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Pterional approach: technical variations, functional, and cosmetic outcomes in a series of 1000 patients

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Abstract

Introduction: Most of the versatility of the pterional approach is based on a series of variations progressively reported by several authors, but little emphasized over the years.

The present study condenses the technical notes which the authors adopted in their practice to maximize the surgical freedom of the pterional approach and to lessen the approach-related complication rate.

Methods: Data of a series of patients who underwent a pterional approach between January 2011 and May 2021 were retrospectively reviewed focusing on the technical variations compared to the original description by Yaşargil. The anatomical rationale, technique, and advantages of these variations were outlined and validated through the appraisal of functional and cosmetic complications.

Results: 994 patients were reviewed. Head extension was avoided in the case of anterior clinoidectomy. A single double-layered galea-pericranium flap was used for duraplasty. The submuscular technique, with compulsive preservation of deep temporal fascia and deep temporal arteries, was preferred for temporalis muscle dissection. McCarty keyhole was never used, thus avoiding exposing the orbit if unnecessary. Widening of the superior orbital fissure and thinning of the orbital roof allowed to significantly increase the working area. The average clinical follow-up was 7.2 years. The overall rate of functional and cosmetic complications was 2.1.

Discussion: According to the authors' experience, the gradual adoption of technical variations related to the positioning of the patient, soft tissue dissection, bony work, dura opening, and reconstruction, allowed to enhance the versatility of the pterional approach, concurrently decreasing the risk of functional and cosmetic complications.

Keywords: *Aneurysms clipping, intracranial aneurysms, neurovascular surgery, pterional approach, Sylvian fissure*

Introduction

More than forty-five years after its original description by Yaşargil,1-3 the pterional approach is still the most used skull base corridor in neurosurgery, and the forerunner of all the anterolateral approaches to the anterior and middle cranial base.

It is routinely employed in the treatment of the vast majority of the anterior circulation aneurysms, small basilar tip ones, cavernomas and arteriovenous malformations of the basal forebrain, anterior and middle skull base tumors, intra-axial tumors of the frontal, parietal, and temporal opercula, insula, mediobasal temporal region, cerebral peduncles, interpeduncular fossa, and orbital lesions.

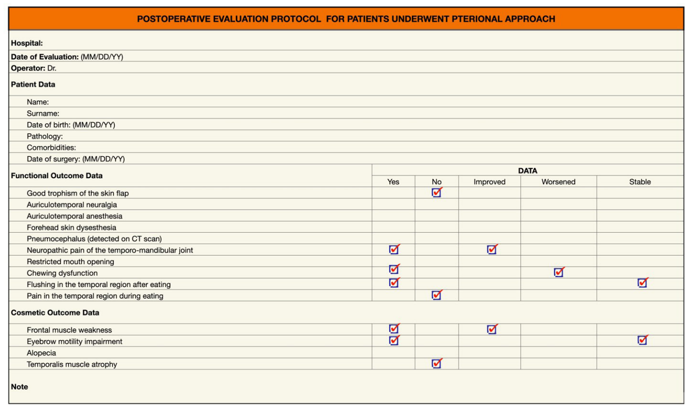
The remarkable versatility of the pterional approach is totally dependent on a perfect knowledge of the surgical technique. The implementation and validation of some technical notes of the approach — compared to the original description — allow achieving important advantages in terms of surgical exposure of the anatomical target, at the same decreasing the risk of complications.

The present study overviews the technical variations of the pterional approach adopted progressively by the authors in their daily neurosurgical practice to 1) maximize the surgical freedom to the target, 2) prevent complications, and 3) improve the functional, and cosmetic outcome. Data analysis was based on a one thousand patients' cohort treated during the last decade.

Methods

The study was approved by each Internal Review Board of the authors' Hospitals. The clinical data, pre and postoperative neuroimaging studies, surgical videos, and functional and cosmetic outcomes of a series of patients who underwent a pterional approach between January 2011 and May 2021, as a consequence of various neurovascular, skull base, and brain pathologies, were retrospectively reviewed. Patients with a history of previous transcranial surgery and those harboring preoperatively facial nerve deficits, ephaptic pathologies of the cranial nerves, or temporomandibular disorders were excluded. Data about the early postoperative outcome were derived from clinical records, whereas clinical and neurological examinations and postoperative radiological studies were used for the evaluation of late complications over the scheduled clinical follow-up. Data analysis focused on the operative technique and variations compared to the original description by Yaşargil, as well as their anatomical rationale and indications, areas of exposure, techniques to enhance the surgical freedom to the target, approach-related complications and their prevention, and functional and cosmetic outcome.

Because of the lack of standardized measures of clinical outcome specifically related to the pterional approach, the functional and cosmetic outcomes were derived by the rate of the respective functional and cosmetic complications, which were listed in a scheduled evaluation protocol (Figure 1). This assessment protocol was used across the different centers.



