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Minimally Invasive Surgical Treatment vs. Classic *Pterional Craniotomy* in Ruptured Intracranial Aneurysms of the Anterior Circulation

J Javier Cuellar-Hernandez*, J Ramón Olivas-Campos, Paulo M Tabera-Tarello, Alan Valadez-Rodriguez

Departments of Neurosurgery, Northeast National Medical Center, Monterrey, Nuevo Leon, Mexico. Av. Lincoln y Fidel Velázquez s/n, colonia Nueva Morelos, ZIP 64180, Monterrey México

***Correspondence:** J Javier Cuellar-Hernandez MD, Departments of Neurosurgery, Northeast National Medical Center, Monterrey, Nuevo Leon, Mexico. Av. Lincoln y Fidel Velázquez s/n, colonia Nueva Morelos, ZIP 64180, Monterrey México. Email: javiercueher@gmail.com

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Abstract

Background: The objective of the treatment of intracranial aneurysms is complete, permanent and safe occlusion, obtaining the definitive exclusion of the aneurysm from the cerebral circulation. The *pterional craniotomy* is the most used; we also have safe and effective minimally invasive techniques.

Objective: To determine the prognostic factor of minimally invasive surgical treatment against classic *pterional craniotomy* in ruptured intracranial aneurysms of the anterior circulation.

Materials and Methods: Descriptive, observational, analytical study. UMAE 25 IMSS patients from January 2019 to July 2020 treated with classic *pterional craniotomy* and minimally invasive craniotomy for clipping of ruptured intracranial aneurysms of anterior circulation, surgical time, trans-surgical bleeding, trans-surgical rupture index, presence of CSF fistula, were evaluated, wound infection and days in ICU. Descriptive, comparative statistical analysis, test of X2 and U de Mann.

Results: 50 patients were evaluated, 25 with traditional technique and 25 with minimally invasive, CSF fistula was presented in 2 patients with minimally invasive surgery and 4 with classic *pterional craniotomy* (p=0.32), infection in the wound in classic *pterional craniotomy* was 10% and in the minimally invasive 4% (p=0.55), in the minimally invasive treatment bleeding was 150 ml and in the classic *pterional craniotomy* 500 ml (p=0.001). The mean surgical time in surgery in the minimally invasive was 120 minutes and in the classic pterional 160 minutes (p=0.017). Stay in ICU for the minimally invasive procedure, median of 3, the traditional procedure, median of 4 days, (p=0.143).

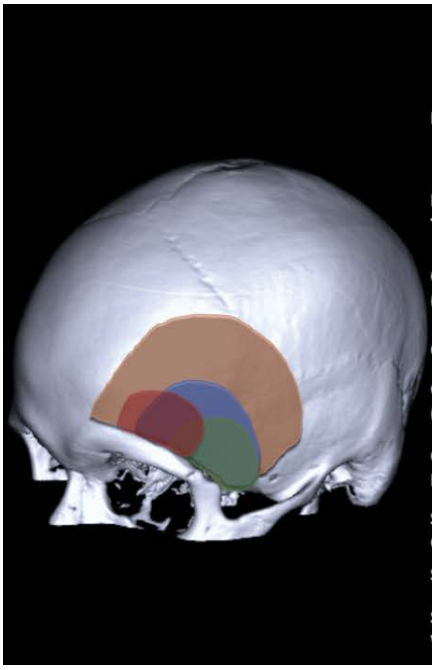
Conclusion: Minimally invasive surgery offers a satisfactory aneurysmal occlusion rate, shorter surgical time, less bleeding, shorter stay in the ICU and a lower rate of post-surgical complications.

Key words: Aneurysms, classic *pterional craniotomy*, minimally invasive surgery.

