The minipterional approach for ruptured and unruptured anterior circulation aneurysms: Our initial experience

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ABSTRACT

Objective: To report our experience with the minipterional (MPT) craniotomy approach for anterior circulation aneurysms and to discuss the clinical outcomes as well as to evaluate the advantages of this unique approach.

Materials and Methods: Single-center retrospective review of 57 cases involving anterior circulation aneurysms both ruptured and unruptured aneurysms treated with the MPT. We analyzed the clinical and patient demographic data, aneurysm characteristics, surgical outcomes, and complications in these individuals.

Results: Between July 2008 and March 2014, of the 57 patients reviewed: 45 had middle cerebral artery (MCA), 6 had internal carotid artery terminus, and 7 had posterior communicating artery aneurysms. 20 of the 57 patients presented with a ruptured aneurysm. The average aneurysm size was 5.8 mm. The length of hospitalization for unruptured aneurysm cases ranged between 3 and 5 days. The average follow-up for all cases was 21.5 months. Successful clipping of the aneurysms was obtained in all patients. None of the cases required additional skin incisions or craniotomy extensions. The overall surgical outcomes were favorable. There was no postoperative facial nerve damage, temporalis muscle wasting, or symptoms of paresthesias around the incision line. Two patients developed a postoperative stroke manifested as symptoms of unilateral arm and facial weakness, receptive aphasia, and dysarthria.

Conclusion: The MPT provides a reliable and less invasive alternative to the standard pterional craniotomy. Furthermore, ruptured and unruptured anterior circulation aneurysms can safely and effectively be treated with limited bone removal which provides better cosmetic outcomes and excellent postoperative temporalis muscle function.

Key words: Middle cerebral artery, minipterional craniotomy, MPT, ruptured aneurysm, temporalis muscle, unruptured aneurysm

Introduction

In 1899, Wilhelm Wagner (1848–1900) was credited as the first surgeon to raise an osteoplastic temporal bone flap in a living human for the evacuation of an epidural hematoma.[1] In 1900, Fedor Krause successfully recovered a bullet resting on the posterior right orbital plate of the frontal bone near the optic nerve, by performing an extradural subfrontal craniotomy along the lesser sphenoid wing.[2] The origin of the frontotemporal or pterional craniotomy was introduced by Walter Dandy and George Heuer in 1914 with their early work on chiasmal lesions using a hypophyseal approach.[3] Their approach was similar to Krause's, however, their craniotomy involved the temporal and frontal bones with a shorter oblique trajectory along the sphenoid ridge allowing for a larger bone flap with increased exposure. The bone flap was eventually further modified by Dandy and known as the "Dandy flap."[4]

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In 1944, Dandy reported the practice of his approach to treat aneurysms in the anterior cerebral circulation.[5] Subsequently, Ludwig Kempe illustrated in his atlas the placement of the critical burr hole at the psychopathic point, the junction of the temporal line, the zygomatic process of the frontal bone, and the orbital ridge.[6] This "keyhole" modification to the pterional flap has been commonly used for anterior communicating artery aneurysm clipping.[6] With the emergence of the microsurgical techniques era, Yasargil *et al*.[7] refined the pterional approach. Their improvements were different from prior techniques they proposed (1) being more basal with more pronounced sphenoid bone removal, (2) having a wider opening of the Sylvain fissure, (3) having a smaller bone flap.

The pterional craniotomy is a versatile approach used to surgically target a variety of different vascular and nonvascular surgical lesions. Approachable lesions are located in the anterior and posterior cerebral circulation, sellar and parasellar regions, sphenoid wing, cavernous sinus, orbit, anterior and mesial temporal lobe, midbrain, and posterior-inferior frontal lobe.[7-15] Despite the pterional approach being so versatile, it is associated with many complication which includes facial nerve branch injuries, temporalis muscle dysfunction, craniotomy site depression, frontal sinus opening, and cosmetically unacceptable results caused by large areas of skin exposure.[16-19] The need to overcome these complications has been a source of increasing interest in microneurosurgical techniques. Several minimally invasive approaches that reduce the size of the craniotomy and improve the cosmetic outcome have been reported; however, the exposure is suboptimal.[13,20-22]

The minipterional (MPT) approach has been described as an alternative microsurgical approach to the traditional pterional craniotomy.[13] However, the clinical application of this novel technique was not widely reported. The MPT approach provides numerous advantages over the traditional pterional craniotomy without compromising the microsurgical exposure. In short, the MPT technique offers minimal brain tissue trauma, bone removal, a decrease in surgical time, improved cosmetic outcomes, and shorter hospital stays.