POSTOPERATIVE EVALUATION PROTOCOL FOR PATIENTS UNDERWENT PTERIONAL APPROACH					
Hospital:					
Date of Evaluation: (MM/DD/YY)					
Operator: Dr.					
Patient Data					
Name:					
Surname:					
Date of birth: (MM/DD/YY)					
Pathology:					
Comorbidities:					
Date of surgery: (MM/DD/YY)					
Functional Outcome Data	**DATA**				
	Yes	No	Improved	Worsened	Stable
Good trophism of the skin flap		☑			
Auriculotemporal neuralgia					
Auriculotemporal anesthesia					
Forehead skin dysesthesia					
Pneumocephalus (detected on CT scan)					
Neuropathic pain of the temporo-mandibular joint	☑		☑		
Restricted mouth opening					
Chewing dysfunction	☑			☑	
Flushing in the temporal region after eating	☑				☑
Pain in the temporal region during eating		☑			
Cosmetic Outcome Data					
Frontal muscle weakness	☑		☑		
Eyebrow motility impairment	☑				☑
Alopecia					
Temporalis muscle atrophy		☑			
Note					

Figure 1. Postoperative evaluation protocol for patients underwent pterional approach

The patients were evaluated by the attending surgeon or residents on the occasion of the clinical follow-ups for the pathology that led to surgery. Complications were considered as approach-related if occurring within 6 months from the procedure and classified as functional or cosmetic. They were differentiated into early, within the first month, and late, second to sixth-month after surgery. The potential early functional complications involved skin-flap necrosis, auriculotemporal neuralgia/anesthesia, forehead skin dysesthesia, and tension pneumocephalus, whereas the late functional complications entailed neuropathic pain of the temporomandibular joint, restricted mouth opening, chewing dysfunction, and Frey's syndrome. The possible early cosmetic complications were frontal muscle weakness and impairment of the eyebrow motility, while late ones included alopecia and temporalis muscle atrophy. Temporalis muscle atrophy was assessed measuring the thickness of the muscle of the surgical site compared with the unaffected side on axial CT scan slice passing through the optic foramina. A difference greater than 5 mm was arbitrarily assumed as diagnostic for atrophy. The patients were evaluated throughout the different follow-ups, with a regularity based on the pathology, to appraise whether the deficit did improve, worsen, or remain stable.

Postoperative approach-related deficits were considered permanent if persisting beyond 6 months.

Results

1.Data Analysis

Table 1 summarizes the patients' demographic, clinical and histological data. A total of 994 patients were selected. Meningiomas, aneurysms, and gliomas of the basal forebrain were the most frequent lesions (Table 1). A long-term follow-up was possible for only 882 patients. The average follow-up was 7.2 years.

Table 1. Demographic, clinical and histological data

Variable	Data
Timeframe	Jan. 2011 - May 2021
Pts. no.	994
Average pts. age (yrs ± SD)	56.2 ± 14
Sex	
Male no. (%)	531 (53.4%)
Female no. (%)	463 (46.6%)
Side of approach	
Left no. (%)	445 (44.7%)
Right no. (%)	549 (55.3%)
Type of lesion	
Meningioma no. (%)	396 (40%)
Craniopharyngioma no. (%)	38 (3.8%)
Aneurysm no. (%)	312 (31.4%)
AVM no. (%)	6 (0.6%)
Cavernoma no. (%)	96 (9.6%)
Glioma no. (%)	124 (12.4%)
Trigeminal schwannoma no. (%)	6 (0.6%)
Fibrous dysplasia no. (%)	4 (0.4%)
Orbital lesion no. (%)	12 (1.2%)
Pts. w/ a long-term (>six-month) follow-up no.	882
Average FU (yrs ± SD)	7.2 ± 2.4

yrs: years; SD: standard deviation; AVMs: arteriovenous malformations; Pts: patients; FU: follow-up

2. Standard operative technique

2.1.Positioning and skull clamp placement

The pterional approach is performed with the patient in the supine position. The head is fixed to a Mayfield–Kees or Sugita skull clamp, and all three pins, or three pins at least for Sugita skull clamp, ought to be positioned below the cranial equatorial line. With Mayfield clamp, two pins are placed along the contralateral superior temporal line and the remaining at the ipsilateral mastoid bone. Care must be taken to avoid the temporalis muscle because of the risk of accidental slippage. The patient's head is elevated 20° above the level of the heart to allow optimal venous outflow. In the classic description by Yaşargil in 1976, an extension of 20° was recommended so the malar eminence became the highest point of the patient's head. A contralateral rotation, ranging from 15° to 45°, according to the different intradural neurovascular targets, is also necessary (Figure 2A).[1,2]

2.2.Skin incision and soft tissue dissection

The skin incision starts 1 cm in front of the tragus, anteriorly to the superficial temporal artery and auriculotemporal nerve, which must be preserved. It arcs upward 2 cm, behind the hairline, makes a posteriorly convex curve, and stops at the midline (Figure 2B, C). Hemostatic spring scalp clips, universally known as Raney clips, are generally placed along the edge of the incision (Figure 2D). In the native description, the skin flap is divided by the temporalis muscle and reflected forward. The superficial and deep layers of the superficial temporal fascia, where the frontal branch of the facial nerve courses along with a fat cushion, are separated to preserve the nerve (interfascial technique).[1,2] The deep layer of the superficial fascia, the temporalis muscle, and the deep fascia is then cut together, dissected from the bone, reflected forward and lateralward, and fixed with hooks (Figure 2E-M). A muscle cuff may be optionally left along the superior temporal line for the reconstruction of the temporalis muscle.