BACKGROUND

The advent of endovascular techniques has stimulated a shift from neurosurgery to minimally invasive techniques with the goal of improving tolerability, cosmetic outcome, and patient acceptability. Ideally, this should translate into safety and efficacy equivalent to surgery through standard craniotomies, but with the benefit of reduced operative time, postoperative pain and length of hospital stay, and better esthetics [1]. In In this context, the *pterional craniotomy* is the most used for the surgical treatment of aneurysms of the anterior circulation [2,3].

Although the pterional approach is very versatile, it can show various complications, such as atrophy of the temporal muscle, risk of damage to the frontal branch of the facial nerve, and chewing difficulties. Since Yasargil's first description in 19753, various modifications have been developed over time. These are based on alternative dissection and reconstruction techniques, such as interfascial and subfascial exposure of the temporal muscle, to limit the risk of injury to the frontal branch of the facial nerve, [4,5] or the use of retrograde subperiosteal dissection, which has been proposed to minimize muscle atrophy [6]. Thus, we can find 3 main variations of the *pterional craniotomy*: mini-*pterional craniotomy*, supraorbital lateral craniotomy and supraorbital Keyhole craniotomy, which are compared in [Figure 1].



	CLASSIC PTERIONAL	SUPRA ORBITAL KEYHOLE	LATERAL SUPRA ORBITAL	MINI-PTERIONAL
INCISION	BEHIND THE HAIRLINE STARTING AT THE ROOT OF THE ZYGOMATIC ARCH (<1CM FROM THE TRAGUS) PASSING MIDLINE	ON THE EYEBROW OR BEHIND THE HAIRLINE, 2 CM SUPERIOR TO THE ZYGOMATIC ARCH AND UP TO 1 CM BEFORE THE SUPRA-ORBITAL NOTCH	BEHIND THE HAIRLINE, 2 CM ANTERIOR ZYGOMATIC ARCH TOWARDS THE MID PUPILLARY LINE	BEHIND THE HAIRLINE, 2 CM ANTERIOR ZYGOMATIC ARCH TOWARDS THE MID PUPILLARY LINE
DISSECTION OF THE TEMPORAL M.	INTERFACIAL; THE TEMPORAL MUSCLE IS COMPLETELY DISCONNECTED	INTERFACIAL, MINIMAL DISSECTION OF THE TEMPORAL MUSCLE IN ITS ANTERIOR PORTION	MYOCUTANEOUS FLAP, ANTERIO-SUPERIOR TEMPORAL INCISION	INTERFACIAL OR MIOCUTANEOUS FLAP
CRANIOTOMY (LOCATION)	FRONTAL, PTERION AND SQUAMOUS TEMPORAL PORTION	BETWEEN THE ORBITAL NOTCH AND THE FRONTO-ZYGOMATIC SUTURE	BETWEEN THE LATERAL ORBITAL RIM, GREATER WING OF THE SPHENOID AND THE SUPERIOR TEMPORAL LINE	SUPERIOR TEMPORAL LINE, PTERION AND SQUAMOUS PORTION OF THE TEMPORALIS
CRANIOTOMY (SIZE)	6 X 6 CM	2.5 X 1.5 CM	4 X 3 CM	2 X 3 CM
CRANIOTOMY (SPHENOIDAL DRILLING)	UP TO SUPERIOR ORBITAL FISSURE	OPTIONAL	OPTIONAL	UP TO SUPERIOR ORBITAL FISSURE
CEREBRAL CORTICAL EXPOSURE	FRONTAL AND TEMPORAL LOBES, AND SILVIAN FISSURE	FRONTAL POLE AND ORBITAL GYRUS	INFERIOR FRONTAL GYRUS, EDGE OF SILVIAN FISSURE	INFERIOR FRONTAL GYRUS AND SUPERIOR TEMPORAL GYRUS, SILVIAN FISSURE
SILVIAN FISSURE OPENING	YES	OPTIONAL	OPTIONAL	YES
SURGICAL CORRIDOR	MULTIPLE	SUBFRONTAL	SUBFRONTAL	TRANS SYLVIAN / LATERAL
SUITABLE ANEURYSMS: WELL VISUALIZED	OPHTHALMIC ICA, COMMUNICATING ICA, ACHA, ACOMA, TERMINAL ICA	ACOMA, MCA, COMMUNICATING ICA	ACOMA, MCA, COMMUNICATING ICA, ACHA	OPHTHALMIC ICA, MCA, TERMINAL ICA, ACHA, ACOMA, COMMUNICATING ICA