The objectives of our study are to present our clinical experience with the MPT craniotomy approach for the surgical management of anterior circulation ruptured and unruputred aneurysms, to discuss the clinical outcomes, and to evaluate the advantages of this novel approach.

Materials and Methods

A retrospective review of 57 cases involving anterior circulation aneurysms from July 2008 to March 2014 treated using the MPT by a single surgeon (KMA) at Allegheny General Hospital in Pittsburgh, PA. Both ruptured and unruptured anterior circulation aneurysms were included in the study. We reviewed and analyzed the clinical and patient demographic data, aneurysm characteristics, surgical outcomes, and complications for each of the 57 patients.

Aneurysm location and characteristics were diagnosed using transfemoral four-vessel cerebral angiography with three-dimensional rotational angiography. All patients underwent computed tomography angiography for not only comparison but also for surgical planning specifically to aid in depicting bony landmarks. The angioanatomic features which favored surgical management included a dome-to-neck ratio ≤ 2, the presence of arterial branches incorporated into the aneurismal neck, and inadequate endovascular treatment options. At our institution, all radiological studies were reviewed by cerebrovascular neurosurgeons and neurointerventionists. Medical and surgical decision-making was based on both teams consensus in conjunction with the patient's preference.

MPT technique

The original technique was described by Figueiredo *et al*.,[13] however; we introduced a few nuances to the approach [Figure 1]. After proper patient positioning, a curvilinear scalp incision is made 1 cm above the zygomatic arch and within 1 cm of the external acoustic meatus. The incision is then extended superiorly and curved gradually up to the superior temporal line and just posterior to the anterior border of the hairline. The scalp flap is then elevated and reflected anteriorly towards the orbit. To prevent injury to the frontotemporal peripheral branches of the facial nerve, a subfascial or interfascial dissection is performed.[17,23] The dissection should then be extended inferiorly to the insertion of both the superior and deep laminae of the superficial temporal fascia on the superior border of the zygomatic arch. The temporalis muscle and fascia is incised between the superior and inferior temporal lines, leaving behind a myofascial cuff for re-approximation at the end of the surgery. In instances when the temporalis muscle is thin, several burr holes are created along the superior temporal line with a drill bit attached to an air-powered drill; then using absorbable sutures through the burr holes, reattachment of the temporalis muscle is achieved. The incision of the temporalis muscle terminates ideally 3 cm above the tragus to avoid postoperative chewing symptoms and temporomandibular joint (TMJ) dysfunction. Using a Penfield dissector #1, the muscular flap is dissected subperiosteally (first from a superior to inferior direction then from an anterior to posterior direction). Dissection difficulties are typically encountered along the sphenoid wing suture lines due to the firm periosteal attachment. Once the temporalis muscle is appropriately incised it is retracted caudally and posteriorly to expose the pterion.

Next, the sphenoid keyhole burr hole is placed at the sphenoidal junction of the pterion. Drilling of the extracranial surface of the greater wing of the sphenoid bone is initiated at the sphenofrontal and the sphenosquamous sutures,