2.3.Identification of the bony landmarks

The frontal, parietal, temporal, and sphenoid bones join at the level of the pterion. Identification of the coronal, spheno-frontal, spheno-parietal, spheno-squamosal, and spheno-zygomatic suture is essential to delimit the lateral third of the greater sphenoid wing at the level of the frontotemporal region. The spheno-squamosal suture forms the anterior third of the temporoparietal suture, also known as the squamosal suture. The highest point of the spheno-squamosal suture is located at the same level of the spheno-parietal and spheno-frontal sutures. This point marks the uppermost limit of the greater sphenoid wing and, the superior orbital fissure (SOF). The spheno-zygomatic suture indicates the midpoint of the lateral wall of the orbit, which is formed by the frontal process of the zygomatic bone anteriorly and the greater sphenoid wing posteriorly. The fronto-zygomatic suture, located anterosuperior to the spheno-zygomatic one, marks the limit between the lateral wall and of the orbit. The supraorbital foramen and supraorbital nerve should be identified early to sign the medial limit of the frontotemporal flap (Figure 2N,O). Rarely, the air frontal sinus extends laterally beyond the supraorbital foramen. In these cases, a careful preoperative evaluation of the pneumatization of the frontal air sinus and the use of the neuronavigation is crucial to avoid its accidental violation.

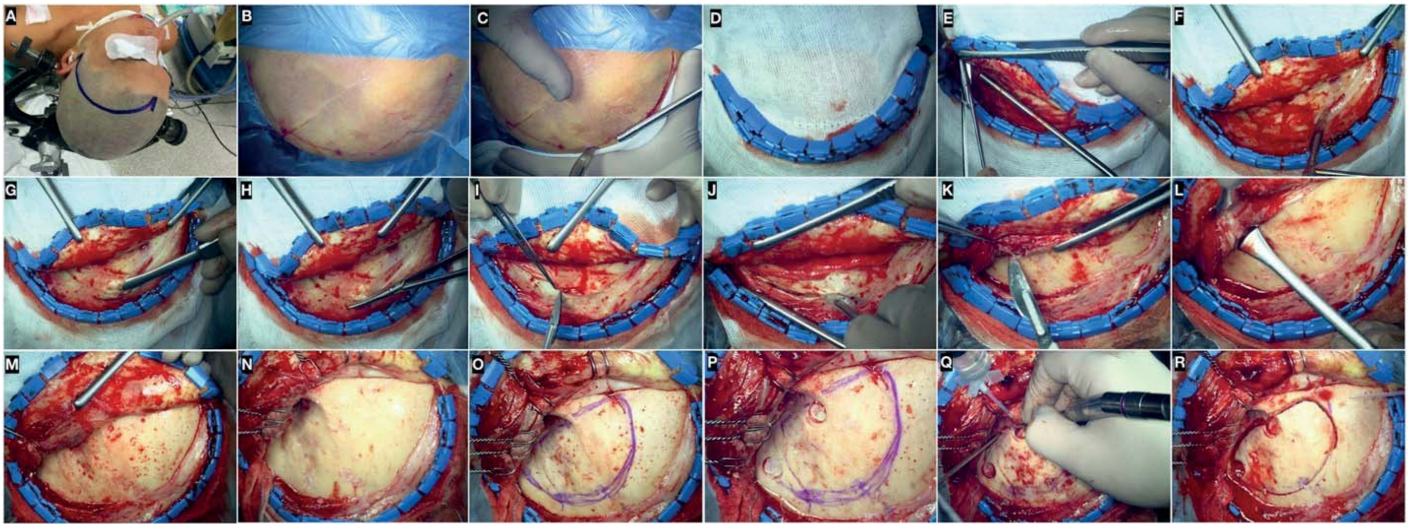


Figure 2. Surgical position (**A**), skin mark (**B**), and incision (**C**). (**D**) Hemostasis of the skin flap with Raney clips. (**E**-**I**) Preparation of the galea-pericranium flap; (**J**-**N**) incision of the superficial temporal fascia, temporalis muscle, and deep temporal fascia (submuscular technique), and retrograde subperiosteal dissection of the deep temporalis fascia according to Oikawa's technique. (**O**) Identification of the sutures of the pterional region and drawing of the bone flap. (**P**) The first and second burr-hole is placed just above the McCarty keyhole and above the posterior root of the zygoma, respectively. (**Q**) Partial drilling of the lateral third of the greater sphenoid wing before completing the craniotomy. (**R**) Frontotemporal bone flap.

