in the middle cerebral artery (MCA). Anterior communicating (ACom) and MCA aneurysms were the aneurysm locations most commonly ruptured (5 each, 62 %). Complete occlusion was achieved in 32 aneurysms (97 %) and near-complete occlusion in 1 (3%). 13 patients (93 %) were independent at 6 month-follow-up. Mortality rate was 0%. Complications included 1 cerebrospinal-fluid leakage.

Conclusion: When indicated (Hunt Hess < 4), performing a MPTc is safe and effective in aSAH cases with multiple aneurysms.

1. Introduction

Minipterional craniotomy (MPTc) has emerged as a promising approach in the neurosurgical armamentarium for approaching lesions located in the parasellar region and middle cranial fossa [1]. In comparison to the standard pterional craniotomy [2], the MPTc results in a smaller cranial opening offering a similar degree of surgical exposure and maneuverability, while being less invasive to soft tissues [1,3].

Despite the proven feasibility and safety for the treatment of single anterior circulation aneurysms, critics of this approach have pointed out

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several limitations for treating more complex vascular lesions, such as distal middle cerebral aneurysms, midline aneurysms (e.g. anterior communicating aneurysms), giant aneurysms, contralateral aneurysms or cases, in which the brain lacks appropriate relaxation (brain edema, subarachnoid hemorrhage [SAH]) [3–6]. Reduced exposure of the frontal lobe and limited exposure of the most distal Sylvian fissure have been identified as the key determinants for such limitations [1,4].

Indications for the MPTc have been expanded over the recent years [7]. For instance, the MPTc has been demonstrated to be suitable in the treatment of parasellar tumors, paraclinoid region aneurysms, or complex middle cerebral aneurysms [5,8–12]. However, the number of articles describing simultaneous treatment of multiple intracranial aneurysms is much smaller [13].

We report a series of several consecutive patients with aneurysmal subarachnoid hemorrhage and multiple cerebral aneurysms that were successfully treated with a single MPTc. The aim of the present work is to assess the safety and effectiveness of the MPTc for the microsurgical clipping of MIA in patients presenting with SAH.

2. Material and methods

2.1. Patients

Patients with MIA and SAH were selected from a retrospective database of 231 patients with ruptured intracranial aneurysms treated at four different Chilean university hospitals between March 2017 and March 2019. The work was presented to the investigational review board of each institution, which waved the need for obtaining informed consent, in light of the retrospective design of the study and the application of strict patient privacy regulations at each site.

Presence of SAH was diagnosed based on clinical symptoms at presentation to the emergency room and computed tomography findings. In cases of high clinical suspicion, but absence of radiological signs, presence of SAH was ruled out with a lumbar puncture [14]. High resolution CT angiogram, and cerebral angiogram (when available), was performed in patients with diagnosis of SAH. Angiographic studies were only available for diagnostic purposes. Preoperative angiogram was performed in cases in which there was a doubt about the anatomical configuration of the aneurysm or the existence of one or more aneurysms, in accordance to the management protocol approved by the National Health System of Chile [15]. Determination of the ruptured aneurysm causing the SAH was assessed by examining the distribution of the SAH on CT, along with other indirect signs, such as the aneurysm morphology (e.g. margin irregularities, Murphy's excrescences) [16].

Only patients with two or more cerebral aneurysms treated with microsurgical clipping through a single MPTc, as initially described by Figueiredo and colleagues [1], were included. Those patients who underwent different types of cranial approaches or endovascular treatment were excluded from the analysis. Patients presenting with a poor neurological condition (Hunt and Hess 4 and 5) were not considered candidates for a MPTc at our institutions, and they usually undergo larger craniotomies. Hence, patients with a Hunt and Hess grade equal or superior to 4 were excluded from this analysis.

Demographic and clinical patient data were drawn from the medical charts. Among clinical and radiological data, Hunt Hess grade scale, Glasgow Coma Scale, modified Rankin score (mRS) at 6 months follow-up, number of aneurysms, aneurysm location and size, and Fisher grade were recorded.

2.2. Surgical technique: minipterional approach for clipping of multiple aneurysms (Fig. 1)

The technique has been widely described in previous reports [1,9,17]. Briefly, the patient is positioned over the rotator bed with the head slightly hyperextended using the Mayfield headholder. A curvilinear incision of 3–4 inches extending between the midpupillary line and the zygoma is placed behind the hairline. An interfascial dissection is performed and the temporalis muscle is retracted inferiorly, exposing the pterion. A minipterional craniotomy is entirely performed below the superior temporal line. A curvilinear incision is used to open the dura. A linear incision over the Sylvian fissure and the optic sheath can also be used in cases with minimal brain swelling to protect the adjacent neural tissue. Then, the Sylvian fissure is dissected proximally and the optico-carotid cistern is opened to release CSF and induce brain relaxation. Once proximal control is obtained, progressive dissection of the suprasellar and prechiasmatic cisterns, along with distal dissection of the Sylvian fissure allows to expose middle cerebral artery, ipsilateral A1 segment of the anterior cerebral artery, anterior communicating artery, and contralateral A2 (Fig. 2). Lamina terminalis is regularly fenestrated in cases of multiple cerebral aneurysms and SAH, in order to facilitate brain relaxation and reduce the incidence of hydrocephalus [18,19]. The aneurysm presenting with features of ruptured is preferentially exposed and clipped. In case of intraoperative rupture, temporary clipping is used to obtain proximal control, following standard microsurgical techniques. Once the ruptured aneurysm is secured, additional aneurysms are treated following same principles. Thereafter, copious cleansing of the cisterns from subarachnoid blood is achieved with profuse irrigation of up to 2 l of normal saline and diluted papaverine [20]. Finally, the duramater is closed in a watertight fashion, the craniotomy is replaced, and the skin is sutured using standard techniques ().