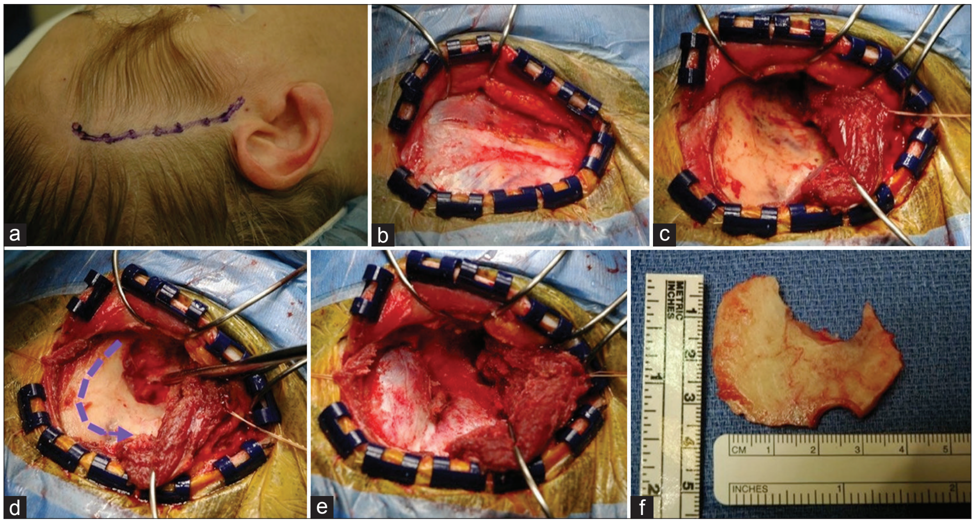

Figure 1: Brief steps of the (MPT) craniotomy approach: (a) The MPT incision: A curvilinear scalp incision starts 1 cm above the zygomatic arch base at the anterior border of the hairline extending superiorly and curving gradually up to the superior temporal line. (b) After the skin flap is reflected, interfascial dissection of temporalis muscle is started. (c) The temporalis muscle is incised leaving behind a myofascial cuff for muscle re-approximation at the end of the procedure. Adequate bony exposure involves exposing the pterion, stephanion, greater sphenoid wing, and portions of the frontal and parietal bones. (d) After the placement of the sphenoid ridge keyhole, the craniotome cut runs immediately below and parallel to the superior temporal line toward the stephanion. Next, the drill is directed sharply downward to include the pterion. After that the cut is proceeded anteriorly and inferiorly along the sphenoid bone to connect with the initial burr hole. (e) After the removal of the bone flap the dura is exposed and intracranial part of the procedure commences. (f) The bony flap should never exceed 4 cm in diameter

posterior to the zygomaticosphenoid suture, and 1 cm behind the frontozygomatic junction. Drilling is continued until the temporal dura, frontal dura, and periorbita are exposed. This burr hole is now large enough to flatten the base of the sphenoid ridge before the removal of the bone flap. Next, the craniotome is directed superiorly and posteriorly towards the stephanion (the point where the upper temporal line converges with the coronal suture) just below and parallel to the superior temporal line. The incision terminates immediately before or at the stephanion. The drill is then curved sharply downward, and the incision extends to include the pterion. The incision subsequently extends anteriorly and inferiorly along the sphenoid bone to connect with the initial burr hole. In short, the bone flap will ultimately include the lateral aspect of the sphenoid, part of the frontal bone inferior to the superior temporal line, and a minimal portion of the temporal and parietal bones. The dimensions of the craniotomy should ideally not exceed 4 cm in length or width.

Once a successful bone flap is acquired, the remaining sphenoid ridge is further drilled and flattened. The dura is then opened in a semilunar fashion with the base of the incision toward the supraorbital rim. The dural opening provides exposure of the inferolateral aspect of the frontal lobe, Sylvian fissure, and superior temporal gyrus. Attention is then directed toward dissecting and splitting the proximal Sylvian fissure providing exposure of the bilateral optic-carotid, chiasmatic, and ipsilateral crural cisterns fissure. Furthermore, this exposure permits cerebrospinal fluid (CSF) drainage and relaxation of the brain parenchyma. At this juncture of the operation, exposure of the ipisilateral internal carotid artery (ICA), middle cerebral artery (MCA), anterior cerebral artery (ACA), anterior communicating artery (AComA), and posterior communicating artery (PComA) can be obtained [Figure 2]. Throughout the dissection to reach the vascular lesion dynamic brain retraction was performed.

Further surgical exposure can be obtained by drilling the marginal tubercle of the zygoma (a prominence on the superior temporal border of the zygomatic bone to which the temporal fascia is attached). According to our observation, we encourage the drilling of the marginal tubercle of the zygoma when the anteroposterior diameter of the frontal process of the zygoma (FPZ) exceeds 12 mm. In selected cases, enhancing the exposure by drilling the marginal tubercle improves the angular exposure and instrument mobility.

Once the vascular lesion is surgically treated attention is then directed to repairing of the sphenoid bone defect using a titanium mesh and/or bone cement. Temporalis muscle and fascia are reattached along the muscle cuff using absorbable running suture. A subgaleal drain is appropriately placed to prevent the collection of fluid.

Results

Between July 2008 and March 2014, 57 consecutive patients with intracranial aneurysms were reviewed. Specifically, 45 MCA, 7 ICA terminus, and 6 PComA aneurysms were identified. All aneurysms (20 ruptured and 37 unruptured) underwent MPT treatment. The patient sample included 20 males and

37 females, with ages ranging between 22 and 76 years (mean of 55.5 years). The mean clinical follow-up was 21.5 months.