2.4.Craniotomy

The first burr hole is referred to as the MacCarty keyhole. The MacCarty keyhole is placed 5 mm behind the junction between the fronto-zygomatic, spheno-zygomatic, and fronto-sphenoidal suture. It exposes the dura of the anterior fossa and the periorbita, which are separated by the thin orbital roof.[4,5] The second burr hole is placed at the level of the temporal squama, just above the posterior root of the zygoma. Two burr holes are sufficient in most patients. If the dura is firmly adherent to the bone, a third burr hole can be placed at the level of the superior temporal line. This is the case of older patients, those with internal frontal hyperostosis, or also chronic kidney failure. A Penfield dissector no. 3 is used to extensively separate the dura from the bone flap (Figure 2P). Before the craniotomy, partial drilling of the lateral third of the greater sphenoid wing with a small-sized cutting burr, or a drill bit used as a reamer, will make easier the passage of the craniotome and the detachment of the bone flap (Figure 2Q). During this step, the cancellous bone of the greater sphenoid wing and the middle meningeal artery may be both sources of bleeding, however, easily controlled with bone wax or bipolar forceps. The first cut starts at the level of the frontal burr hole and is directed toward the midline; as medial as greater is the need for exposure of the subfrontal area. In general, craniotomy should not extend beyond the supraorbital foramen. Frequently, the medial limit of the craniotomy must be the superior temporal line because of the hyperpneumatization of the frontal air sinus. The second cut is directed in a curvilinear fashion from the temporal burr hole to the most medial edge of the first cut. The third cut connects the temporal and frontal burr holes passing through the lateral third of the greater sphenoid wing at the level of the temporal fossa (Figure 2R). The bone flap is then elevated with the aid of a periosteal elevator ensuring the complete detachment of the underlying dura (Figure 3A-C). In case the bone flap is still partially attached to the inner cortical surface of the greater sphenoid wing, it can be easily fractured. This first step of the approach does not differ from a frontotemporal approach. The crucial aspect of the pterional approach consists in the next step, namely the drilling of the lateral part of the greater sphenoid wing until the SOF. The meningo-orbital artery serves as a useful landmark for the early identification of the lateral third of the SOF between the lesser and greater sphenoid wing. Its detection is also paramount for anterior clinoidectomy.[6-8]

2.5.Dura opening

The dura is opened in a curvilinear fashion around the SOF. Tack-up sutures along the edge of the craniotomy and tenting temporary stiches of the dural leaflets are paramount to maintaining a clean surgical field and avoiding subdural blood collection (Figure 3D, E).

2.6. Intradural corridors

The pterional approach is related to four well-defined surgical perspectives, namely, subfrontal, transsylvian, pretemporal, and anterior subtemporal. The opening of the Liliequist's membrane expands the transsylvian corridor to the tip of the basilar artery and the interpeduncular fossa. Transsylvian corridor to the infratentorial space has four deep windows from medial to lateral: the optico-carotid, carotid-oculomotor, supra-carotid, and oculomotor-tentorial. The splitting of the sylvian fissure is the key to accessing all of these corridors, which can also be used in various combinations depending on the lesion to be treated (Figure 3F-K). The combined subfrontal-transsylvian perspective is used for all anterior circulation aneurysms, whereas the pretemporal route allows treating aneurysms involving the basilar tip, P1 segment of the posterior cerebral artery (PCA), and proximal segment of the superior cerebellar artery. The anterior clinoidectomy, both extradural and intradural, dramatically increases the working space around the proximal intradural portion of the optico-carotid complex. It also allows for the lateral mobilization of the internal carotid artery (ICA) after the opening of the distal dural ring. Instead, the intradural posterior clinoidectomy is the key of Krisht's pretemporal transcavernous approach to the basilar tip aneurysms and lesions of the anterior upper third of the posterior fossa.[9,10]

2.7.Closure

The dura must be closed in a watertight fashion to avoid cerebrospinal fluid leaks. The bone flap is fixed to the skull with low-profile titanium plates and burr-hole covers, and 4- or 5-mm self-tapping screws. In those cases where a full exposure of the temporal lobe is necessary a bony gap may be the result of wider drilling of the greater sphenoid wing and temporal squama. If compulsive preservation of the deep fascia of the temporalis muscle has been performed during the approach, this gap does not represent a problem because it is covered by the temporalis muscle. A titanium mesh or, more rarely, an autologous fat graft may be used to avoid the defect (Figure 3L). An interrupted suture of the muscle and superficial temporal fascia is separately performed with absorbable 3/0 vicryl stiches. If the galea is not used for duraplasty, it can be reapproximated with 3/0 vicryl stiches. A subcutaneous drainage, to be left in place for 2 days, can be useful to prevent blood collections. The skin suture may be performed with silk stiches or agraphes.

3.Technical variations

The progressively implemented variations concerned the patient's positioning, the dissection of the galea aponeurotica and the temporalis muscle, the craniotomy, the dura opening, and the reconstruction.

A 15° of head rotation, without extension, was used for paraclinoid aneurysms and in those procedures involving the posterior communicating artery (PCoA) and the anterior choroidal artery (AChA). In the middle cerebral artery (MCA) bifurcation aneurysms, ICA terminus, and the inferior projecting anterior communicating artery (ACoA) ones, the extension and rotation were of 15° and 10°, respectively. A solution containing lidocaine hydrochloride 1% or mepivacaine chlorhydrate 2% plus adrenaline diluted in normal saline 0.9% (1:1) was used to execute local anesthesia along the mark of the skin incision. If unaffected by the lesion, the galea aponeurotica, and pericranium, were prepared together as a single double-layered galea-pericranium flap. Hemostatic scalp clips were avoided in case of thin or hypovascularized flaps, or also chronic radiation-induced dermatitis of the scalp. Two variations of the interfascial dissection technique of the temporalis muscle were endorsed and used on a case-by-case basis: the subfascial technique and the submuscular one. In the subfascial technique, the incision of temporal fascia involved the superficial and deep layers making a single double-layered fascial leaflet with the facial nerve protected between the two layers. In the submuscular technique, the superficial fascia, the temporal muscle, and the deep fascia were cut together down to the periosteum of the temporal squama. This maneuver allowed for a subperiosteal blunt dissection of the temporalis muscle and a forward reflection of the myocutaneous flap. The muscle was cut just above the posterior root of the zygoma as much as possible parallel, to the course of the fibers, and detached from the underlying bone in a retrograde superior to posterior and backward to forward direction according to the Oikawa technique.[11] Noteworthy, electrocautery was never used. The muscle cuff along the superior temporal line was never left when the submuscular technique was used. The first burr hole was generally placed just above the McCarty keyhole avoiding exposing the orbit. After craniotomy and drilling of the greater sphenoid wing, two additional maneuvers were usually accomplished, namely, the enlargement of the SOF, with the aid of a small bone rongeur, and the thinning of the bone of the ipsilateral orbital roof with a small-sized burr. The dura was opened making a cut parallel to the posterior ramus of the sylvian fissure, to which two further curvilinear cuts were added at the level of the frontal and temporal lobes.