Figure 1: Comparison between pterional craniotomy and minimally invasive derived approaches. Abbreviations: ICA, Internal Carotid Artery; AchA, Anterior Choroidal Artery; AcomA, Anterior communicating.

Among the variations of minimally invasive craniotomies, most of the experience in the last 20 years has been acquired with the supra-orbital key-hole craniotomy. Aneurysms were located mainly in the middle cerebral artery (29.2% -36.43%), anterior communicating artery (23.0% -46.6%) and internal carotid artery (ICA) communicating segment (13.4% -27.7%) [7-11]. The first series focused on the feasibility of accessing an aneurysm in a certain location using this approach [12,13], while later reports compared the clinical results of patients with ruptured and unruptured aneurysms treated with the supra orbital key hole compared to the classic *pterional craniotomy* [9,13-16].

Functional results were consistently comparable between supra orbital keyhole and classic *pterional craniotomy*. Fischer et al. They reported their 20-year experience with 1297 aneurysm surgeries, in which the supra-orbital key hole constituted 74.7%.12 A good result was reported with a modified Rankin scale ≤2 (mRS≤2) in 96.6% and 72.2% for unruptured and ruptured aneurysms, respectively. Similarly, Radovanovic et al reported a series of cases and paired controls of 30 cases of ruptured aneurysm and 24 consecutive ruptures treated with supra orbital key hole and classic *pterional craniotomy* in which a good result (mRS≤2) was achieved in all unruptured cases and in 91.7% of ruptured cases treated with supra orbital key hole, compared to 86.9% with classic *pterional craniotomy* [11].

Chalouhi et al and Paladino et al, reported comparable results in studies of ruptured aneurysms, where they obtained favorable results with a Glasgow Prognostic Scale ≥4 (GOS≥4) in 76.6% to 82.6% of supra orbital key hole and 75% to 79.5% of the cases of classic *pterional craniotomy* [8].

Intraoperative rupture (IOR) is a factor that can negatively affect the functional outcome of aneurysm surgery, it was analyzed in a systematic review of 9,488 aneurysms treated for supra orbital key hole and classic *pterional craniotomy* for 15 years.13 In general, the IOR rate was 5.8% in supra orbital key hole versus 10.1% with classic *pterional craniotomy*, but among 3,039 ruptured aneurysms, there was a statistically higher IOR rate of 19.4% in supra orbital key hole versus 13.8% with classic *pterional craniotomy* (odds ratio 1.5, 95% confidence interval 1.003-2.119, P <0.05). Compared with the results of Radovanovic et al. and Chalouhi et al. IOR rates for supra orbital keyhole were 12.5% and 10.6% for classic pterional craniotomy [16,17]. Caplan, et al. reported their experience of 82 unruptured aneurysms treated with mini-pterional craniotomy for 4.5 years, which as arterial topography included MCA (44%), PComA (27%) and ICA ophthalmic segment (27%). 18 84.2% of the aneurysms were clipped, 13.4% were wrapped with cotton wool and fibrin glue, and the average length of hospital stay was 4.0 days. Welling et al conducted a randomized trial that

evaluated the clinical, functional, and aesthetic outcomes between mini-*pterional craniotomy* and classic *pterional craniotomy* for ruptured and ruptured aneurysms. Between the 2 groups, similar mRS scores, mortality, IOR rates (14% for mini *pterional craniotomy vs*. 17% for classic *pterional craniotomy*), but higher aesthetic satisfaction results were observed (79% vs. 52% respectively, P=0.07) and significantly reduced degree of temporal atrophy (14.9% versus 24.3%, P <0.01) for mini-*pterional craniotomy* [18].