3. Results

Patients from 4 high volume centers were selected for the present study. Sixteen patients (13 females, 3 males) harboring 33 aneurysms met the inclusion criteria (15 patients had two aneurysms and one patient harbored 3 aneurysms). Patients included were all treated by four junior vascular neurosurgeons (1 neurosurgeon from each center, RMP, JLC, IP, OJP), former fellows of the same formative center, working at different centers in extreme areas of the country. All patients underwent pre- and postoperative CT angiographic studies. Pre and postoperative digital subtraction angiography were performed in 6 cases (42 %). All patients were treated in the acute phase of the onset of the SAH, within the first 48 h of admission, as dictated by the management protocols approved by the National Health System of Chile [15].

Clinical and demographic data of the patients included are displayed in Table 1. The patients' age was 54 $\pm$ 9 year-old. The mean aneurysm size was 5.7 $\pm$ 2.1 mm (all aneurysms), and 6.5 $\pm$ 2.1 mm, if we were only to consider those that were ruptured. Middle cerebral artery aneurysms are the most common ones that were treated in this series (12 out of 33, 36.3 %). Anterior communicating and middle cerebral artery aneurysms were equally represented in the subgroup of ruptured aneurysms (5 out 16 each, 31.25 %). Anterior communicating and middle cerebral artery aneurysms accounted for more than half of the aneurysms included in this study (57.6 % of the total number of aneurysms, 62.5 % of the ruptured aneurysms). At the time of clinical admission, three patients presented with a Hunt & Hess grade 1, four patients with grade 2, and nine with grade 3. Regarding the SAH distribution, 9 out of 14 patients (64.2 %) presented with a Fisher grade of of 3 or 4 (Table 2). Figs. 3 and 4 show examples of patients with aneurysmal SAH and multiple cerebral aneurysms treated through a single MPTc.

Complete occlusion was achieved in 32 out of 33 aneurysms (97 %). One posterior communicating aneurysm was seen to be subtotally occluded (>95 %) in the postoperative angiogram. Since this particular aneurysm was unruptured, it was decided to follow it up with serial CT angiograms. After 2.5 years of follow-up, no significant changes of the residual aneurysm was observed, and the patient did not experience any other complication. Five patients developed clinical vasospasm, 3 of which were managed medically with vasopressors and intravenous fluid, and 2 underwent intraarterial administration of verapamil with radiological improvement in the vessel narrowing. Four patients

