Cranio-Orbito-Zygomatic Approach

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Abstract. The cranio-orbito-zygomatic (COZ) approach consists of an extension of the pterional approach characterized by the removal of the superolateral part of the orbital rim and zygoma. This key step tremendously increases the angular exposure to some deep targets and overall surgical freedom to the lesion. In this article we review the technical variations of the COZ approach, mainly focusing on the differential quantitative effects coming from the orbital osteotomy compared to the zygomatic one. (www.actabiomedica.it)

Keywords: Carotid-oculomotor Window; Optic-carotid Window; Orbito-Zygomatic Approach; Orbitopterional Approach; Pterional Craniotomy; Skull Base Approach; Surgical Anatomy

Introduction

The cranio-orbito-zygomatic (COZ) approach allows wide exposure of the anterior and middle skull base until the upper clivus.

It involves the addition of an orbito-zygomatic (OZ) osteotomy to the pterional approach. Removal of the OZ bar has three main advantages (1-16). The first is the dramatic increase in the subfrontal and subtemporal view angle for those skull base lesions extensively projecting upward. The second is the shortening of the working distance. The third is obtaining a wide working space with the capability of handling the lesion from different angles.

Herein we overview the different techniques reported for the COZ approach. We also analyze the differential quantitative effects of the orbital and zygomatic osteotomy on the angular exposure of the target and overall surgical freedom.

Indications

The COZ approach is indicated for high-riding large to giant aneurysms of the anterior communicating artery (ACoA) and basilar apex, especially when projecting posteriorly. Large meningiomas of the anterior clinoid and spheno-orbital region, large craniopharyngiomas, and giant pituitary adenomas are additional indications. The COZ approach also provides direct access to the ipsilateral crural and ambient cisterns, interpeduncular fossa, ipsilateral cerebral peduncle, and hypothalamic region. Therefore, it is also the most widely used corridor for the treatment of

cavernous hemangiomas of the anterior midbrain and hypothalamus.

Technique

Positioning

The patient is placed in a supine position with the head secured to a Mayfield–Kees skull clamp. The head is elevated, extended 20°, and rotated 20° to 60° to the contralateral side depending on the target. The malar eminence is the highest point of the patient's head. A rotation of 30° leads to a line of sight that is parallel to the long axis of the anterior clinoid. Conversely, a rotation of 45° optimizes the exposure of the subfrontal area.

Skin Incision and Soft Tissue Dissection

The curvilinear skin incision is made behind the hairline, from the contralateral midpupillary line to the level of the zygomatic process of the temporal bone, 1 cm in front of the tragus to spare the superficial temporal artery and auriculotemporal nerve. The skin flap is separated from the galea and reflected forward. Then, the preserved galea is incised along the superior temporal line and reflected anteriorly. Subperiosteal dissection prepares the galea-pericranium vascularized

flap which, along with the fat graft, can be used for repair of the frontal sinus in case of violation. At the level of the temporalis muscle, the superficial and deep layers of the superficial temporal fascia are incised together 2.5 cm behind the fronto-zygomatic suture. This cut is directed obliquely toward the posterior root of the zygoma, thus making an anterior two-layer leaflet, containing the frontotemporal branch of the facial nerve with its interfascial fat pad, and a posterior one. This technique is referred to as subfascial dissection.

The temporalis muscle is cut at the level of the fronto-zygomatic suture, 2 cm below the superior temporal line, to leave a myofascial cuff. It will be useful in anchoring the temporalis muscle during closure.

