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Original article

Far Lateral Approach

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Abstract. The far lateral approach is an inferolateral extension of the lateral suboccipital approach. Designed for clipping of the aneurysms of the vertebrobasilar junction and proximal segments of the posterior inferior cerebellar artery, it became over the years a workhorse approach for ventral foramen magnum meningiomas and other intradural lesions located anterior to the dentate ligament. This article summarizes the technical key aspects of the far lateral approach and transcondylar, supracondylar, and paracondylar extension. (www.actabiomedica.it)

Key words: Far-lateral approach; Foramen magnum; Jugular tubercle; Occipital condyles; Posterior-Inferior cerebellar artery; Transcondylar Approach.

Introduction

The far lateral approach was described by Roberto Heros in 1986 (1). It consists of an extension further lateral of the lateral suboccipital approach where drilling of the posterolateral aspect of the foramen magnum (FM) and C1 hemilaminectomy tremendously increases the working space in front of the brainstem, thus eliminating the need for retraction. This route has unquestionable advantages in exposing the intradural vertebral artery (VA), the vertebrobasilar junction (VBJ), the proximal segment of the posterior inferior cerebellar artery (PICA), and anterolateral versant of the medulla oblongata and the upper cervical cord.
The far lateral approach also involves a transcondylar, supracondylar, or paracondylar extension with a further increase in the working space at the anterior border of the FM, jugular tubercle (JT) area, and posterior edge of the jugular foramen (JF), respectively.

Because of this wide versatility, the far lateral approach is today considered as a pillar among the approaches to the posterolateral skull base.

This article overviews the surgical technique of the far lateral approach and transcondylar, supracondylar, and paracondylar extension.

Indications

The far lateral approach is indicated for those lesions lying in front of the dentate ligament between the lower third of the clivus and the superior aspect of the body of C2 (2). Extra-axial lesions of this area involve the premedullary and lateral cerebellomedullary cistern. They are ventral FM meningiomas, aneurysms of the V4 segment of the VA, VBJ, and anterior and lateral medullary segment of the PICA, schwannomas of the lower cranial nerves, and arteriovenous malformations of the lower brainstem having the nidus located anterior to the dentate ligament. Gliomas and cavernous hemangiomas affecting the anterolateral aspect of the medulla oblongata and upper cervical cord may be reached with the far lateral approach.

Technique

Positioning

Several surgical positions have been proposed for the far lateral approach, according to the different preferences of each group or proposed technical variation. They can be summarized as follows:

- lateral position with the head tilted toward the ipsilateral shoulder and the shoulder pulled down (1, 3);
- sitting position with the head rotated toward the lesion (4-8);
- three-quarter prone (modified park-bench) position with the head rotated toward the floor and flexed onto the contralateral shoulder. The arm is secured below the upper end of the operating table and the axilla is padded (9, 10);
- supine position with the head rotated 45° toward the contralateral shoulder (11, 12);
- prone position with the head in a neutral position (13).

Skin Incision and Nuchal Muscles Mobilization

A reverse hockey-stick, linear, and C-shaped skin incision has been proposed for the far lateral approach (4, 5, 9, 10, 14-20).