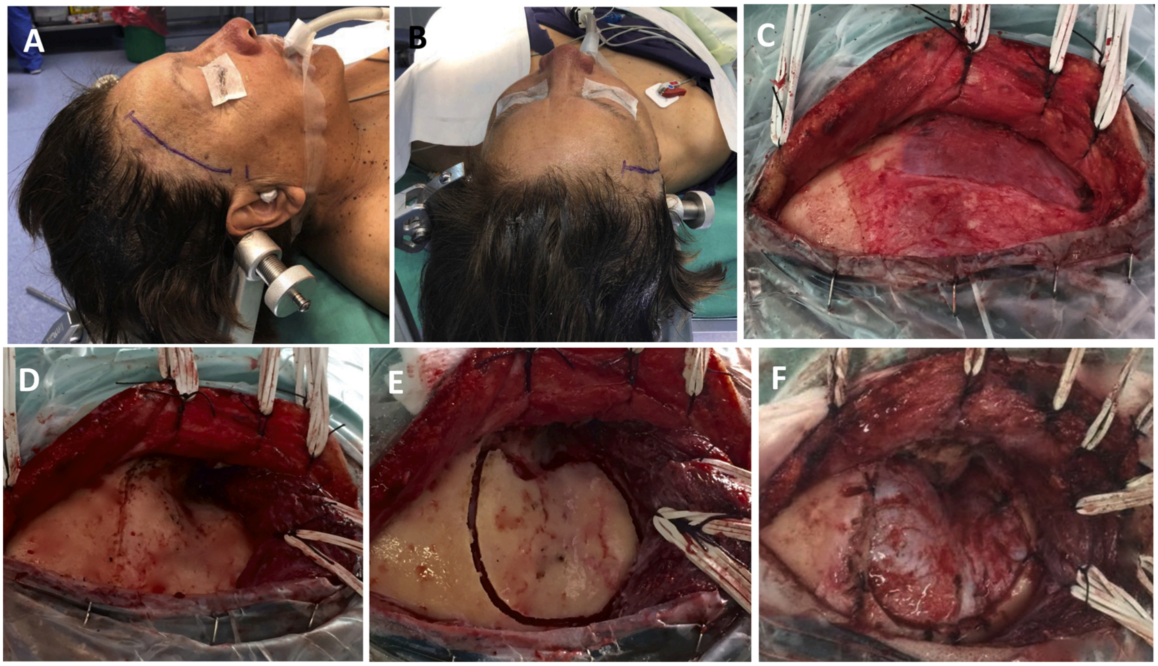

Fig. 2. Stepwise dissection Minipterional approach. A curvilineal skin incision extending from the zygoma to the midpupillary line is performed (A) and the temporalis muscle is dissected using the interfascial technique (B). The temporalis muscle needs to be retracted inferiorly until the pterion is exposed, in order to allow the craniotomy to extend below this limit and expose the temporal dura (C). Once the dura is opened, the minipterional craniotomy allows to perform a proximal Sylvian dissection and obtain a good visualization and surgical maneuverability along the most relevant neurovascular landmarks in the anterior circulation (D). *(ACA = anterior cerebral artery, ICA = internal carotid artery; MCA = middle cerebral artery; ON = optic nerve).*

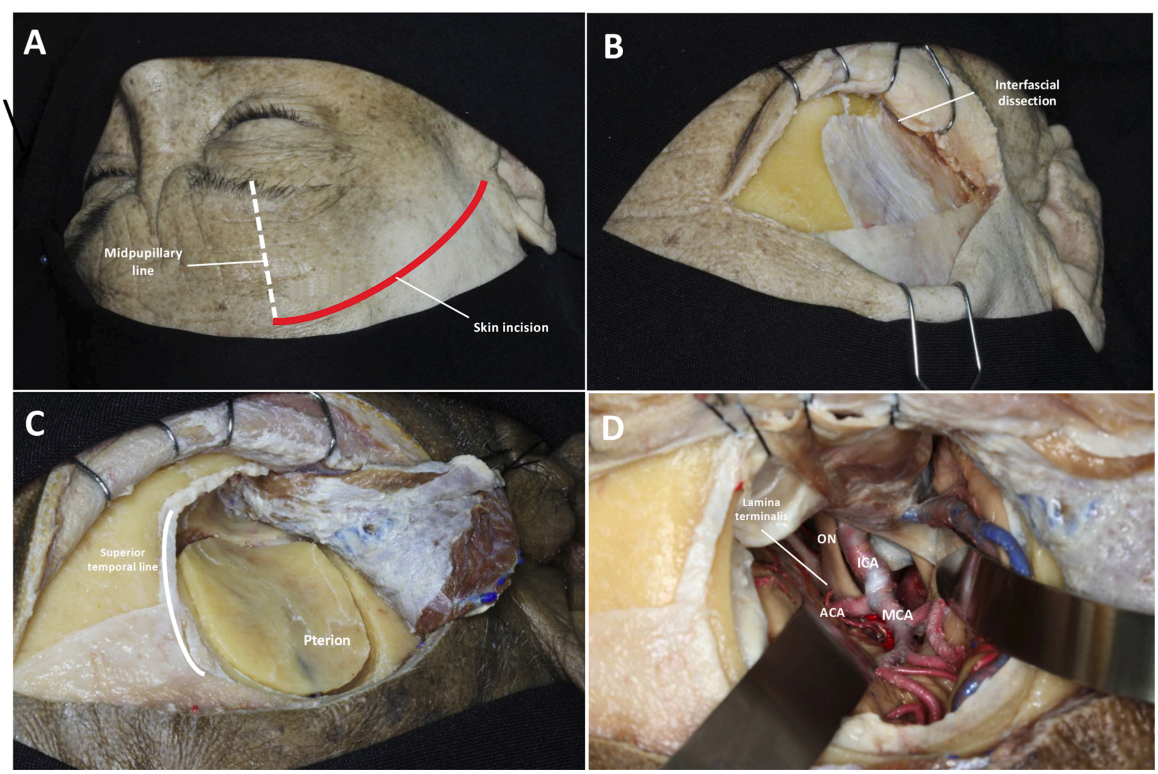

Fig. 1. Patient positioning and minipterional craniotomy. The patient's head is positioned slightly hyperextended over the Mayfield headholder (A, lateral, and B, superior views). A interfascial dissection is performed (C) and the temporalis muscle is pulled downward to expose the pterion (D). The minipterional craniotomy is centered over the pterion and is place below the superior temporal line (E). The minipterional craniotomy allows to expose the temporal and frontal dura (F).

presented with hydrocephalus, requiring external ventricular drainage (EVD) insertion in two of them prior to the surgical intervention. In all patients EVD was removed after the fenestration of the lamina terminalis and successful clipping.

Our patients were followed for and average of 19.7 months (range of 6–42 months). Regarding the functional outcome, 15 patients (97 %)

Table 1
Summary of patients with Multiple Intracranial Aneurysms and Subarachnoid Hemorrhage treated through a Minipterional Approach (* represents the aneurysm with radiological signs and intraoperative confirmation of rupture; ACoA = Anterior Communicating Artery; ACho = Anterior Choroidal Artery; An. = aneurysm; F = Female; HH = Hunt Hess scale; ICA = Internal Carotid Artery; M = Male; MCA = Middle Cerebral Artery; mRS at FU = modified Rankin Scale at 6-month-follow-up; OphA = Ophthalmic Artery; PCoA = Posterior Communicating Artery).