The cut curves posteriorly to reach the posterior third of the zygoma and the muscle is subperiosteally detached from the underlying bone in a retrograde superior-to-posterior and backward-to-forward direction, according to the Oikawa technique (17). Electrocauterization must be avoided during this phase to preserve the blood supply from the internal maxillary artery, through the deep temporal arteries, and prevent muscle atrophy (11, 17-19). Then, the periorbita is freed from the superior and lateral orbital wall to a depth of 3 cm until the lateral most point of the superior orbital fissure (SOF). Care must be taken for the lacrimal gland and to maintain the periorbita intact to prevent postoperative orbital enophthalmos (Figure 1).
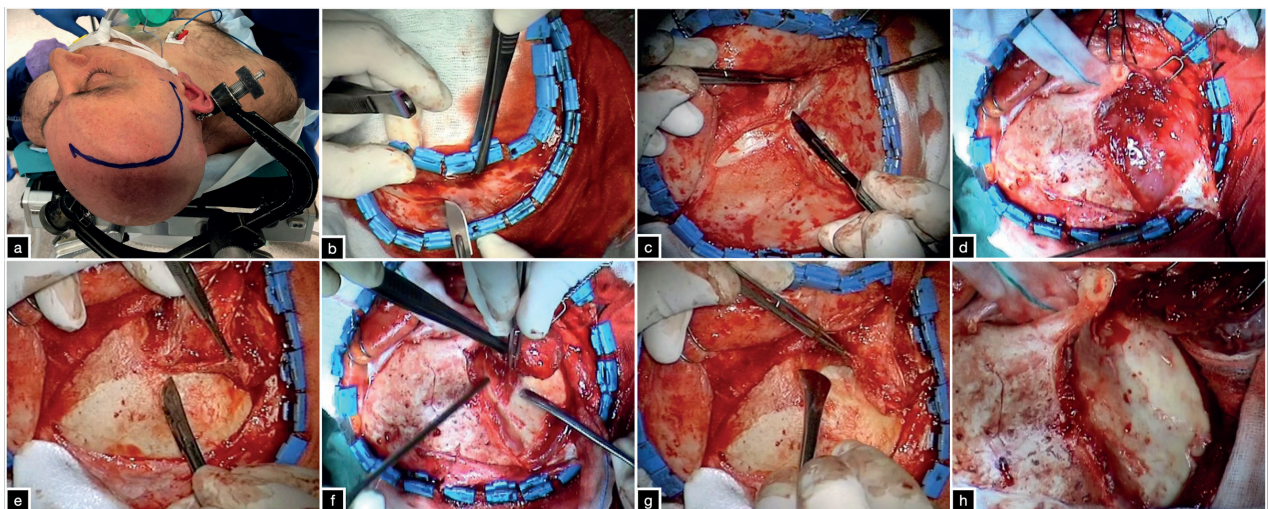

Figure 1. (a) position and skin incision. (b-d) galea-pericranium vascularized flap and subfascial dissection of the superficial temporal fascia. (e-g) retrograde subperiosteal dissection of the temporalis muscle according to the Oikawa technique and the skeletonization of the orbito-pterional region.

Craniotomy

The COZ craniotomy can be performed in a one-(1-6), two- (9-11), or three-piece technique (13, 14) (Figure 2).

One–Piece Orbito–Zygomatic Craniotomy

MacCarty keyhole is placed 5 mm behind the join between the fronto-zygomatic, spheno-zygomatic, and fronto-sphenoidal sutures. The anterior fossa dura, periorbita, and orbital roof separating them are thus exposed (4, 20). An additional burr hole is placed at the level of the temporal squama above the posterior root of the zygoma.