The classic reverse hockey-stick incision starts below the mastoid tip, is directed upward to the superior nuchal line, curves medially to reach the inion, and then is advanced downward until C3 (9) **(Figure 1 A)**. Some authors recommend a variation of the reverse hockey-stick incision where the cut starts at the level of the midline, 5 cm below the inion, reaches the opisthocranion upward, follows laterally the superior nuchal line, passes above the mastoid, and follows down the posterior border of the sternocleidomastoid muscle to terminate 5 cm below the mastoid tip (5, 10, 14-16). This type of incision involves that the muscle block is reflected medially, thus allowing for an unobstructed view of the lateral aspect of the C0–C1 complex and V3 segment of the VA. The linear incision is placed between the inion and mastoid tip and aims at obtaining an easy, fast, and direct transmuscular exposure of the suboccipital triangle (4, 17-19). The retroauricular C-shaped incision starts 4 cm above the pinna, curves 4 cm behind the mastoid tip, and reaches the anterior border of the sternocleidomastoid muscle. It has been reported to have a lower risk of postoperative cerebrospinal fluid leakage (20). The nuchal muscles are generally reflected in a single block to skeletonize the lateral suboccipital region, lateral (C1) condyle, and C1 hemilamina. In doing this, it is paramount to leave a muscle cuff onto the superior nuchal line that will serve as the approximation of the myocutaneous flap during closure. Nevertheless, knowledge of the layering of the nuchal muscles is important for the harvesting of the occipital artery in case of bypass and to safely perform the interfascial technique for the exposure of the VA in the suboccipital triangle (21). Some of these muscles also serve as landmarks for certain neurovascular structures. The first layer is composed of the trapezius and sternocleidomastoid muscles. They are both unsheathed in the most superficial layer of the deep cervical fascia, the so-called investing or anterior layer. The trapezius and sternocleidomastoid muscles blend upward into the galea aponeurotica and the occipitofrontal muscle. Between the lateral border of the trapezius and the posterior border of the sternocleidomastoid muscle lies the posterior triangle of the neck. The investing fascia forms the roof of the posterior triangle, whereas the semispinalis capitis muscle medially, and splenius capitis muscle laterally forms the floor (Figure 1 B, C). Beneath the investing fascia, the deepest layer of the deep vertebral fascia, the so-called prevertebral fascia, envelops the deep muscles of the neck. The splenius capitis completely covers the longissimus capitis. The anatomical relationship between the occipital artery and longissimus capitis is variable since the artery may course under the longissimus capitis or above it (Figure 1 E). On a deeper plane, lateral to the midline, the semispinalis capitis muscle spans from transverse processes of C4-C7 as far as to the occipital bone. The detachment of the semispinalis capitis from the occipital squama exposes the superior suboccipital triangle. The superior suboccipital triangle is bounded by the muscles rectus capitis posterior major supero-medially, superior oblique supero-laterally, and inferior oblique inferiorly. In the superior suboccipital triangle lies the horizontal V3 segment of the VA along with its periarterial autonomic neural plexus, vertebral venous plexus, and C1 nerve root (Figure 1 F). Lateral to the suboccipital triangle lies the rectus capitis lateralis, a short flat muscle attaching upward onto the jugular process of the occipital bone which forms the posterior border of the JF. The facial nerve, at its exit from the stylomastoid foramen, is lateral to the rectus capitis lateralis muscle. The rectus capitis lateralis is an important landmark in the identification of the jugular bulb.

Craniotomy

The far lateral approach comprehends a lateral suboccipital craniotomy, extended to the posterolateral edge of the FM until the posteromedial tip of the condyle, and a C1 hemilaminectomy. For the suboccipital craniotomy, Bertalanffy and colleagues reported a technical tip which they called the "C0" concept (4, 22). The "C0" concept considers the posterolateral rim of the FM, thicker compared to the remaining part of the occipital squama because of the cancellous bone, similar to the hemilamina of C1. The suboccipital craniotomy should initially spare the "C0 hemilamina". This technique allows better visualization of the caudal third of the sigmoid sinus, serving as a landmark for an adequate caudal exposure, an easier detachment of the atlanto-occipital membrane, and easier removal of the posterolateral rim of the FM. The C0 and C1 hemilaminectomy complete the approach. The main difference between the lateral suboccipital and far lateral craniotomy lies in the fact that the latter allows full exposure of the dural pierce of the VA. In the far lateral approach, the dura opening is medial to it (Figure 2 A, B).

The far lateral approach has three variants known as transcondylar, supracondylar, and paracondylar approach.

Far Lateral Transcondylar Approach

Drilling of the posterior portion of the condyle allows a progressive increase in the working space in front of the brainstem. The amount of the condyle to be drilled may range from the posterior third, with no sequelae on the biomechanics of the craniovertebral junction (CVJ), to the posterior half, generally associated with instability and need of fixation. The "complete" far lateral transcondylar approach has the anterior condylar canal (hypoglossal canal) as anterior limit (Figure 2 C, D) (5, 10, 17, 23-26).

Supracondylar (Transcondylar Fossa Trans-Jugular Tubercle) Approach

The supracondylar extension of the far lateral approach is considered a tailored approach to the JT area. The supracondylar approach consists of a transcondylar fossa trans-jugular tubercle route that completely spares the condyle. The condylar fossa is a small depression lying superiorly and posteriorly to the condyle forming the external surface of the posterior portion of the JT. The condylar fossa and JT are on the same plane, and both lie 5 mm above the level of the hypoglossal canal. The condylar fossa contains the posterior condylar canal at the bottom, which transmits the posterior condylar vein. The drilling of the bone of the condylar fossa results in a defect in the posterior part of the JT (5, 10, 23-28) (Figure 2 E, F).