Age, gender	An. location	An. Size	Fisher	HH	mRS at FU	Follow-up (months)	An. Occlusion
42, F	ACoA*	4	3	1	0	42	Complete
	MCA	3					Complete
53, F	ACoA*	8	3	3	3	38	Complete
	MCA	5					Complete
69, M	PCoA*	11	3	3	1	30	Complete
	MCA	3					Complete
71, M	PCoA*	8	4	3	0	7	Complete
	ACoA	9					Complete
41, F	MCA*	4	3	1	0	28	Complete
	ICA	3					Complete
57, F	MCA*	8	3	3	0	6	Complete
	ACoA	8					Complete
62, F	ACoA*	5	2	2	1	6	Complete
	PCoA	4					Complete
55, F	MCA*	7	3	2	0	6	Complete
	ICA	3					Complete
55, F	PCoA*	5	3	2	0	24	Complete
	MCA	4					Complete
47, F	MCA*	7	3	3	0	14	Complete
	ICA	5					Complete
61, F	ICA*	6	3	1	0	10	Complete
	MCA	4					Complete
59, F	MCA*	10	3	2	0	6	Complete
	OphA	5					Complete
45, F	ACoA*	7	4	3	0	26	Complete
	ICA	5					Complete
	PCoA	4					Complete
50, F	Acho*	4	3	2	0	12	Complete
	MCA	7					Complete
40, F	ACoA*	5	2	1	0	32	Complete
	MCA	5					Complete
50, F	Acho*	5	4	3	1	29	Complete
	PCoA	7					Subtotal (>95 %)

Table 2
Demographic, clinical, and radiological data of patients included in the series (ACoA = Anterior Communicating Artery; ACho = Anterior Choroidal Artery; An. = aneurysm; F = Female; HH = Hunt Hess scale; ICA = Internal Carotid Artery; M = Male; MCA = Middle Cerebral Artery; mRS at FU = modified Rankin Scale at 6-month-follow-up; OphA = Ophthalmic Artery; PCoA = Posterior Communicating Artery; Rup = Number of Ruptured aneurysm; T = Total number of aneurysms).

		N or mean ± SD	Percentage or range
Total of patients (N)		16	
Aneurysms		33	
Age		54 ± 9	40 - 71
Gender (M:F)		3 : 13	
Aneurysm location (total / ruptured)			
	ACoA	T = 7; Rup = 5	T = 21.2 %; Rup = 31.3 %
	PCoA	T = 6; Rup = 3	T = 18.2 %; Rup = 18.8 %
	MCA	T = 12; Rup = 5	T = 36.4 %; Rup = 31.3 %
	ICA	T = 5; Rup = 0	T = 15.2 %; Rup = 0%
	OphA	T = 1; Rup = 0	T = 3%; Rup = 0%
	ACho	T = 2; Rup = 2	T = 6.1 %; Rup = 12.5 %
	Total	T = 33; Rup = 16	T = 100 %; Rup = 100 %
Hunt Hess			
	1	4	25%
	2	5	31.3 %
	3	7	43.8%
	4 or 5	0	0%
Fisher			
	1	3	18.8 %
	2	4	25%
	3	6	37.5%
	4	3	18.8 %
Occlusion			
	Complete	32	96.9%
	Subtotal (>95 %)	1	3%
	Partial	0	0%

were independent at 6-month-follow-up (mRS ≤2). One patient, who presented with a diffuse SAH (Fisher 3, Hunt & Hess 3) developed clinical vasospasm that was managed medically as previously stated, obtaining a mRS score of 3 at 6 month-follow-up. Our mortality rate was 0%. Complications requiring further surgery occurred in 1 patient (6%), who suffered a CSF leakage and late-onset hydrocephalus, requiring a reintervention for closure of the dural defect and placement of a ventriculoperitoneal shunt. One patient experienced a temporary frontalis branch palsy that recovered in about a month without requiring additional treatment (Table 2).

4. Discussion

Our results suggest that the MPTc represents a safe and a feasible approach for microsurgical clipping of MIA, also in the context of aneurysmal SAH. The size of the craniotomy has not affected the treatment effectiveness in this group of patients. The present study is in alignment with previous studies, which concluded that utilization of appropriate skull base drilling and adequate microsurgical techniques (basal cisterns opening, brain relaxation, Sylvian fissure dissection) lead to surgical corridors that provide adequate exposure of several aneurysm locations [3,6,9,13,21] (Fig. 5).