20 patients presented with ruptured aneurysm resulting in subarachnoid hemorrhage. Presenting symptoms in patients' with ruptured aneurysms included severe headaches and/or visual disturbances (photophobia and blurring of vision). Four patients were diagnosed with a sentinel hemorrhage. 32 patients had intracranial aneurysms that were incidentally detected. The mean aneurysm size was 5.8 mm. Aneurysm sizes and locations are summarized in Tables 1 and 2.

All aneurysms and their respective adjacent parent artery were readily identified using the MPT. Successful surgical clipping and in one case wrapping of the aneurysms was obtained [Figure 3]. Note, temporary clips were utilized intermittently for no more than 5 min in certain ruptured aneurysm cases. None of the 57 cases required an extended skin incision or craniotomy extension. Moreover, there were no intra-operative surgical complications (including aneurysmal rupture). The patient's clinical and angioanatomic details are summarized in Tables 1 and 2. A lumbar drain (LD) was placed in all cases ruptured aneurysm cases to encourage brain relaxation. An extraventricular drain (EVD) was placed in 5 ruptured aneurysm cases due to significant hydrocephalus and brain edema.

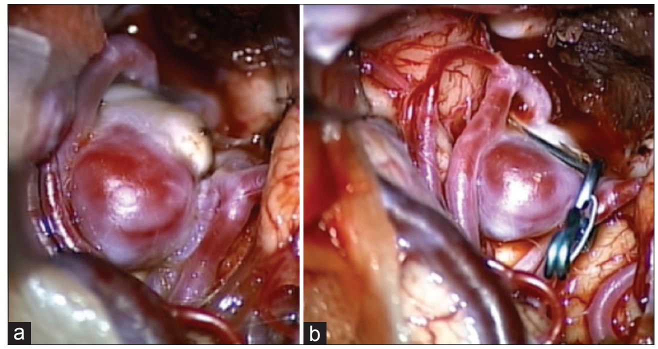

Figure 2: Intra-operative microsurgical view showing middle cerebral artery aneurysm. (a) Preclipping, (b) postclipping

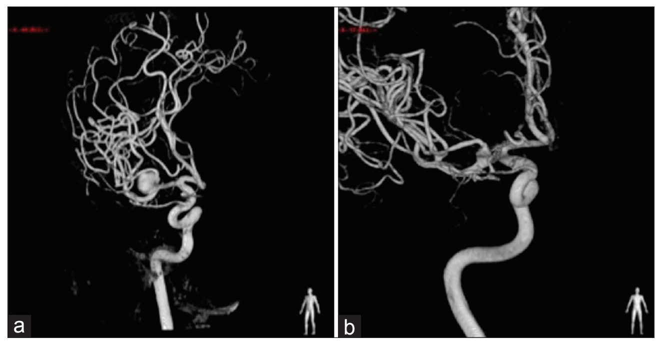

Figure 3: (a) Preoperative three-dimensional digital subtraction angiography of M1 bifurcation aneurysm, (b) postoperative three-dimensional digital subtraction angiography showing successful clipping and complete obliteration of M1 bifurcation aneurysm

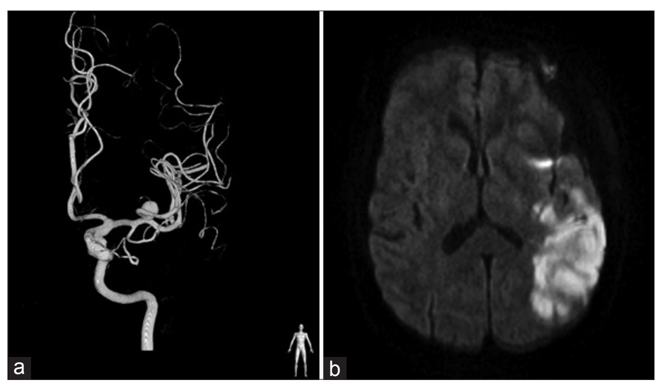

Figure 4: Pre- and post-operative images of a 50-year-old female with incidentally discovered left middle cerebral artery aneurysm. Following the MPT she developed expressive aphasia as such she was readmitted and aspirin was initiated following the confirmation of the infarction. The patient's speech subsequently gradually improved after aspirin therapy. (a) Three-dimensional angiogram of left internal carotid artery demonstrating a left middle cerebral artery bifurcation aneurysm. (b) Postoperative magnetic resonance imaging (diffusion weighted imaging) of the same patient showing areas of restricted diffusion consistent with ischemia and infarction of the left posterior middle cerebral artery territory

Postoperative courses were grossly uneventful in most of the cases. None of the 57 MPT treated patients experienced frontal temporal nerve damage, temporalis muscle wasting, craniotomy site depression, or paresthesias around the incision line. Appropriate cosmetic results were obtained in all cases without cranial disfigurement secondary to temporal hollow or complications of the incisional scar. Furthermore, none of the 57 treated patients complained of pain or dysfunction of the TMJ.