Paracondylar Approach

The paracondylar extension of the far lateral approach is considered as a possible corridor to those lesions primarily involving the posterior edge of the JF. The paracondylar approach is directed through the jugular process of the occipital bone, for identification of which the rectus capitis lateralis muscle is a landmark.
The paracondylar approach involves the skeletonization and opening of the hypoglossal canal and, in selected cases also the partial drilling of the lateral portion of the occipital condyle and the mastoid tip (5, 10, 23-28) (Figure 2 G, H). The paracondylar variant is the approach of choice for dumbbell schwannomas of the lower cranial nerves and paragangliomas of the JF area.

Dura Opening

The dura is opened in a curvilinear fashion medial to the dural pierce of the VA (Figure 2 B). This

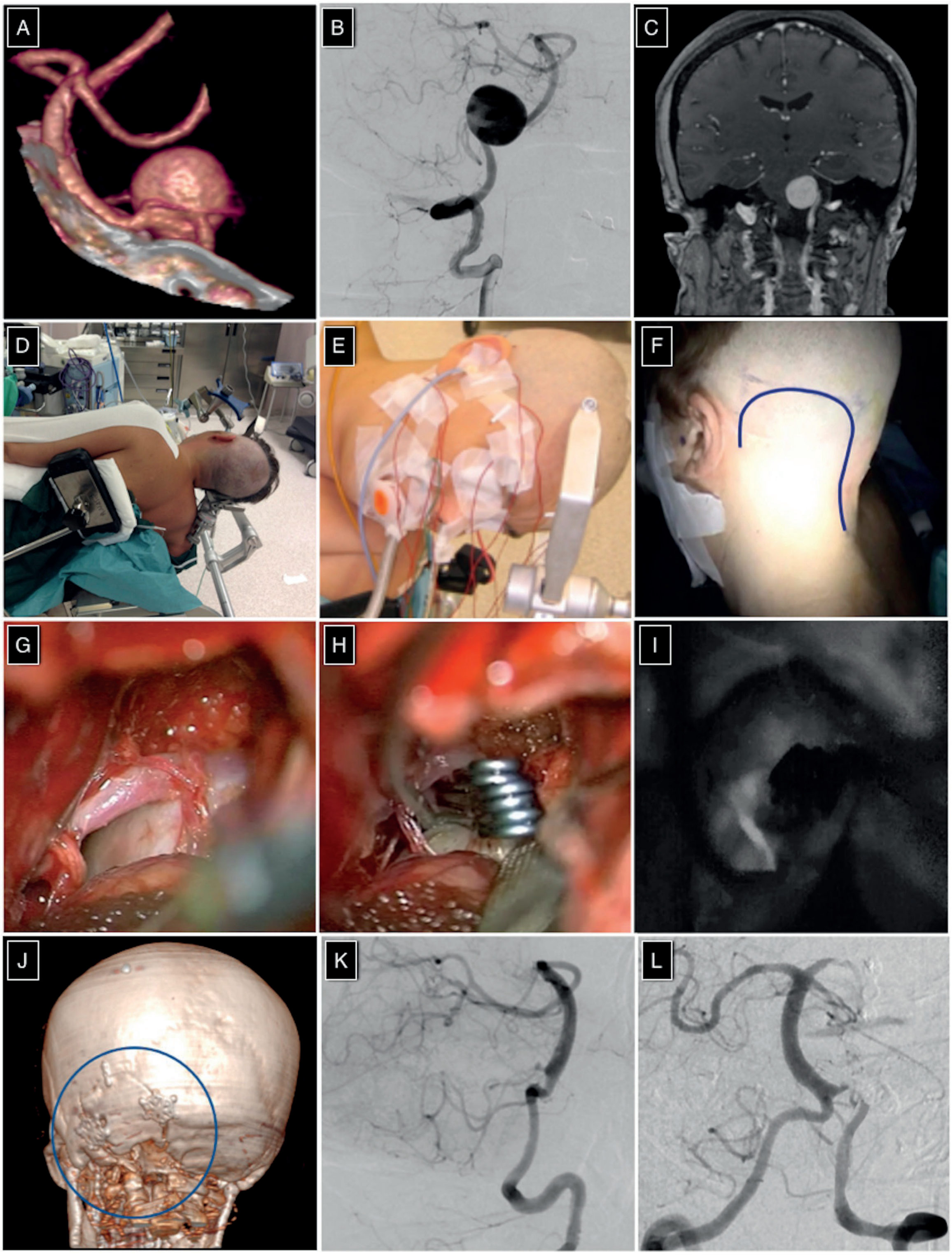

Figure 1: Layer-by-layer dissection of the nuchal muscles. **(A)** Skin incision. First **(B)**, second **(C)**, third **(D)**, fourth **(E)** muscular layer. IO: inferior oblique muscle; LC: longissimus capitis muscle; OA: occipital artery; PT: posterior triangle of the neck; RC Maj: rectus capitis posterior major muscle; SCM: sternocleidomastoid muscle; Sem. C: semispinalis capitis muscle; Sem. C: semispinalis capitis muscle; SO: superior oblique muscle; Spl. C: splenius capitis muscle; T: trapezius muscle.