Galea-pericranium flap was used as a free patch graft in case of duraplasty, or reflected as a vascularized flap over the frontal sinus in case of accidental violation. For skin closure, an interrupted suture with 3/0 silk stiches was always employed.

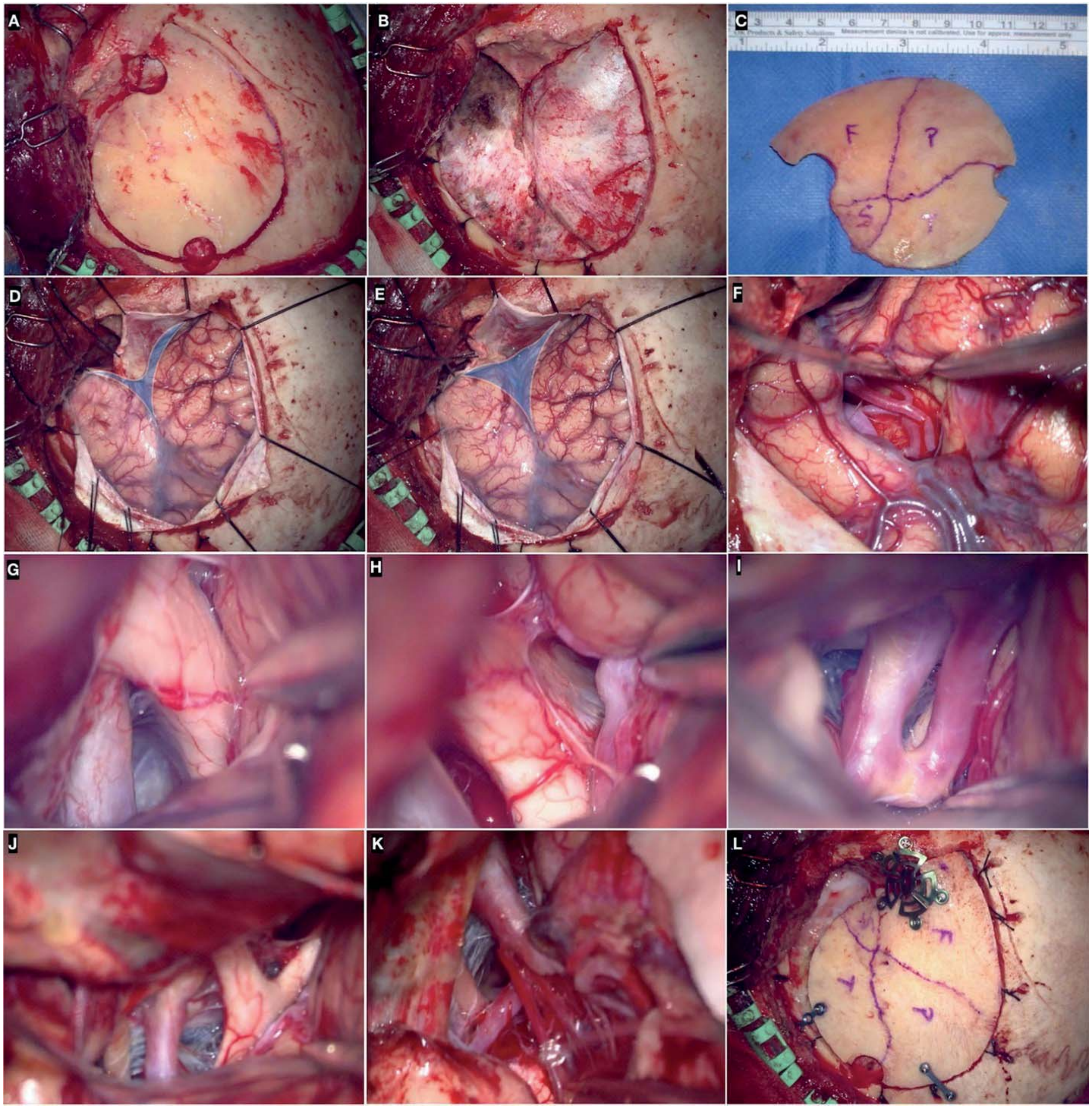


Figure 3. (A-C) Left frontotemporal craniotomy and bone flap. Exposure of the sphenoidal part of the sylvian fissure (blue area) before (D) and after (E) drilling of the lateral third of the greater sphenoid wing. Splitting of the sylvian fissure (F) and intradural exposure of optico-carotid complex (G), lamina terminalis (H), anterior cerebral artery (I), Liliequist's membrane (J), posterior communicating, and posterior cerebral artery (K). (L) Osteosynthesis of the bone flap with titanium low profile burr-hole covers, mini plates, and self-screwing unicortical screws.