An additional burr hole is placed at the level of the temporal squama above the posterior root of the zygoma. The first cut involves the posterior root of the zygoma and is generally accomplished through the reciprocating saw. Preplating may be useful for osteosynthesis. The second cut connects the keyhole with the inferior orbital fissure (IOF). A simple method to
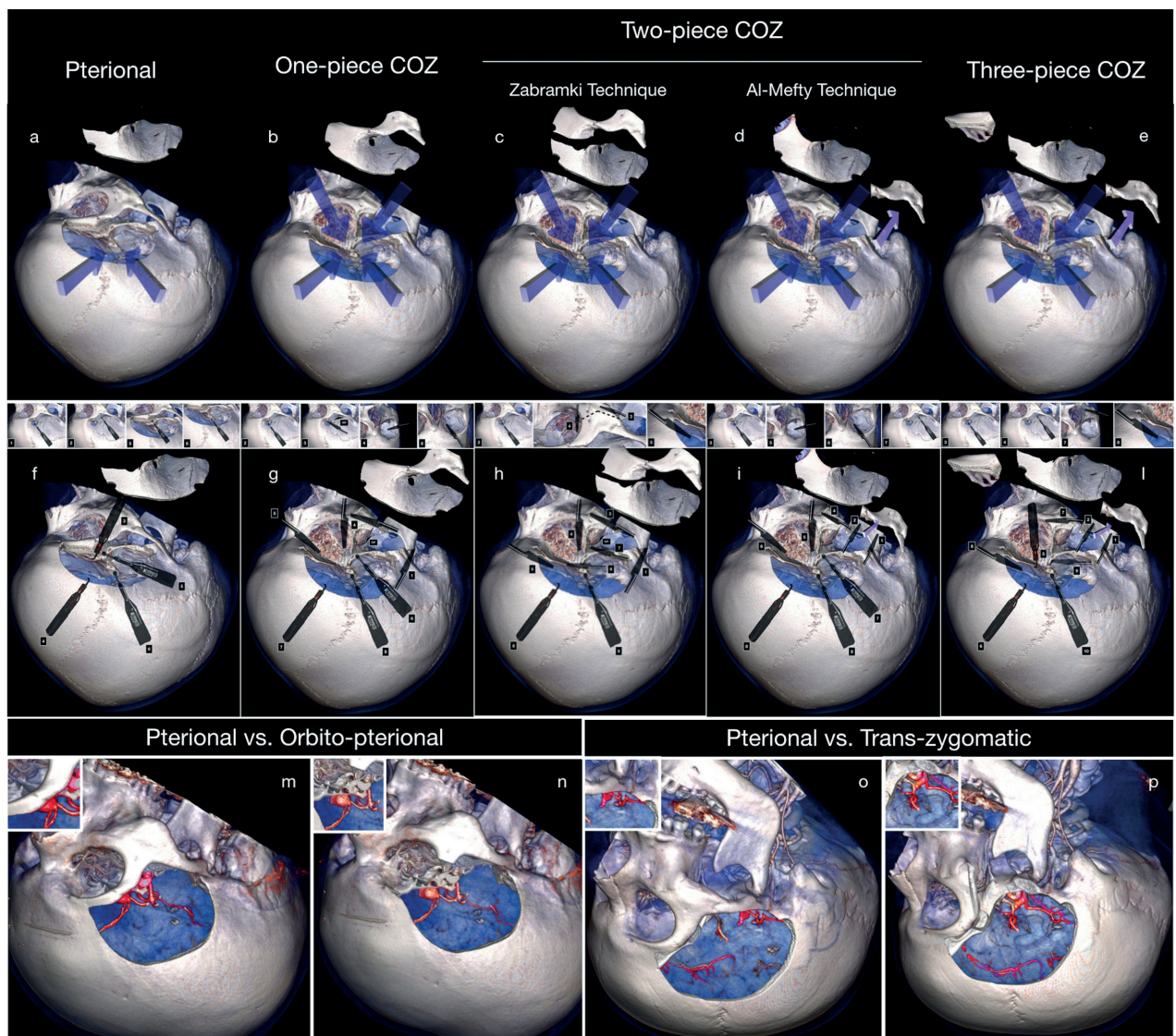

Figure 2. Comparison between pterional (a) approach and one-piece (b), two-piece (c,d), and three-piece COZ craniotomy with the relative surgical steps (f–l). Comparison in the surgical exposure between the pterional (m) vs O-pt approach (n) and pterional (o) and transzygomatic (p) approach.

identify the IOF at the level of the infratemporal fossa is passing Penfield Dissector No. 4 placed parallel to the zygoma. The third cut involves the lateral orbital wall and is conducted across the malar eminence. The supraorbital nerve may be released and mobilized. The fourth cut is made on the intraorbital side lateral to the supraorbital notch. It crosses the superior orbital rim and orbital roof to reach the SOF. The keyhole and temporal and frontal burr holes are then connected. In the case of particularly adherent dura, a further burr hole can be placed.

The temporalis muscle is reflected downward. Galea-pericranium flap is tented with stiches protecting the eyeball and allowing for a line of sight as flat as possible to the anterior skull base.

Two-Piece COZ Craniotomy

Two variants have been reported to perform the two-piece COZ. The first, namely Zabramski's technique, includes the pterional craniotomy plus the OZ osteotomy. Al-Mefty's technique consists of an orbitopterional flap completed with an osteotomy and downward mobilization of the zygoma.

Orbito-zygomatic Craniotomy (Zabramski Technique)

The first step consists of pterional craniotomy. Six different cuts are necessary to complete the removal of the OZ bar. The first cut involves the posterior root of the zygoma; the second divides the lateral and medial part of the malar eminence; the third is executed across the lateral orbital wall, from medial to lateral. In contrast with the one-piece variant, the orbital roof cut (fourth cut) is performed intracranially. It is performed from the lateral end of the SOF to the superior orbital rim. The fifth and sixth cuts unite the SOF and IOF, while the sixth one involves the anterior part of the middle fossa and is advanced up to the lateral limit of the IOF (11).