Prevalence of multiple intracranial aneurysms among patients with intracranial aneurysms varies between 2 and 45 % [13,22–24]. There has been a growing controversy whether multiple aneurysms should be treated with clipping or endovascular techniques. There are some reports that support the idea that endovascular treatment is, at least, as safe as the microsurgical technique in the treatment of multiple aneurysms [23,25,26]. Most of the recent reports agree, however, that even when endovascular coil occlusion can be achieved for all aneurysms, the operative and radiation time is considerably increased, and each procedure adds extra risk for potential complications, particularly in the context of SAH [23,27–29]. On the other hand, clipping of multiple cerebral aneurysms can be achieved through one single approach, with a similar risk of complications to that experienced by clipping of a single aneurysm [27,29–32]. It could be argued that small aneurysms are not always suitable for emergent surgical treatment, given their low risk of rupture [33–35]. On the other hand, this assumption is contradicted by the fact that the presence of small MIA triples the risk of rupture, which is the reason behind most authors recommendation advocating simultaneous treatment of all aneurysms [16,36].

Considering the advantages of transcranial clipping of MIA in SAH, it is reasonable to develop less invasive techniques that afford similar clinical outcomes, while shortening operative times and improving cosmetic outcomes. Previous anatomical studies have proven that the MPTc provides optimal surgical exposure of most common types of the aneurysm located in the anterior circulation [1,9,37]. While there are some reports proving the surgical feasibility of the MPTc for treating MIA, the role of this approach for treatment of MIA in the setting of an acute SAH has not been completely addressed [13]. The surgical results

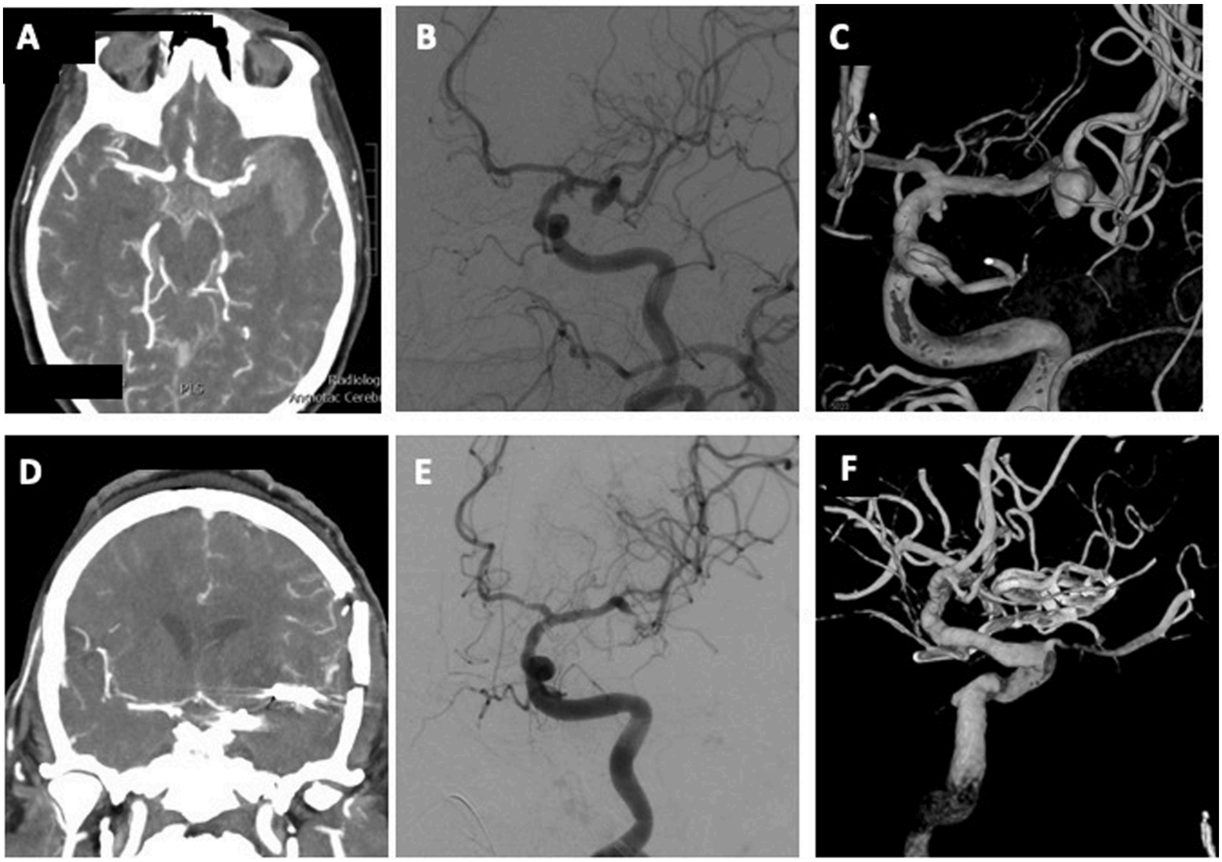

Fig. 3. Case 15 – 40-year-old female presented with a Fisher grade 3 subarachnoid hemorrhage (A). Preoperative diagnostic angiogram demonstrated the presence of a bi-lobulated wide neck anterior choroidal aneurysm and a 7 mm aneurysm located in the bifurcation of the middle cerebral artery (B and C). Postoperative CT angiogram (D) and digital subtraction angiography (D and E) confirmed the complete occlusion of the aneurysms.