4. Functional outcome

Forehead skin dysesthesia, chewing dysfunction, and neuropathic pain of the temporomandibular joint were the relatively most frequent functional complications; in the context of an overall functional complication, rate was 2.1% (Table 2).

5. Cosmetic outcome

Temporalis muscle atrophy was the cause of a poor cosmetic outcome in 7 patients (0.7%). Paralysis of the frontalis and corrugator supercilii muscles, secondary to iatrogenic damage of the frontal branch of the facial nerve, frequently occurred in association with dysesthesia of the skin of the forehead. The overall cosmetic complication rate was 2.1% (Table 2).

Table 2. Functional and cosmetic complications

Type of complication	N° of patients (%)
Functional	
Early	
Skin-flap necrosis no. (%)	0
Auriculotemporal neuralgia/anesthesia no. (%)	3 (0.3%)
Forehead skin dysesthesia no. (%)	4 (0.4%)
Tension pneumocephalus (accidental opening of the frontal air sinus) no. (%)	2 (0.2%)
Late	
Neuropathic pain of TMJ no. (%)	4 (0.5%)
Restricted mouth opening no. (%)	2 (0.2%)
Chewing dysfunction no. (%)	3 (0.3%)
Frey's syndrome no. (%)	2 (0.2%)
Total no. (%)	20 (2.1%)
Cosmetic	
Early	
Frontal muscle weakness no. (%)	4 (0.4%)
Eyebrow motility impairment no. (%)	3 (0.3%)
Late	
Alopecia no. (%)	2 (0.2%)
Temporalis muscle atrophy no. (%)	7 (0.7%)
Total no. (%)	14 (1.6%)

TMJ: temporo-mandibular joint

6. Illustrative Case

Unilateral pterional approach to bilateral multiple anterior circulation aneurysms

A 58-year-old woman was diagnosed with a subarachnoid hemorrhage mainly involving the left sylvian and parasellar cisterns. The patient had a Hunt-Hess score of 4. CT and catheter-based angiography revealed six aneurysms. On the left side, an MCA bifurcation was found, along with two further aneurysms involving the PCoA, and the AChA, respectively. On the right side, a PCoA aneurysm, an M1 segment MCA one, and an MCA bifurcation one were present. Because of the poor neurological condition, the patient was a candidate for late surgery. Three weeks later, in light of a partial recovery, the patient underwent a left pterional transsylvian approach, and five of the six aneurysms were successfully clipped with a single-stage surgery. A suprachiasmatic corridor was used to clip, with the aid of the endoscopic assistance, the contralateral, unruptured, medial projecting PCoA aneurysm. The right unruptured M1 segment MCA aneurysm was also clipped through the same corridor. The left giant MCA bifurcation aneurysm partially thrombosed was clipped after further two months using a right pterional approach (Figure 4). The overall outcome was good, and the patient completely recovered with no deficits after 6 months.

Discussion

The pterional approach allows operating through the transsylvian and subfrontal surgical corridor avoiding fixed brain retraction. The very low rate of approach-related complications reported on a large cohort of patients in the present study validates the technical variations progressively implemented by the authors in the execution of the pterional approach. Nevertheless, it should be stressed that ours is a prevalence study concerning the application of some variations of the standard technique originally described by Yaşargil. Accordingly, further studies are needed to definitively validate the present data. Most of the technical notes underlying the good functional and cosmetic outcome came from the constant improvement and refinement of the microneurosurgical technique and the rigorous preservation of the anatomy. Our group has persistently stressed that these aspects are fundamental to achieve minimal invasiveness in any neurosurgical approach.[12-29] The technical variations that the authors adopted over the years involved the patient's positioning, dissection of the galea aponeurotica, dissection of the temporalis muscle, craniotomy, opening of the dura, and closure. Based on the anatomical relationships between the ICA, PCoA, and AChA with the anterior and posterior clinoid process,[30,31] we modified the extension and rotation of the patient's head for anterior circulation aneurysms, in accordance to the suggestions by Chaddad-Neto et al.[32] They demonstrated that excessive extension of the head causes the hindering of the optico-carotid complex by the orbital roof and deepens the anterior clinoid process and ICA, making anterior clinoidectomy and exposure of the ophthalmic artery more difficult.