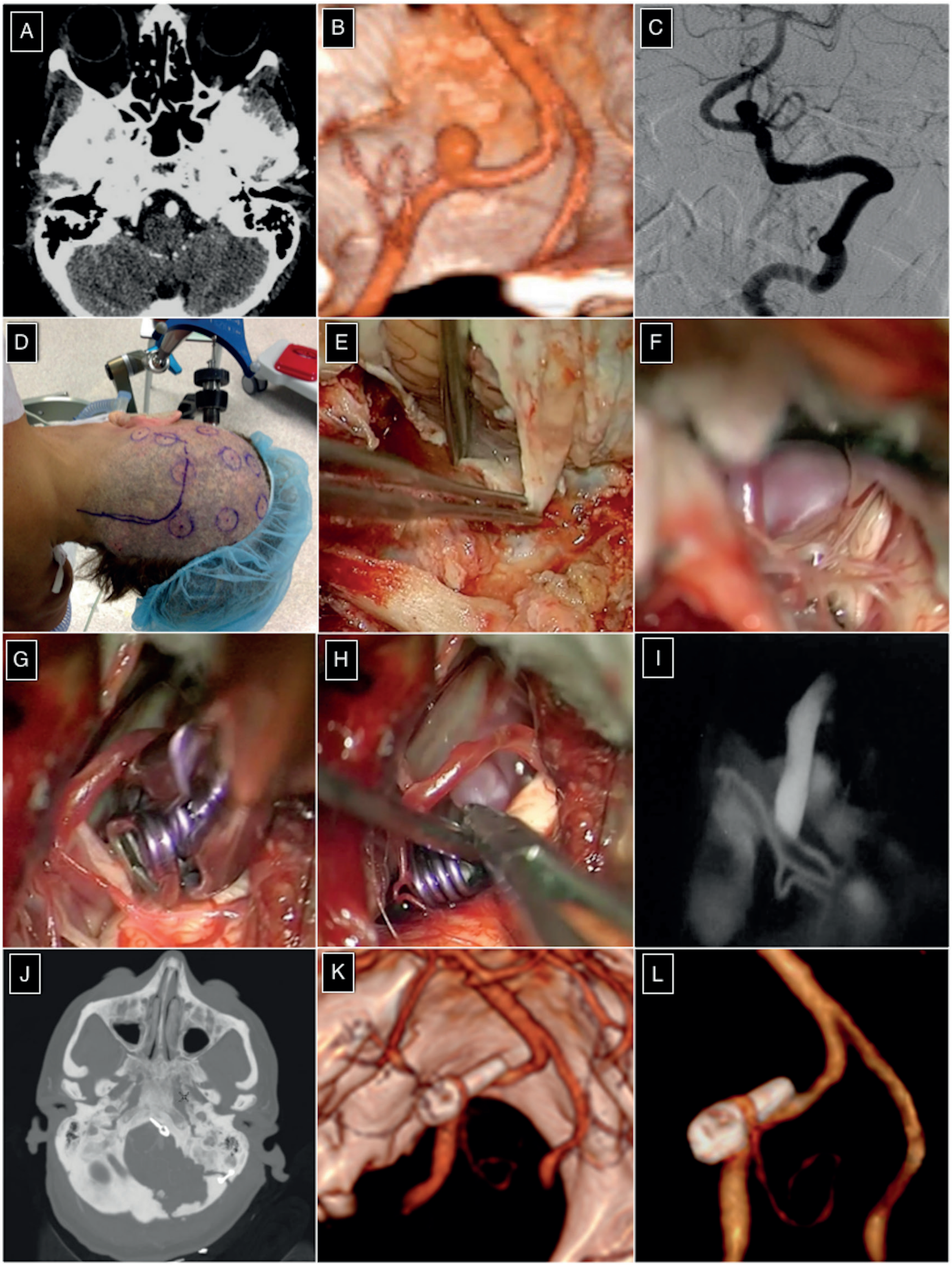

Figure 2: (A, B) Far lateral approach. Transcondylar **(C, D)**, supracondylar **(E, F)**, and paracondylar **(G, H)** extension of the far lateral approach as regards craniotomy (left column) and intradural exposure (right column). IHT: infrahypoglossal triangle; SHT: suprahypoglossal triangle; VAT: vagoaccessory triangle.

aspect is the key to understanding the main difference between the far lateral transcondylar approach and extreme lateral approach (also known as transcondylar approach), where the dura is opened lateral to the VA (11, 18, 29-31). Care must be taken during dura opening to avoid damaging the PICA which may originate just beyond the dural pierce of the VA or even at the level of the dural pierce itself.

Intradural Corridors

The opening of the arachnoid of the cisterna magna and the upward retraction of the cerebellar tonsil exposes the lateral medullary cistern and all the possible intradural corridors to the VBJ, VA-PICA junction, and proximal segments of the PICA. Lawton et al. described three well-defined triangles, delimited by the course of the lower cranial nerves, which are the working corridors related to the far lateral approach. They are the vagoaccessory triangle (VAT) and the two triangles forming it, namely the suprahypoglossal triangle (SHT) and infrahypoglossal triangle (IHT) (32). Because of the high anatomical variability of the PICA, the surgical corridors of the far lateral approach should be referred to specific medullary zones known as the anterior zone, lateral zone, and tonsillo-medullary zone. The SHT is the corridor to the anterior medullary zone, where the VBJ, VA-PICA junction, and anterior medullary segment of PICA are located. The IHT is the route for the lateral medullary zone harboring the lateral medullary segment of PICA. In the case of a more distal origin of the PICA from the VA, the VA-PICA junction can also be found within the lateral medullary zone. The VA-PICA junction is rarely located more distally, at the level of the tonsillo-medullary zone. The tonsillo-medullary zone contains the aneurysms involving the tonsillo-medullary segment, also known as the cranial loop of PICA. Although being within the VAT, these aneurysms lie behind the plane of the lower cranial nerves.