One patient with a PComA aneurysm did develop a transient third nerve palsy. Two patients developed an ischemic stroke involving the left MCA. One stroke patient manifested symptoms of right arm and facial weakness in addition to dysarthria and the other as a receptive aphasia. Pre and postoperative imaging for this aforementioned case are demonstrated in Figure 4. None of the 57 patients experienced postoperative aneurysm rupture. Note, a postoperative subdural hematoma at the craniotomy site was identified in one case, which required subsequent evacuation. The postoperative hospital stay for unruptured aneurysm cases ranged between 3 and 5 days. Complications and patient response to treatment are listed in Tables 1 and 2.

Discussion

The theoretical concept of skull base surgical approaches is to create a balance between maximizing exposure and minimizing the degree of parenchymal brain manipulation. Yaşargila, a pioneer in the field of microneurosurgery, expressed a creed that modern skull base surgeon strive to follow: "In principle it would be ideal if the brain could be left completely undisturbed while the dissection and clipping of an intracranial aneurysm

Table 1: Patient characteristics of unruptured anterior circulation aneurysm

Demographics		Aneurysm side/location	Presentation	Aneurysm size (mm)	Lumbar drain	Procedure related complications	Follow-up (months)	Improvement
Patient number	Gender/age							
1	Male/43	Left/ICA terightminus	Incidental	5	No	No	2	N/A
2	Male/58	Right/ICA terightminus	Incidental	6.2	No	No	4	N/A
3	Female/37	Right/ICA terightminus	Incidental	5	No	No	8	N/A
4	Male/54	Right/PComA, right/MCA	Incidental	7.7 (PComA), 4.5 (MCA)	No	Transient 3rd CN palsy	24	Yes
5	Female/64	Right/MCA	Incidental	8	No	No	-	N/A
6	Female/50	Right/MCA	Incidental	4.6	No	No	36	N/A
7	Male/76	Right/MCA	Incidental	6	No	No	36	N/A
8	Male/72	Left/MCA	Incidental	8	No	SDH-evacuated	13	Yes
9	Female/55	Right/ICA terightminus	Incidental	6	Yes	No	53	N/A
10	Female/41	Right/MCA	Incidental	6	No	No	28	N/A
11	Female/65	Right/MCA	Incidental	6	No	No	2	N/A
12	Male/54	Right/MCA	Incidental	3	No	No	40	N/A
13	Female/76	Right/MCA	Incidental	12	No	No	26	N/A
14	Female/50	Right/MCA	Incidental	6	No	No	16	N/A
15	Female/39	Right/MCA	Incidental	7	No	No	36	N/A
16	Male/63	Right/MCA	Incidental	5	No	No	34	N/A
17	Female/54	Right/ICA terightminus	Incidental	6	N	No	35	N/A
18	Male/61	Right/MCA	Incidental	6	No	No	39	N/A
19	Female/66	Right/MCA	Incidental	4	No	No	1.5	N/A
20	Female/74	Left/MCA	Incidental	4	VP shunt	No	26	N/A
21	Female/42	Right/MCA	Headache (sentinel hemorrhage)	5	No	No	22	N/A
22	Male/54	Right/MCA	Incidental	5	No	No	27	N/A
23	Female/52	Right/MCA	Incidental	10	No	No	36	N/A
23	Male/70	Left/MCA	Incidental	7	No	No	4	N/A
24	Female/62	Left/MCA	Incidental	7	No	No	3	N/A
25	Male/53	Right/MCA	Headache (sentinel hemorrhage)	6	No	No	24	N/A
26	Female/41	Right/MCA	Headache (sentinel hemorrhage)	12	No	No	12	N/A
27	Female/60	Left/MCA	Non-Subarachnoidal headache	8	No	No	24	N/A
28	Male/69	Left/MCA	Incidental	6	No	No	10	N/A
29	Female/45	Right/MCA	Incidental	5	No	No	12	N/A
30	Female/54	Right/MCA	Incidental	5	No	No	13	N/A
31	Female/53	Right/MCA	Incidental	4	No	No	18	N/A
32	Male/55	Right/MCA	Incidental	6	No	No	13	N/A
33	Female/46	Left/MCA	Headache (sentinel hemorrhage)	12	Yes	No	24	Yes
34	Female/26	Left/MCA	Incidental	3		No	24	N/A
35	Female/50	Left/MCA	Incidental	7		Stroke-receptive aphasia	13	Yes
36	Female/68	Left/MCA	Incidental	4	No	Stroke-right/arm, facial weakness, dysarthria	18	Yes
Average	56.9			6.4			21	