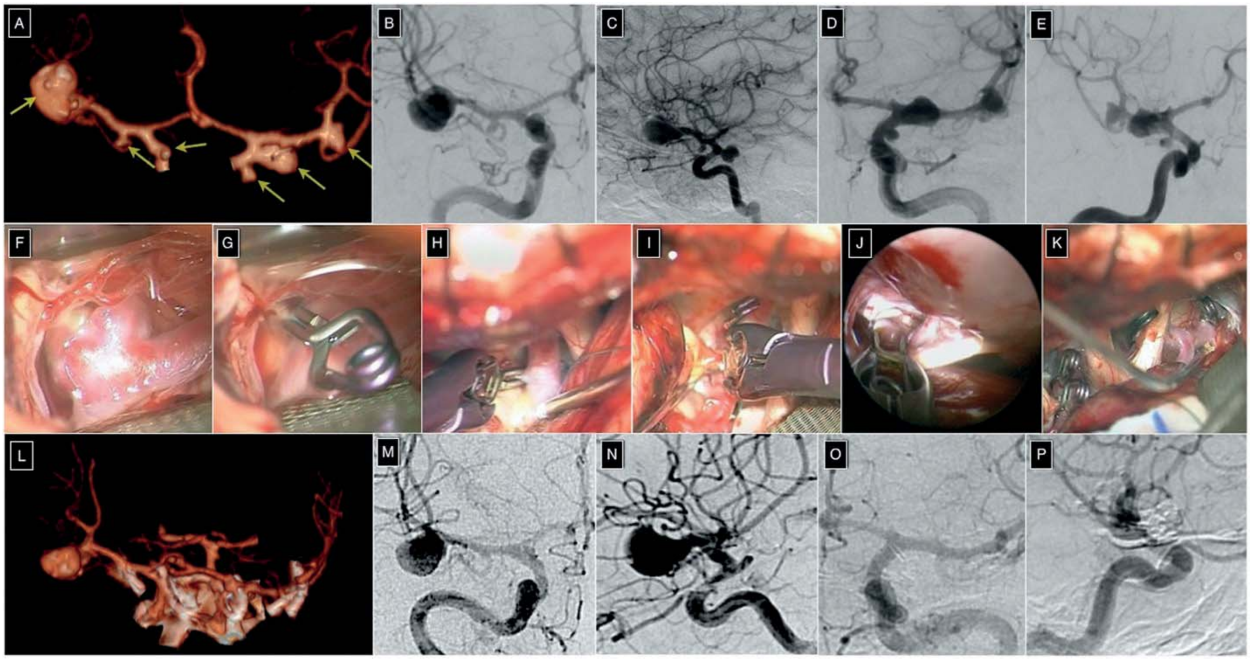


Figure 4. (**A**) Pre-operative 3D CT-angiography. Anterior (**B**) and lateral (**C**) projection digital subtraction angiography (DSA) of the right internal carotid artery (ICA). Anterior (**D**) and lateral (**E**) projection DSA of the left ICA. Clipping of the aneurysm of the left middle cerebral artery (MCA) bifurcation (**F**-**G**), left posterior communicating artery (PCoA) (**H**), left anterior choroidal artery (**I**), right PCoA (**J**), and right M1 segment MCA (**K**) aneurysm. (**L**) Post-operative 3D CT-angiography. Anterior (**M**) and lateral (**N**) projection DSA of the right ICA. Anterior (**O**) and lateral (**P**) projection DSA of the left ICA.

A 15° rotation without extension makes the longest axis of the clinoid process parallel to the floor.[32] Consequently, we prefer a neutral position of the head with 15° rotation for ophthalmic, PCoA, and AChA aneurysms. On the other hand, we found advantageous a 15° extension with 10° rotation for aneurysms involving the MCA bifurcation and ICA, as well as anterior and inferior projecting ACoA aneurysms.

Apart from the antalgic purpose, the local anesthesia along the mark of the skin incision allows also for an easier detachment of the skin flap from the subcutaneous layers. We use a solution containing lidocaine hydrochloride 1% or mepivacaine chlorhydrate 2% plus adrenaline diluted in normal saline 0.9% (1:1). Care ought to be taken to avoid placing the skin incision too anteriorly in those cases where full exposure of the posterior ramus of the sylvian fissure is planned. Further rationale is that the splitting of the sylvian fissure should start at the tip of the pars triangularis of the frontal operculum, which, for that reason, ought to be entirely exposed. The preservation of the auriculotemporal nerve during the skin incision and soft tissue dissection prevents the occurrence of troublesome dysesthesias of the pinna. To avoid necrosis of the edges of the flaps, we discourage the use of Raney hemostatic scalp clips in case of thin or hypovascularized flaps, or also chronic radiation-induced dermatitis of the scalp. Conversely, their use can be advantageous in the case of acquired coagulopathies.[33] The galea-pericranium can be used as a double-layered autologous patch graft in case of duraplasty. Moreover, it can be reflected over the frontal sinus as a vascularized pedicled flap in case of accidental violation. Electrocautery must be avoided during the submuscular dissection of the temporalis muscle to preserve the anatomical integrity of the deep fascia and, at the same time, the blood supply to the muscle coming from the deep temporal arteries.[11,34-40] A meticulous blunt subperiosteal dissection of the temporalis muscle is greatly helpful in the recognition of the sutures, which is important for the following bony step on the approach. The fronto-zygomatic suture and superior edge of the posterior root of the zygomatic process of the temporal bone should always be exposed. Oikawa's technique involves proceeding with the subperiosteal dissection of the temporal muscle from backward to the frontward, and from downward to upward, toward the superior temporal line, which is the point where the muscle is more tenaciously attached because of the fusion of the superficial and deep temporal fascia.[11] For this step, a semi-sharp instrument tip — like that of a Langenbeck periosteal elevator — can be useful.