Closure

The dural closure can be challenging in this area. Whenever possible, it should be performed in a watertight fashion. Abdominal or gluteal fat graft has proved to be a valuable alternative in the remaining cases.

The lateral suboccipital bone flap may be fixed to the skull with low profile titanium mini plates and 4 mm self-tapping screws.

The nuchal muscle block is re-approximated by suturing the investing fascia to the galea at the level of the superior nuchal line. An interrupted suture with 2-0 silk stitches is used for skin closure.

Complications Avoidance

Vascular injuries of the VA and iatrogenic biomechanical instability of the CVJ are the main potential complications of the far lateral approach.

The V3 segment of the VA, the vertebral venous plexus, and the first cervical nerve have a common periosteal sheath. The compulsive subperiosteal dissection of this sheath on the hemilamina of C1 is the key to preventing VA injuries and bleedings from the vertebral venous plexus. The skeletonization should be started from the posterior tubercle of the atlas and directed from the medial to lateral. The use of blunt instruments is recommended. On the hemilamina of C1, the horizontal segment of the VA courses into a groove or, sometimes, in a bony canal which can be complete or incomplete. Not infrequently the posterior arch of the atlas has a partial defect coming from the nonunion of the primitive ossification nuclei.

All these aspects need to be evaluated on a CT scan during preoperative planning. Based on the needs, the partial drilling of the occipital condyle can dramatically increase the angular exposure of the approach. However, a risk of biomechanical instability of the CVJ does exist in the case of generous condylectomy. The skeletonization of the epistropheus should be avoided since the elimination of the muscular pivot of the CVJ contributes to increasing the risk of instability. In case of suspected instability, the occipitocervical stabilization can be postponed after dynamic x-ray studies.