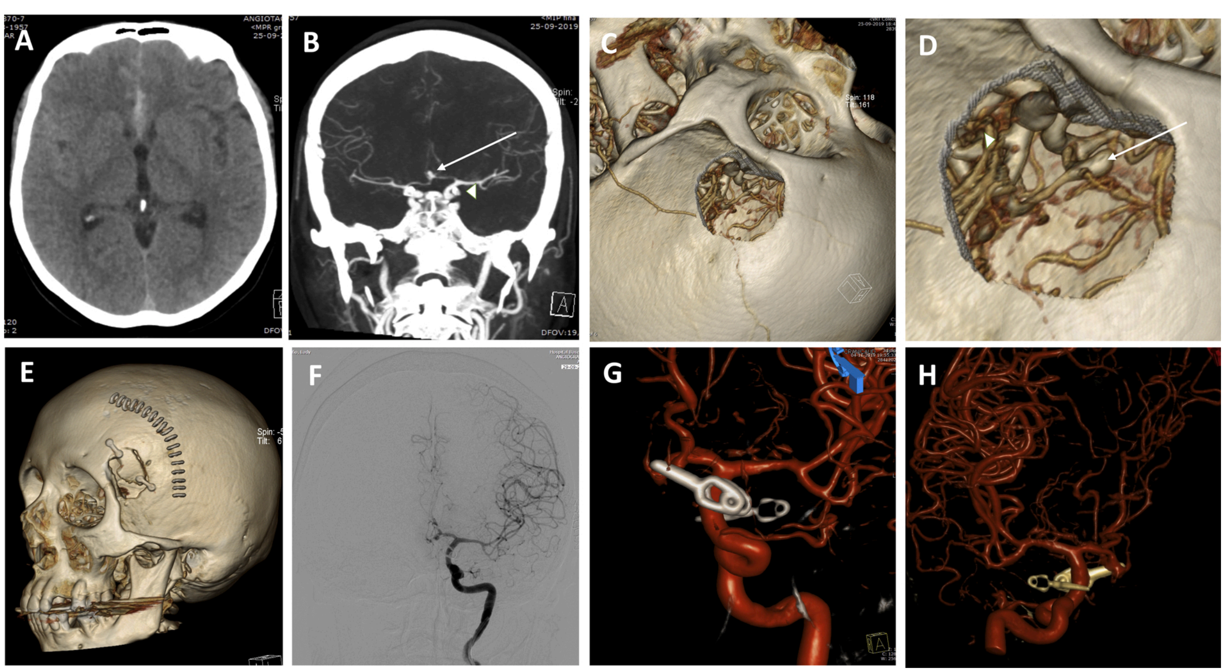

Fig. 4. Case 7 – 62 year-old female with a Fisher grade 2 subarachnoid hemorrhage (A) secondary to a ruptured 5-mm anterior communicating aneurysm (B, arrow head). Preoperative angioCT (B) also demonstrated the presence of a concurrent 4 mm posterior communicating aneurysm (white arrow). Preoperative planning (C and D) provided a 3D view of the anterior communicating (arrow head) and the posterior communicating aneurysm (white arrow). The patient underwent clipping throughout a minipterional craniotomy (E). Postoperative Digital subtraction angiogram (F) and 3D reconstruction (G - anteroposterior view, H – posteroanterior view) demonstrated the complete occlusion of both aneurysms.