MCA – Middle cerebral artery; ICA – Internal carotid artery; PComA – Posterior communicating artery; N/A – Not available

were carried out. To approach this ideally, a craniotomy must take advantage of those natural planes and spaces which nature has provided to expose the base of the brain without significant brain retraction."[11] In short, the notion of minimizing cerebral cortex retraction and manipulation has become an obsession among neurosurgeons thereby leading to increased proposals for new innovative surgical approaches that optimize exposure while reducing brain manipulation.

Table 2: Patient characteristics of ruptured anterior circulation aneurysm

Demographics		Aneurysm side/ location	Presentation	Hunt and Hess	Aneurysm size (mm)	Lumbar drain	Procedure related complications	Follow-up (months)	Improvement
Patient number	Gender/age								
1	Female/58	Right/MCA	Headache	2	4	Yes	No	6	N/A
2	Female/70	Left/MCA	Headache	2	6	No	No	9	N/A
3	Female/62	Right/PComA	Headache-visual	3	12	No, + EVD	No	52	Yes
4	Male/60	Left/MCA	Headache	2	6	Yes	No	38	N/A
5	Female/56	Left/PComA	Headache	2	5	Yes	No	27	N/A
6	Male/55	Right/PComA	Headache-visual	2	7	Yes	No	28	N/A
7	Female/63	Left/MCA	Headache-visual	2	5	Yes	No	26	N/A
8	Female/57	Right/MCA	Headache	1	5	Yes	No	15	N/A
9	Female/70	Left/MCA	Headache	4	10	No	No	10	N/A
10	Female/50	Left/MCA	Headache	2	3	Yes	No	23	N/A
11	Female/68	Right/MCA	Headache	2	1	Yes	No	18	N/A
12	Female/58	Right/PComA	Headache-visual	2	4	Yes	No	21	N/A
13	Female/55	Left/PComA	Headache	2	4	Yes	Transient aphasia	12	Yes
14	Female/56	Right/MCA	Headache-visual	4	4	EVD	No	16	N/A
15	Male/52	Right/MCA	Headache-visual	2	4	EVD	No	19	N/A
16	Female/22	Left/ICA terightminus	Headache-visual	2	4	EVD	No	-	N/A
17	Male/41	Right/MCA	Headache	2	8	Yes	No	12	N/A
18	Male/59	Right/MCA	Headache	4	6	Yes	No	-	
19	Female/55	Left/PComA	Headache	2	7	Yes	Infection	41	Yes
20	Male/48	Right/MCA	Headache	2	7	EVD	No	32	N/A
Average	55.75			2.3	5.6			22.5	

MCA – Middle cerebral artery; ICA – Internal carotid artery; PComA – Posterior communicating artery; EVD – Extra ventricular drain; N/A – Not available

The traditional pterional craniotomy is a sound and versatile operation used to approach and treat various vascular and nonvascular surgical lesions. The pterional craniotomy provides access to lesions located in the anterior and posterior cerebral circulation, sellar and parasellar regions, sphenoid wing, cavernous sinus, orbit, anterior and mesial temporal lobe, midbrain, and the posterior-inferior frontal lobe.[7-15] Although the pterional craniotomy approach provides an excellent exposure it is associated with a variety of complications including facial asymmetry, depression of the temporal fossa, and TMJ dysfunction secondary to the extensive temporalis muscle manipulation; in addition, there is risk of injury to branches of the facial nerve and large areas of unnecessarily exposed cerebral cortex.[17-19,24,25] As such, less invasive surgical approaches have been proposed to reduce the extent of the pterional craniotomy and expectantly its related complications.[26-28] Multiple microsurgical approaches have been proposed (i.e. supraorbital craniotomy and lateral supraorbital craniotomy); however, arguably these approaches failed to provide an adequate balance between the exposure, the reduction in the size of the craniotomy, and patient safety for proper handling of surgical instrumentation during the operation.[25]