Illustrative Cases

Case #1. Unruptured VA-PICA Aneurysm

A 42-year-old female patient suffering from severe drug-resistant systemic hypertension was diagnosed with an incidental small left VA-PICA aneurysm.

The aneurysm involved the lateral medullary zone and was located anterior to the JT. A left far lateral approach with the patient in a modified park-bench position was performed. Minimal drilling of the condyle was performed to widen the working space around the aneurysm. The aneurysm was approached through the IHT and clipped without complications. The patient had no deficits and postoperative CT angiography showed the complete exclusion of the aneurysm and the preservation of the PICA **(Figure 3)**.

Case #2. Giant Unruptured VBJ Aneurysm

A 41-year-old woman with a long history of dizziness was diagnosed with a left giant unthrombosed VBJ aneurysm. The origin of the PICA was close to the aneurysm neck and the patient failed the balloon test occlusion. A left far lateral approach with the patient in a modified park-bench position was performed. The aneurysm was exposed through the suprahypoglossal corridor. A temporary clipping of both the VAs was performed before the placement of a pilot clip which collapsed the sac. The use of the staking-seating technique allowed the fragmentation of the aneurysm and final clipping. The patient was discharged without deficits on the fifth postoperative day. Postoperative catheter-based angiography showed the complete exclusion of the aneurysm (Figure 4).

Discussion

Over the years the far lateral approach has become the elective surgical corridor to ventral FM lesions and aneurysms of the VA and PICA (1-4, 6-8, 12, 13, 18, 19, 33, 34). The reasons for this lie in a wide versatility mainly coming from its variants, namely the supracondylar, transcondylar, and paracondylar. The far lateral approach with no drilling of the condyle is adequate to treat most ventral meningiomas of the FM. Having a slow growth, they displace posterolaterally the medulla oblongata and upper cervical cord widening the working corridor. Conversely, small-sized tumors, VBJ aneurysms, and proximal PICA ones need a wider exposure. About the surgical position, the planning of the approach should take into account some fundamental principles, namely, to achieve the widest possible exposure of the lesion, select the shortest distance to the target, obtain full control of the VA and, especially, minimize the need for cerebellar retraction. All these aspects should be balanced with the personal preferences of the surgeon. In the skeletonization of the posterolateral skull base, the medial mobilization of the nuchal muscles, as suggested by the De Oliveira group (5, 10, 14-16), is a valuable alternative to achieve an unobstructed line of sight to the lower clivus. Deep knowledge of the intradural corridors is mandatory to limit the manipulation of the lower cranial nerves and decrease the risk of postoperative deficits. A large number of reported anatomical studies on the FM region led to identifying some technical aspects that are critical for tailoring the lateral and posterolateral approaches (5, 10, 11, 23, 26, 29, 31, 35-46). Furthermore, the progressive improvement of the endoscopic techniques and their more increasing use for skull base lesions led to the need to redefine the indications of the transcranial and endoscopic approaches to the lower clivus and FM (47-63). Our group analyzed the dimensional morphometric variability of the basilar and condylar part of the occipital bone stressing that these data should be taken into account in the choice between the far lateral approach and endoscopic endonasal one to the ventral lesions of the FM (64). We reported that the sagittal intercondylar and anterior condylar angles exhibit the highest variability within the bony structures of the CVJ. The average ratio between the interline of the JTs and that of the hypoglossal canals was 0.8. Accordingly, we found that a wider sagittal intercondylar and anterior condylar angle with a higher JT-hypoglossal canal interline ratio makes the far lateral approach advantageous. An endoscopic endonasal medial or far-medial approach is indicated in opposite conditions. Over the years, the increasing amount of morphometric data coming from a more growing number of anatomical studies has laid the foundations for a tailored and minimally invasive approach also for the pathologies affecting the FM region, similar to what was observed in other fields of neurosurgery (65-68). About neurovascular pathology, this data is worth some additional considerations regarding the type of lesion. VBJ aneurysms and proximal PICA ones require in most cases partial drilling of the condyle or JT. A consensus does exist in the need