O-pt Craniotomy (Al-Mefty Technique)

The O-pt variant of the two-piece COZ consists of, as the first step, two zygomatic cuts performed at the level of the anterior and posterior roots of the zygoma. This technique avoids the detachment of the masseter muscle and decreases the risk of postoperative masticatory imbalance. Apart from the zygomatic osteotomy, the remaining steps are the same already described for the one-piece COZ, and all cuts are made extracranially (3).

Three-Piece COZ Craniotomy

The three-piece COZ approach comes from the combination of both the two-piece techniques. It entails a zygomatic osteotomy, downward mobilization of the zygomatic arch, and pterional and orbital bone flaps in separated pieces (13, 14).

Intradural Corridors

The COZ is related to four intradural corridors: subfrontal, transsylvian, pretemporal, and subtemporal, whose accessibility is conditioned by the wide splitting of the Sylvian fissure.

The transsylvian and pretemporal corridors are associated with the optic-carotid, carotid-oculomotor, supra-carotid, and oculomotor-tentorial window. The subfrontal and transsylvian perspectives are largely used to clip large and giant ACoA aneurysms, whereas the deep windows represent the main access routes to basilar tip aneurysms.

The removal of the orbital rim, which is the roof of the subfrontal perspective, allows increasing obliquity of the line of sight backward and upward.

A shorter internal carotid artery (ICA) is related to a narrower optic-carotid and carotid-oculomotor window and a wider supra-carotid corridor to the basilar tip.

The anterior clinoidectomy, including the opening of the distal dural ring, enlarges the working space of the deep windows through lateral or medial mobilization of the ICA.

The lateral mobilization of the ICA can be required to furtherly increase the optic-carotid route to basilar apex aneurysms, also achieving the proximal control of the upper part of the mid basilar trunk. Conversely, medial mobilization of the ICA, posterior clinoidectomy and splitting of the tentorium expands the carotid-oculomotor window.

While the removal of the orbital rim is useful for high-riding basilar tip aneurysms, the increased illumination and shallowing of the surgical field coming

from the zygomatic osteotomy provide advantages during pretemporal, subtemporal transtentorial, and subtemporal transpetrosal (Kawase's) approaches in low-riding aneurysms.

The accessibility of the supra-carotid window may be reduced by perforating arteries from the ICA terminus to the anterior perforated substance.

Tailoring The COZ Approach

From a quantitative standpoint, the comparison between the pterional and COZ approach in terms of overall surgical freedom has led to assess that the removal of the OZ bar osteotomy, as a single bloc, increases the angular exposure of 8°, 6°, and 10° on the sagittal, coronal, and axial plane, respectively (21). About the surgical perspectives, the estimated angular exposure to the ACoA, basilar bifurcation, and posterior clinoid have been reported to be 75%, 46%, and 86% in the subfrontal, pterional, and subtemporal corridors, respectively (21).

For the basilar apex and posterior clinoid, the removal of the orbital rim and zygomatic arch in separate pieces leads to increases in the exposure of 28% and 22%, respectively (22).

Table 1 presents the average area of exposure of pterional, O-pt, pterional plus zygomatic, and COZ osteotomy based on the data of Schwartz and colleagues (22).

Table 2 shows the percentage increase in exposure to different targets, provided by O-pt, pterional + zygomatic, and COZ osteotomy compared with that in the pterional approach (22).

These morphometric data represent the basis for tailoring the COZ approach.

Complications Avoidance

The COZ-related complications can be functional or aesthetic. Injury of the frontotemporal branch of the facial nerve, atrophy of the temporalis muscle, masticatory imbalance, enophthalmos, diplopia, blindness, and cerebrospinal fluid leakage are the most frequent. The dissection of the superficial temporal fascia via the subfascial technique avoids damage to the frontotemporal branch of the facial nerve, while a subperiosteal blunt and "cold" (without electrocauterization) dissection of the deep temporal fascia lessens the risk of temporalis muscle atrophy.

The subfascial technique is proved to be safer than the interfascial one due to the variable anatomical course of the frontotemporal branch of the facial nerve. In fact, in 30% of cases, many nerve twigs were found within the two fascial layers (23).