Other benefits of minimally invasive craniotomies may include reduced operative time, length of hospitalization, and costs [7,11,19]. Radovanovic et al reported that the duration of minimally invasive surgery was approximately half that of craniotomy Classic pterional for ruptured and unruptured aneurysms, and for unruptured aneurysms, the length of stay was reduced from an average of 4.3 to 2.3 days [20]. This translated into significantly lower overall treatment costs for unruptured aneurysms due to shorter length of stay. Cha et al reached similar conclusions about the reduction of surgery time and length of hospitalization in a series of 61 patients in whom the supra-orbital keyhole compared with the classic *pterional craniotomy* in cohorts that have similar demographics and aneurysm locations [7].

MATERIALS AND METHODS

Patient Selection

After Institutional Review Board Approval, a retrospective chart review was conducted of patients diagnosed with ruptured intracranial aneurysms of the anterior circulation treated by clipping with classic *pterional craniotomy* and minimally invasive surgery (mini-pterional, supra orbital and supra orbital lateral keyhole), January 2019 as of July 2020. Inclusion criteria were as follows: (1) Women or men over 18 years of age, (2) angiographic diagnosis ruptured intracranial aneurysms of the anterior circulation, (3) patients treated with classic *pterional craniotomy* or minimally invasive surgery. Patients were excluded if (1) received endovascular treatment for coil application in ruptured intracranial aneurysms of the anterior circulation, (2) angiographic diagnosis of intracranial aneurysms of the posterior circulation, and (3) clipping of unruptured intracranial aneurysms of the anterior circulation.

Data Collection and Statistical Analysis

Demographic information was collected from patient chart review. The sample was divided into two groups: (1) Patients undergoing classic *pterional craniotomy*, and (2) Patients undergoing minimally invasive treatment (mini-pterional, supra-orbital and supra-orbital lateral keyhole), evaluating surgical time, trans-surgical bleeding, index of trans-surgical rupture, presence of cerebrospinal fluid (CSF) fistula or wound infection and days in intensive care unit. It will be analyzed with absolute frequencies and percentages, a comparative analysis between both groups (1 and 2) will be carried out for the independent variables established for our study: using X2 test or Fisher's exact test; a p <0.05 was considered significant. Furthermore, the odds ratio was obtained to estimate the magnitude of the association between variables, with its 95% confidence interval. The statistical program IBM SPSS 19.00 was used.

RESULTS

Fifty patients were included in this study with a predominance of females (M=33 66%, H=17 34%), there was no significant difference in age with 57 ± 13.6 (± SD) for classic *pterional craniotomy* and 55 ± 16 for minimally invasive treatment (p=0.080). The most frequent location of the aneurysm was the communicating segment internal carotid artery (38%) followed by the middle cerebral artery (20%). There was no significant difference in the day of evolution of Subarachnoid Hemorrhage (SAH) in which surgery was performed, being a median of 13 days for the classic *pterional craniotomy* and 18 for the minimally invasive treatment (p=0.20).

In the Trans and postoperative variables, the surgical bleeding was 168 ± 93.4 for the minimally invasive treatment and 518 ± 391 for the classic pterional craniotomy (p=0.001). In the surgical time, the minimally invasive treatment presented a median of 120 minutes compared to the classic *pterional craniectomy* with 160 minutes (p=0.017) significant in favor of the minimally invasive treatment. IOR occurred in 5 patients (10%), 4 in classic pterional surgery and 1 in minimally invasive surgery specifically with a mini-*pterional craniotomy* (p=0.162). The presence of CSF fistula was reported in 2 of those treated with minimally invasive surgery (1 with supra orbital keyhole and 1 with mini-pterional) and 4 of those treated with classic *pterional craniotomy* (p=0.32). There was infection in the wound after the classic *pterional craniotomy* in 10% of the patients who underwent this procedure, in the minimally invasive surgery it was 4% (p=0.55). When analyzing the days of ICU stay, no significant difference was observed; we found a median stay of 3 days in the minimally invasive procedure compared to the traditional procedure with a median of 4 days (p=0.143). Clinical, pre-surgical and post-surgical characteristics classified according to the type of surgical treatment are summarized in [Table 1].