We found unnecessary the routinary preparation of a muscle cuff along the superior temporal line in the pterional approach, especially when the submuscular technique is used. The submuscular technique is employed nowadays by most surgeons because is considered faster and is associated with a negligible risk of iatrogenic damage to the frontal branch of the facial nerve, as also confirmed by our results. Preservation of the deep fascia and deep temporal arteries is the key to preventing the atrophy of the temporalis muscle and related functional and cosmetic complications (Figure 5).[3,11,34-41] A simple trick to ensure having achieved skeletonization sufficiently basal of the temporal fossa is to expose the midpoint of the spheno-zygomatic suture. Regarding the handling of the temporalis muscle, Baldoncini and colleagues reported two "vascular free" safe zones for the hooks' retraction, that are based on the course of the anterior and posterior deep temporal arteries. They are the anterior safe zone, 14 mm posterior to the frontozygomatic suture, and the posterior safe zone, 30 mm anterior to the external auditory meatus.[42] The sparing of the vascular zone decreases the risk of postoperative atrophy of the temporalis muscle. Most of the advantages of the pterional approach depend on the perfect execution of the bone work. For this purpose, the exposure and recognition of all the sutures forming the pterion are of utmost importance, since they serve as landmarks to localize the lateral third of the sphenoid wing and the SOF. In sum, this facilitates the anatomical orientation necessary in the tailoring of the pterional approach.

The key step of the pterional approach consists in the drilling of the lateral part of the greater sphenoid wing until the SOF. This allows for a full and unobstructed view of the sphenoidal part of the sylvian fissure. Drilling of the lateral part of the greater sphenoid wing avoids the fixed brain retraction and the need for spatulas. It also makes the surgical target shallower and shortens the working distance.[1] Considering that in most cases the exposure of the orbit and its contents is not necessary to treat the lesion for which the pterional approach is indicated, we place the first burr hole just above the McCarty keyhole, thus accessing only the anterior cranial fossa. After the removal of the bone flap and drilling of the sphenoid wing, we perform two additional maneuvers, namely, the enlargement of the SOF, to obtain an easier reflection of the dural flap after the opening of the dura, and the thinning of the ipsilateral orbital roof with a small-sized burr, to achieve a line of sight and working corridor as flat as possible to the floor of the anterior cranial fossa. The dura may be opened in a curvilinear fashion around the SOF, but this cut is perpendicular to the sylvian fissure and middle meningeal artery. As a consequence, the Sylvian veins may be potentially damaged, especially in the case of brain edema, and the middle meningeal artery can become a source of copious bleeding. To prevent these complications, we suggest making a cut parallel to the posterior ramus of the sylvian fissure, and two further curvilinear cuts at the level of the frontal and temporal lobes. In the case of duraplasty, we prefer to use autologous galea compared to any other heterologous

Figure 5. (**A**-**C**) Illustrative examples of good functional and cosmetic outcomes of three randomly selected patients from the cohort.

or synthetic dural substitutes because of documented advantages about the risk of infections or rejections, and also the cost-effectiveness of autologous grafts.[43-45]

Bone dust can be used in case of a gap on the temporal side of the bone flap. Over the years, we also noted its intrinsic hemostatic power. The use of 3/0 silk or ethilon stiches is strongly recommended for skin closure to obtain a very good aesthetic result.

Tailoring the pterional approach

The versatility of the pterional approach is such that it can be used even for aneurysms of the contralateral side, as demonstrated by many authors,[46-50] and confirmed by the reported illustrative case. Our long-lasting experience in the surgical management of intracranial aneurysms allowed us to identify some variables at the basis of the tailoring of the pterional approach;[51-56] which are the size of the bone flap and the prevalent extension toward the frontal versus temporal area. Flaps limited in size are generally adequate for those unruptured aneurysms of the paraclinoid ICA, where a wide splitting of the sylvian fissure is unnecessary, and for those small unruptured of the MCA bifurcation, for which a limited opening on the posterior ramus of the sylvian fissure is generally sufficient. Conversely, larger bone flaps are required for ruptured or giant aneurysms, and also ACoA complex aneurysms. Supraclinoid ICA aneurysms, those anteriorly and inferiorly projecting of the ACoA, and the MCA bifurcation ones, require the symmetrical exposure of the frontal and temporal opercula on both sides of the sylvian fissure. A wider frontal extension is useful in those cases where the subfrontal perspective is the prevalent working corridor. This is the case of the superiorly and posteriorly projecting ACoA aneurysms. A greater temporal extension is instead required for the basilar tip or P1 PCA aneurysms, where the pretemporal corridor is the elective route to the target. A greater temporal extension is necessary also in the case of the combined transsylvian–pretemporal working route to the basilar tip, the so-called “half-and-half approach”.[57,58]

Limitations of the Study

The present study has several limitations due to its retrospective nature, the expertise heterogeneity of the group of surgeons, the lack of a control group, the use of a protocol arbitrarily conceived by the authors and not universally validated for the assessment of functional and cosmetic outcomes, and the operator-dependent assessment of most of the parameters employed for the evaluation of the functional and cosmetic outcomes.

Conclusion

Deep knowledge of the skull base anatomy, accurate planning, and meticulous execution of the pterional approach are critical factors to operate through transsylvian and subfrontal corridor avoiding brain retraction.

In the authors’ experience, the progressive implementation of some technical notes regarding the patient’s positioning, dissection, and handling of the galea aponeurotica and temporalis muscle, craniotomy, opening of the dura, and closure, contributed to enhancing the versatility of the pterional approach, concurrently decreasing the risk of functional and aesthetic complications.

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