Table 1. Average Area of Exposure to Different Targets of Pterional, O-pt, and COZ Osteotomy

Approach	Area of exposure (mm² ± SD)		
	Posterior clinoid	Tentorial edge	Basilar tip
Pterional	2915 ± 585	2521 ± 301	1639 ± 244
O-pt	3702 ± 943	3536 ± 539	2020 ± 350
COZ	4170 ± 1053	4249 ± 1186	2400 ± 386

O-pt, orbitopterional; COZ, cranio-orbito-zygomatic

Table 2. Percentage Increase in Exposure to Different Targets Provided by O-pt, Pterional + Zygomatic Osteotomy, and COZ Osteotomy Compared with That in the Pterional Approach (22)

Approach	Surgical target (% increase in exposure)		
	Posterior clinoid	Tentorial edge	Basilar tip
O-pt	26*	39*	28*
Pterional + Zygomatic Osteotomy	13	17	22
COZ	43*	64*	51*

O-pt, orbitopterional; COZ, cranio-orbito-zygomatic; *p < 0.05

About the atrophy of the temporalis muscle, two points are recommended: first, the subperiosteal retrograde dissection of the deep temporal fascia according to the Oikawa technique (17), second, avoid excessive compression of the muscle against the zygomatic arch during its downward displacement (24).

The main reason for mobilization rather than resection of the zygomatic arch is to avoid detachment of the masseter muscle, thus preventing postoperative masticatory imbalance.

Diplopia and orbital asymmetry can be avoided by meticulous osteosynthesis, generally performed using low-profile mini plates and screws. The anatomical integrity of the periorbita is of greatest importance to prevent enophthalmos and postoperative orbital hematomas. A potential risk for the optic nerve is the excessive downward displacement of the eyeball in the effort to maximize the exposure of the subfrontal area. The need to expand the subfrontal corridor may also cause the violation of the frontal air sinus. Cranialization of the sinus and use of autologous fat graft and galea-pericranium vascularized flap significantly reduces the risk of infections and cerebrospinal fluid leakage.

Illustrative Cases

Case 1: Complex Basilar Tip Aneurysm

A 54-year-old woman was diagnosed with an incidental large basilar tip aneurysm. On digital subtraction angiography, the aneurysm had a dome-to-neck ratio of 1.5, and the dome was projecting superiorly. Both P1 segments of the posterior cerebral arteries arose from the neck, which was also calcified. The basilar bifurcation was low-riding, at 0.8 cm below the dorsum sellae.

The patient underwent a COZ approach with an extradural anterior clinoidectomy, lateral mobilization of the ICA, and posterior clinoidectomy. Posterior clinoidectomy allowed the widening of the carotid-oculomotor window, thus gaining an optimal exposure of the mid basilar trunk. The anterior clinoidectomy and lateral mobilization of the ICA expanded the optic-carotid deep window leading to successfully clipping the aneurysm. The transsylvian and pretemporal corridors were used. The patient was discharged neurologically intact on the fifth postoperative day (Figure 3).