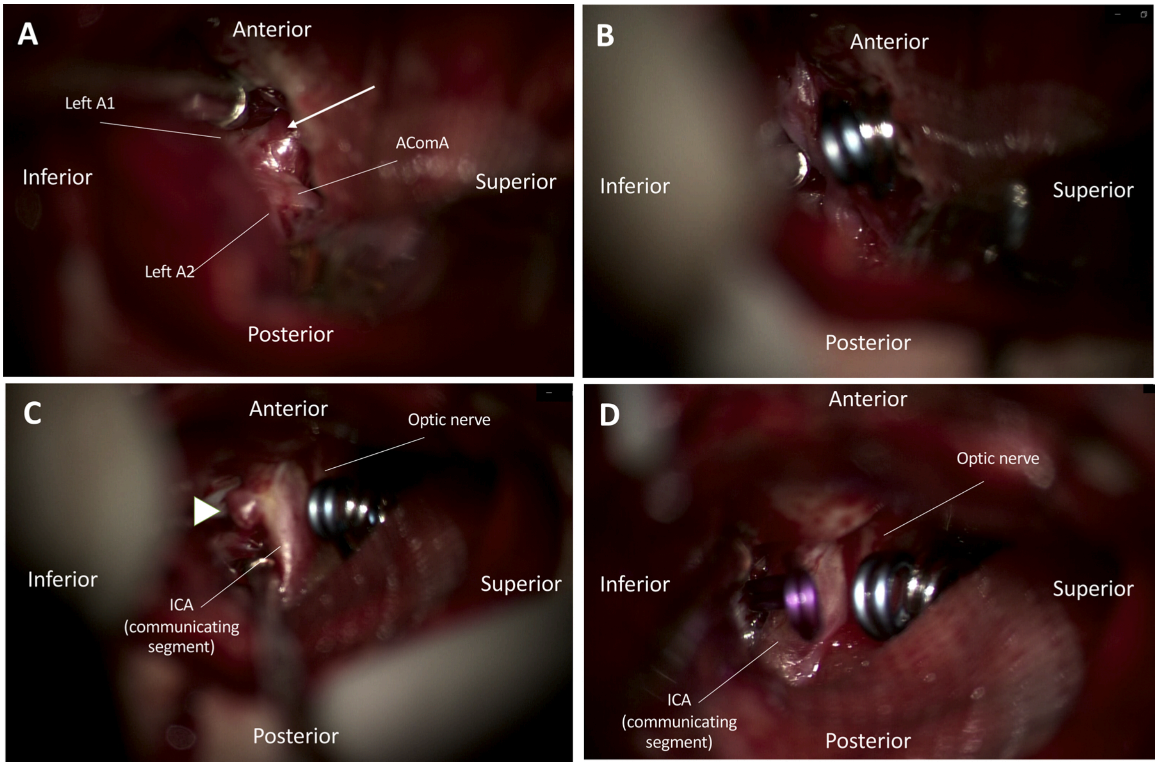

Fig. 5. Case 7. Intraoperative images in case#7 microsurgical clipping of a ruptured anterior communicating aneurysm and a left posterior communicating aneurysm through a left minipterional craniotomy. Once proximal control is obtained, aneurysm dome of the anterior communicating aneurysm is dissected (A, arrow head). Clip positioning must ensure complete occlusion of the aneurysm before dissecting the non-ruptured aneurysm (B). Proximal dissection along the lateral and posterior walls of the internal carotid artery expose the posterior communicating aneurysm (C, white arrow). Final view of the surgical field throughout a minipterional craniotomy (D).

obtained by this group that utilizes the MPTc were, at the least, similar to those described by others that use a more traditional pterional or fronto-orbito-zygomatic (FOZ)craniotomy. Mirzoi and colleagues [30] reported an overall morbidity of 19 % and mortality of 8% in 372 patients, who underwent a pterional craniotomy for surgical clipping of MIA. In a different study, Orz and colleagues [32] treated 221 patients with MIA via pterional or orbit-zygomatic approaches, and obtained excellent results (no neurological deficits) in 51 % of patients and with 73 % of patients being independent at last follow-up. Although the mortality rate in this series was as high as 12.7 %, significantly higher to the one reported in our study, it can be explained by the inclusion of posterior circulation aneurysms and patients presenting with poor neurological condition. In a more recent clinical series, Vega-Basulto and colleagues [38] presented their surgical experience after treatment of 113 patients with MIA that presented with SAH, however, only patients with WFNS grade I and II were included. Although almost 80 % of patients experienced a good recovery (GOS 4–5), the mortality rate was still higher than the one reported in the present study, using standard, traditional craniotomies.

Our results were closer to those experienced by groups that routinely utilize the MPTc for treatment of a large variety of anterior circulation aneurysms. A large systematic review of 1482 patients with 1628 intracranial aneurysms treated through a MPTc demonstrated a complete aneurysm occlusion in 97 % of cases. The rates of postoperative infarction, frontalis palsy and CSF leakage were 2.6 %, 1.2 % and 0.3 %, repectively [13]. Although the number of MIA that were treated were considerably less than in our study (9.9 % vs 100 %) and only a third of cases were treated in the context of a SAH, aneurysm occlusion and complication rate did not differ from the outcomes we are reporting, and both were significantly better than those obtained with the supraorbital approach [13]. Similarly, Welling and Figueiredo [6] published their clinical experience with 28 patients with intracranial aneurysms (19 ruptured and 9 non-ruptured). While they faced a higher mortality (14.3 %), it is important to note that this was not significantly different to that experienced in the group of patients that underwent a traditional pterional craniotomy [6]. Comparisons between these groups, using MPTc for single aneurysms, and our present work strongly support the goal of achieving an one-time surgical clipping through a MPTc, as it was previously suggested by other authors using larger craniotomies [30,32].

Beyond the enthusiasm derived from these encouraging results, we must highlight the importance of applying strict selective criteria when choosing this less invasive approach. In a previous review, Rychen and colleagues [5] emphasized that the MPTc is as safe as the pterional craniotomy, when performed on properly selected patients. In our study, patients with Fisher grades 3 and 4 were successfully treated through a MPTc, although any patients with poor neurological grade (Hunt Hess 4 and 5) were excluded. In accordance to the results reported in the largest randomized controlled trials, patients with poorer neurological condition at presentation are prone to have worse clinical outcomes after treatment [28,39]. Hence, we do not consider this subgroup of patients to be good candidates for this less invasive approach. Indeed, for those patients with poor neurological status, in which an intracerebral hematoma or infarct were responsible for their neurological deterioration, a large craniotomy or hemicraniectomy was indicated, if pupillary response was still present. Cerebral edema compromises the surgical corridors, even when applying maneuvers, such as use of the extradural corridor, skull base drilling, or large sylvian splitting, limiting the surgical maneuverability and the visualization of the operative field [4]. An exception to this rule applies to those patients, in which the deterioration is due to acute post-hemorrhagic hydrocephalus. In which case, an EVD can be inserted prior to performing a MPTc for clipping.