A detailed literature search yields that the MPT craniotomy is a suitable alternative to the classic pterional craniotomy. According to Figueiredo *et al*. "… this (MPT) technique represents an optimal balance among the size of craniotomy, extent of dissection of the temporalis muscle, splitting of the Sylvain fissure, and microsurgical exposure."[13] Specifically, the MPT craniotomy ensures suitable exposure of the anterior ascendant ramus. Thus, the two main principles of the standard pterional technique, the extensive drilling of the lateral aspect of the sphenoid wing and the wide exposure of the Sylvain fissure, remain achievable in the MPT.[13]

There are a number of advantages obtained by this less invasive approach. Our practice noted the MPT craniotomy provides dissection in natural anatomical planes which affords preservation of the temporalis muscle and, therefore, avoids injury to the facial nerve branches, minimizes exposure and manipulation of brain parenchyma, and importantly for our patient population results in an excellent cosmetic outcome. Primarily, the anterior placement of the incision reduces the risk of unintentional injury to the superficial temporal artery. Moreover, this reduces postoperative temporalis atrophy and facial asymmetry.[29] Unlike the pterional craniotomy where the incision extends to the contralateral mid-pupillary line, the MPT incision does not extend beyond the ipisilateral superior temporal line. Patient satisfaction and comfort have been appreciated in the follow-up postoperative clinic visits, in terms of incision scar tightness, postoperative pain, scarring, and overall cosmetic outcome.

Second, performing an interfascial or a subfascial dissection avoids temporalis muscle wasting via protection of the frontotemporal branch of the facial nerve.[23,29] In addition, since the craniotomy is entirely located underneath the anterior part of the temporalis muscle, retraction of the muscle is performed more distally to the primary neurovascular branches; therefore, reducing temporalis muscle atrophy.[13] Furthermore, the overall shorter surgical exposure time in comparison to the traditional pterional craniotomy leads to relatively shorter periods of muscle ischemia since the temporalis muscle is less vulnerable to ischemic atrophy caused by prolonged interruption of the primary arterial supply.[30,31] Since the temporalis muscle incision terminates, 3 cm superior to the tragus TMJ complications were avoided. Avoidable complications include joint pain, limited chewing, malocclusion symptoms, and difficulties in lateral movement of the jaw.[31] Another benefit is that the MPT approach does not violate the frontal sinus, thus reducing CSF leaks and postoperative infection rates. Furthermore, we avoided using fixed brain retractors because the small craniotomy site never exceeded 4 cm in diameter. Brain edema, contusion, and retractor induced parenchymal infarction are injuries associated with utilizing fixed brain retractors.[32] Ideally, we strived to have an area of exposed cortex, which was limited to the amount needed for dynamic retraction of the brain. The proper dimensions and location of the craniotomy centered on the Sylvain fissure axis created optimum microsurgical exposure. The surgical corridor could be modified accordingly to a surgeon needs by employing the suction shaft and surgical instruments as mobile retractors. Applying these aforementioned techniques explains the low incidence of postoperative brain edema noted in our case series.

A recent study by Caplan *et al*.[33] reported employing the MPT approach solely on unruptured anterior circulation aneurysms. Our case series included 20 ruptured anterior circulation aneurysm cases (13 MCA, 6 PComA, and 1 ICA terminus). We managed these patients by placing intraoperative LDs to monitor intracranial pressures (ICP) and drain the CSF in hopes of alleviating brain edema. An EVD was predominately used for patients presenting with hydrocephalus. We credit, ICP monitoring and CSF drainage as crucial elements in the success of the MPT craniotomy for ruptured aneurysms. Son *et al*.[34] described the value of utilizing navigation-guided mini-craniotomies to approach distal M1, MCA bifurcation, and distal MCA unruptured aneurysms. However, such a minimally invasive procedure cannot be performed on ruptured aneurysm cases without violating brain tissue and causing complications. The narrow surgical corridor provided by navigation-guided mini-craniotomies hinders the ability to work on the swollen brain. Thus, we propose that the MPT approach proves to be superior to other less invasive open techniques in terms of surgically treating ruptured anterior circulation aneurysms.

We would like to stress on the additional value provided by drilling the marginal tubercle of the zygomatic bone. Occasionally, the posterior border of the FPZ, the marginal tubercle, obscures the sphenozygomatic suture (SZ) which represents the anterior limit of the MPT approach. Drilling through the marginal tubercle in selected cases will expose the SZ suture thereby improving the microsurgical exposure [Figure 5]. Although our practice noted a benefit in select cases, further anatomical studies are needed to demonstrate the relation between the microsurgical exposure and the marginal tubercle conclusively.