Case 2: Large ACoA Aneurysm

A large ACoA aneurysm was found incidentally in a 48-year-old female patient. The left A1 segment was hypoplasic, and both A2 segments originated from
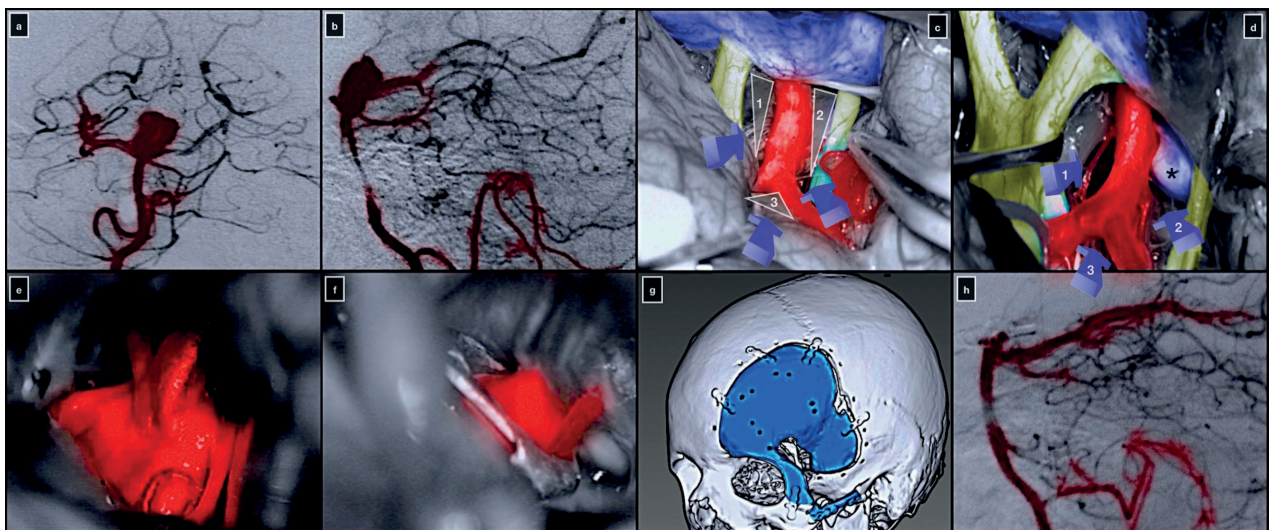

Figure 3. Preoperative digital subtraction angiography of the right vertebral artery in anterior-posterior (a) and lateral (b) projection. (c,d) Intraoperative pictures showing the right optic-carotid (1), carotid-oculomotor (2), supra-carotid (3), and oculomotor-tentorial (4) deep windows. Exposure (e) and clip ligation (f) of the basilar tip aneurysm. (g) 3D volume-rendered post-operative CT scan highlighting the COZ approach. (h) Postoperative digital subtraction angiography of the right vertebral artery in lateral projection.

ACoA near to the neck. The aneurysm was anterior superior projecting. The blind spot was on the left A2, hidden by the orbital rim. An O-pt approach was performed. The aneurysm was successfully clipped, and the postoperative course was uneventful (Figure 4).

Discussion

Morphometric quantitative studies clarified the consequences of OZ osteotomy on the overall surgical freedom of the COZ approach (3, 25-33).

OZ osteotomy has three main advantages, namely, wide working space, shorter operative distance, and increased angular exposure of the target. All of these factors contribute to decreasing the need for brain retraction.

Amid the anterolateral approaches to the skull base, the COZ allows the maximum surgical freedom to deep targets, deriving from the possibility to combine the subfrontal, transylvian, pretemporal, and subtemporal perspectives.