Mirzoi et al. [30] reported a mortality as high as 27 % for patients with MIA located in the posterior circulation. Similar poor results have been reported in the treatment of posterior circulation aneurysms [29, 40]. None of the patients included in this series harbored aneurysms in the posterior circulation. It is true that aneurysm location in the posterior circulation is not a contraindication for open surgical treatment at our centers, nor an exclusion criterion in the present study. However, we acknowledge that treatment of posterior circulation aneurysm through less invasive approaches warrant a separate detailed surgical analysis, and our conclusions should not be extrapolated to this subgroup of aneurysms.

The main limitation is posed by the study design itself. Patients included in our analysis belong to a cohort of carefully selected cases by 4 different surgeons with comparable training experience (vascular and skull base fellowship). Larger series are required to confirm our encouraging results, while it is important to emphasize that appropriate dedicated training in microsurgical techniques is needed to achieve such satisfactory results. As a matter of fact, one of the main criticisms to ISAT study focuses on the lack of training assessment of participating surgeons [39,41,42]. The learning curve is steeper in cases of microsurgical clipping, and larger numbers are required to acquire a certain degree of experience and treatment comfort, in comparison to coiling 41,43]. Several studies have proven that when microsurgical practice is well implemented across a pool of trained surgeons, it results in similar complication, morbidity, and mortality rates to those obtained by endovascular techniques, while ensuring longer treatment durability and a lower retreatment rate [29,44]. The Chilean health care system lacks sufficient numbers of endovascular suites, and, therefore, clipping is grossly overutilized compared to coiling. Each participating neurosurgeon in our series surpasses 30 cases a year, so then it accomplishes with the minimum number of aneurysm clipping interventions required to warrant a safe intervention 43]. As demonstrated, when surgeons have had appropriate microsurgical training, clipping of multiple aneurysms through a MPTc in the context of SAH is safe and effective in patients with good or moderate neurological condition (Hunt Hess 1–3).

Highlighting, however, the importance of long microsurgical training to tackle cerebrovascular pathology can wrongly convince some that aneurysm clipping through a MPTc can only be performed successfully by few gifted neurosurgeons. We strongly disagree with such statement. Indeed, all patients included in the present study were treated by junior neurosurgeons with less than 10 years of experience. We believe that microsurgical vascular and skull base skills are required to succeed in the microsurgical treatment of cerebral aneurysm through any approach, and when those techniques are mastered during the training process, they can be efficiently used to tailor the craniotomy size to each individual patient. Previous other reports have sustained these thesis, showing that, if appropriate skull base techniques are applied (temporal fossa peeling, maximal sphenoid ridge drilling, interfascial temporalis muscle dissection, sylvian splitting, wide basal cisterns opening), the MPTc provides excellent degrees of surgical exposure and maneuverability [6,8,9,45].

Another potential drawback of the current study is that only 42 % underwent pre- and postoperative cerebral angiogram. Although none of our patients experienced any complication because of it, we feel that the benefits associated to the cerebral angiogram do not surpass the risks associated to it, especially when lack of availability of cerebral angiography, in some cases, causes a delay on the surgical treatment [46,47]. The protocol established by our National Health System strongly supports treatment of ruptured aneurysms within 48 h [15]. In this regard, our centers followed the same criteria previously proposed by Nagai and colleagues [48], and are also supported by the AHA Stroke Guidelines [14] that state: “CT angiogram is sometimes considered sufficient on its own, when an aneurysm will be treated with surgical clipping”. Still, we agree that the cerebral angiogram is considered the gold standard in the diagnosis of cerebral aneurysms, and such images could have provided additional relevant information to the current manuscript.

5. Conclusion

Despite some limitations, this study supports the MPTc as a feasible and a safe technique for the treatment of multiple cerebral aneurysms in the context of aneurysmal subarachnoid hemorrhage. Larger prospective studies are required to confirm our preliminary results.

Appropriate training in microsurgical techniques and creation of centralized centers for the treatment neurovascular pathology is of paramount importance, in order to ensure optimal care of patients with aneurysmal subarachnoid hemorrhage.

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Declaration of Competing Interest

Authors do not report any conflict of interest relative to the elaboration of this work

Ethical approval and informed consent (to participate and for publication): Informed consent and ethical approval were not deemed necessary by the local ethics in view of the design of the study (retrospective case series study).

Availability of data and material (data transparency): This manuscript has not been previously published in whole or in part or submitted elsewhere for review.

Code availability

Case series. Level of evidence IV

Authorship contribution

Conception and design of study: Rafael Martinez-Perez, Asterios Tsimpas, acquisition of data: Rafael Martinez-Perez, Jorge Mura; analysis and/or interpretation of data: Rafael Martinez-Perez, Asterios Tsimpas. Drafting the manuscript: Rafael Martinez-Perez; revising the manuscript critically for important intellectual content: Asterios Tsimpas, Jorge Mura; Approval of the version of the manuscript to be published: Rafael Martinez-Perez, Asterios Tsimpas, Jose L. Cuevas, Ivan Perales, Oscar Jimenez

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