Table 1. Clinical, pre-surgical and post-surgical characteristics of 50 patients with ruptured aneurysm classified according to the type of surgical treatment.

		Type of treatment		
	Total (n=50)	Classic Pterional Craniotomy (n=25)	Minimally invasive treatment (n=25)	*p*
Age (years)	56±14.7	57±13.6	55±16	0.808
Female	33 (66%)	16 (48.4%)	17 (51.6%)	0.089
Male	17 (34%)	9 (52.9%)	8 (47.1%)	
Location of the aneurysm				
ICA communicating segment	19 (38%)	5 (26.3%)	14 (73.6%)	0.005
Middle cerebral artery	10 (20%)	5	5	
ICA bifurcation	7 (14%)	7	-	
ICA choroidal segment	6 (12%)	4	2	
Anterior communicating artery	5 (10%)	1	4	
Anterior cerebral artery	3 (6%)	3	-	
Minimally invasive treatment modalities				
Supra orbital keyhole	-	-	9 (36%)	-
Mini-pterional	-	-	8 (32%)	-
Lateral supra orbital	-	-	8 (32%)	-
SAH Evolution Days	15±5.4	14±6.0	16±4.7	0.202
Intraoperative bleeding (ml)	343±332.2	518±391	168±93.4	0.000
Surgery time (minutes)	129±62.8	152±69.1	106±46.3	0.017
Intraoperative aneurysmal rupture	5 (10%)	4 (80%)	1 (20%)	0.162
CSF fistula	6 (12%)	4 (66%)	2 (34%)	0.389
Surgical wound infection	3 (6%)	2 (66.6%)	1 (33.3%)	0.018
ICU stay	4±2.5	4±2.7	3±2.2	0.143

ICA = Internal Carotid Artery

Results are presented as mean, ± SD or absolute frequencies (percentages)

DISCUSSION

Due to recent advances in the clipping technique, microscope optics and a better understanding of micro neuroanatomy, it has been possible to treat intracranial aneurysms of the anterior circulation with minimally invasive techniques [9,12,16,21,22]. In the service of Neurosurgery UMAE 25 as of 2019, minimally invasive surgery began to be used as an alternative to the treatment of intracranial aneurysms, obtaining important favorable results. Until now, there are no studies that comprehensively compare the use of minimally invasive procedures against the use of classical procedures in our country, so we decided to carry out this study with the aim of demonstrating the benefits in relation to surgery time, bleeding and Trans-surgical complications of minimally invasive treatment against classical *pterional craniotomy*.

The most frequent location of aneurysms in this study was in the internal carotid artery communicating segment in 38% (n=19), followed by the middle cerebral artery in 20%, in a series of cases published by Radovanovic et al. Fischer G et al report the location of aneurysms mainly in the middle cerebral artery (29.2% -36.43%), anterior communicating artery (23.0% -46.6%) and internal carotid artery (ICA) communicating segment (13.4% - 27.7%). 9,22.

The presence of trans-surgical rupture in our study was found that in classical pterional surgery it is reported in 4 patients (19%), in minimally invasive surgery it is reported in 1 patient treated with mini-pterional surgery (4%) p=0.157 not significant despite registering that there were more patients with trans-surgical rupture in patients who underwent classical pterional surgery. Chalouhi, et al. They reported a trans-surgical rupture rate of 5.8% in supra orbital keyhole versus 10.1% with classic *pterional craniotomy*, but among 3,039 ruptured aneurysms, there was a statistically higher intraoperative rupture rate of 19.4% in supra-orbital keyhole versus 13.8% with craniotomy classical pterional [23-30].