Several studies highlighted the advantages of the OZ osteotomy for lesions projecting upward, as high-riding ACoA and basilar tip aneurysm. An equally large number of anatomical studies supported the COZ approach for lesions extending downward, as basilar bifurcation aneurysms in patients with low-
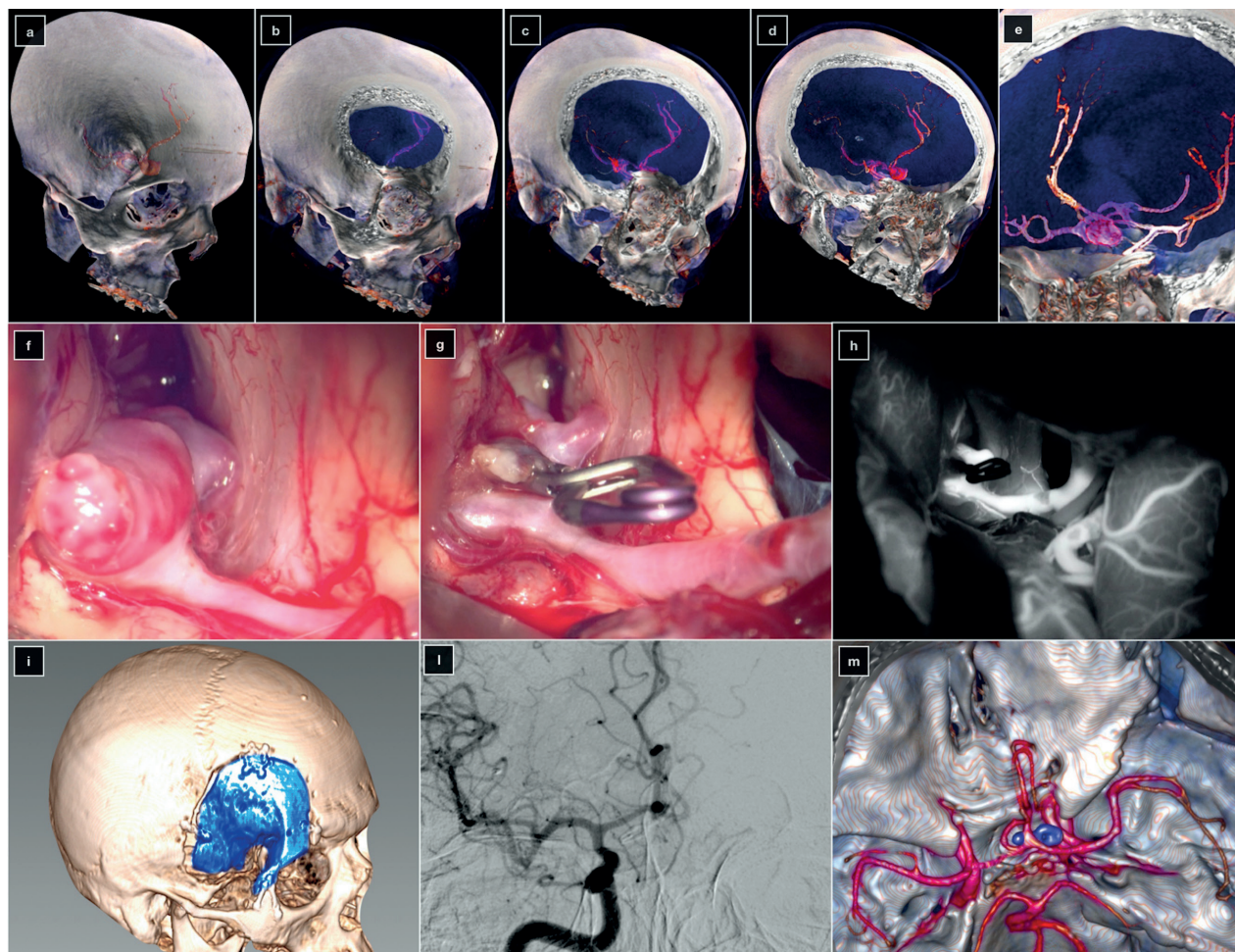

Figure 4. (a-e) 3D volume-rendered preoperative CT angiography. Intraoperative pictures were taken before (f) and after (g) the clipping of the aneurysm. (h) Post-clipping indocyanine green videoangiography. (i) 3D volume-rendered postoperative CT scan showing the orbito-pterional approach. (l) Digital subtraction angiography of the right internal carotid artery in anterior-posterior projection. (m) Postoperative 3D volume-rendered CT angiography.

riding basilar apex, large parasellar tumors, and even infratemporal fossa lesions (21, 22, 25, 27, 30, 31, 33-38).

Indeed, the COZ approach is indicated in both upward and downward projecting lesions, since the additional exposure related to OZ bar removal is spherical rather than linear. This increase in surgical freedom is the key of the multangular approach to the target.

About the angular exposure, the superolateral orbitotomy has quantitative and qualitative effects different from those of the zygomatic osteotomy, these aspects being arguments for tailoring the COZ (21, 22, 31, 33, 36, 39).

The removal of the orbital rim markedly raises the roof of the subfrontal corridor, also enhancing the anterolateral perspective of the subfrontal area through the transylvian route. Conversely, the zygomatic osteotomy provides substantial advantages in the expansion of the pretemporal and subtemporal corridors (22).

The constant refinement of skull base surgical techniques, on a par with other fields of neurosurgery (40-50), has led to a progressive shift from one- to three-piece technique, the reasons for this mainly lying in a greater facility of execution and better functional and cosmetic outcomes (6, 11, 51, 52).

Conclusion

The COZ approach is an extension of the pterional approach where the removal of the OZ bar dramatically increases the angular exposure of the subfrontal, transylvian, pretemporal, and subtemporal corridors. The COZ approach finds its main indication in high-riding, giant, or complex ACoA aneurysms, in the basilar apex ones, and large tumors of the anterior and middle skull base. A careful planning and meticulous execution of the approach, along with deep knowledge of the skull base anatomy, are paramount factors to exploit all advantages of the COZ approach and decrease concurrently the risk of complications.

Conflict of Interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

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