Endovascular treatment of unruptured intracranial aneurysms offers a less invasive, and potentially equivalent alternative to surgical clipping.[35-37] However, there remains controversy as to which mode is best to treat exclusively MCA aneurysms. High failure rates of endovascular obliteration for unruptured MCA aneurysms have been reported and there are several reasons contributing to this failure rate.[7-15] MCA aneurysms often have an unfavorable aneurysm geometry that might limit endovascular therapy.[38] Aneurysms with a fundus-to-neck ratio of <2 and major branches incorporated into the aneurismal base are considered as limiting factors for endovascular treatment.[38] Such aneurysms are subjected to coil migration and parent vessel compromise lowering the occlusion rates. In addition, a distantly located MCA aneurysm may complicate the process of endovascular occlusion. In a recent systematic review that included 1030 patients with MCA aneurysms, perioperative combined mortality and neurological morbidity related to the endovascular procedure were 6.0%.[39] The incidence of major recurrences requiring re-treatment was 9.6%.[39] Moreover, in a retrospective review of 90 patients with MCA aneurysms treated with an endovascular or surgical approach, Diaz *et al*.[40] reported a 14% (7/50) and 0% (0/40) $P = 0.0137$ re-treatment rate for endovascular and surgical groups, respectively. Thus, surgical clipping of MCA aneurysms is generally considered superior to endovascular treatment.

Common vascular structures such as the MCA, PComA, and ICA bifurcation are sufficiently exposed and can be adequately treated via the MPT craniotomy. Our practice confirmed comparable results in basal microsurgerical exposure of

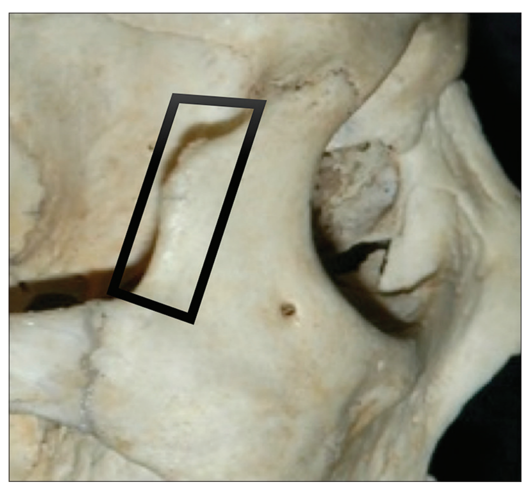

Figure 5: Drilling of the marginal tubercle of the zygomatic bone will expose the sphenozygomatic suture which is helpful in select cases to enhance the microsurgical exposure

relevant anterior circulation areas between the MPT and pterional craniotomy approach. Using a cadaveric anatomic model Figueiredo *et al*. concluded that the MPT and pterional approach provide comparable surgical exposures and "… the same anatomic targets could be reached, dissected, and secured."[13] Moreover, the angular exposure and surgical freedom, which can be enhanced by bone drilling the sphenoid ridge, exhibited no statistical difference between the pterional and MPT approach in the same basal areas.

As with any surgical exposure, there are some limitations to the MPT approach for clipping aneurysms. AcomA, ACA, and ophthalmic ICA aneurysms are still preferably clipped via transpalpebral orbitofrontal craniotomy (institution preference).[41] The transpalbebral approach offers better proximal and distal control of these specific aneurysms with minimal brain retraction. Distal MCA and distal ACA aneurysms are unfortunately difficult to access via an MPT approach. In our 57 patient cases, the MPT approach was not selected for patients with ruptured aneurysms associated with severe hemorrhage and massive brain edema requiring decompressive hemicraniectomy. To our knowledge, there are no other published studies that document using the MPT craniotomy for the management of these types of cases.

Conclusion

Our 57 patient case review, suggests that the MPT approach provides a reliable alternative to the traditional pterional craniotomy for both ruptured and unruptured anterior circulation aneurysms. Unlike previously described microneurosurgical approaches, the refinements introduced to the classic pterional approach by the MPT approach create an optimal balance between the surgical exposure and the craniotomy size. Despite the comparable surgical exposure provided by both the MPT and pterional approach for anterior circulation aneurysms, the MPT offers less tissue trauma, limited bone drilling, better cosmetic outcome, and excellent temporalis function.

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Conflicts of interest
There are no conflicts of interest.

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