Regarding post-surgical complications, the presence of CSF fistula after the surgical procedure used was the following: presence of CSF fistula in minimally invasive surgery in 1 patient who underwent the supra orbital keyhole and 1 patient The minipterional was performed, that is, in 8% of the patients treated with this procedure; and in classic *pterional craniotomy* surgery, in 24% of the patients treated with this procedure presented a CSF fistula, this agrees with what was reported by Lucio et al who in a series of 68 patients where the classic *pterional craniotomy* was compared with Mini-pterional, this complication was identified only in the classic pterional reported in 5 patients.14 Likewise, they report 2 cases of surgical wound infection similar to the result of our study, with 2 patients undergoing classic *pterional craniotomy* and only 1 patient undergoing minimally invasive surgery.

Regarding surgical bleeding, in the minimally invasive treatment, there was surgical bleeding that varied between: 50ml 12%, 500ml 4% with a median of 150ml of bleeding, in the classic *pterional craniotomy* it is striking that bleeding is reported during this procedure maximum of 1500 ml in 1 patient, and the minimum reported bleeding was 100 ml in 1 patient, with a median of 500 ml, this in favor of minimally invasive treatment, Cha et al obtained similar conclusions on the reduction of trans-surgical bleeding and the duration of the hospitalization of a series of 61 patients in whom the supra-orbital keyhole compared with the classic *pterional craniotomy* in cohorts that have similar demographics and aneurysm locations [7].

In the surgical time we found that the minimally invasive treatment presented a median of 120 minutes compared to the surgical time of the classic pterional craniectomy, the median reported was 160 minutes. Radovanovic et al. noted that the duration of minimally invasive surgery was approximately half of the classic *pterional craniotomy* for ruptured and unruptured aneurysms, and for unruptured aneurysms, the length of stay was reduced from an average of 4.3 to 2.3 days [11]. This translated into significantly lower overall treatment costs for unruptured aneurysms due to shorter length of stay.

When analyzing the days of stay in the ICU, we found in the minimally invasive procedure a median of 3 days of stay in the ICU compared to the traditional procedure with a median of 4 days. In the literature, there is no report on days of stay specifically in the intensive care unit due to the different criteria for admission to the unit.

CONCLUSION

In the present study, we compared treatment with classic *pterional craniotomy* (25 patients) with minimally invasive treatment (25 patients) in the 3 main modalities mini-*pterional craniotomy*, supra-orbital lateral craniotomy and supra-orbital Keyhole craniotomy, finding prognostic factors such as such as trans surgical rupture in classic pterional surgery in 4 patients (19%), and in minimally invasive surgery in 1 patient, the presence of CSF fistula after surgery in minimally invasive surgery in 2 patients (8%) and in those treated with classic *pterional craniotomy* 4 patients (24%). There was infection in the wound after the surgical procedure in the classic *pterional craniotomy* in 10% of the patients, in the minimally invasive surgery in 4%, the surgical bleeding in the minimally invasive treatment, the median bleeding was 150 ml, with an average of 350 ml The time required for surgery was shorter, the minimally invasive treatment was reported to be less than 40 minutes, the post-surgical stay in the ICU in the minimally invasive procedure a median of 3 days of stay in the ICU compared to the traditional procedure with a median of 4 days.

Minimally invasive surgery in the treatment of ruptured anterior circulation aneurysms offers a satisfactory aneurysmal occlusion rate, a short surgical time, less blood loss, a short ICU stay, a lower rate of post-surgical complications, and a good overall surgical outcome. This with the main benefit to the patient, both aesthetically and functionally, as well as to the institution due to the significant reduction in the costs it generates, being superior to the classic *pterional craniotomy*.

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Nil.

CONFLICTS OF INTEREST

There are no conflicts of interest.

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