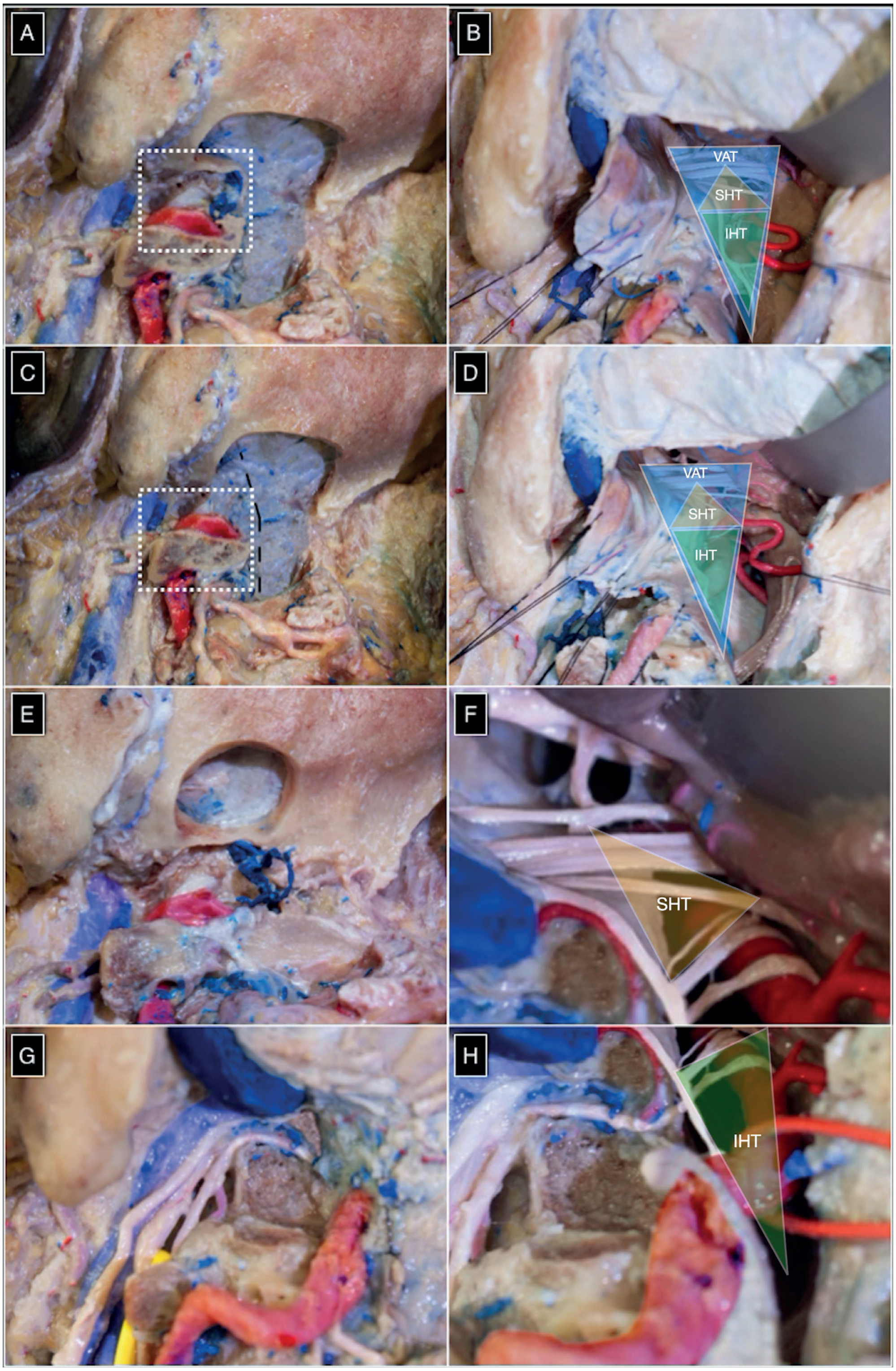

Figure 3: Axial contrast-enhanced CT scan **(A)** and CT angiography **(B). (C)** Digital subtraction angiography of the left vertebral artery in anterior–posterior projection. Right modified park-bench position **(D),** dura opening **(E),** and aneurysm exposure **(F)**. **(G, H)** Clipping of the aneurysm. **(I)** Indocyanine green videoangiography after clipping. **(J)** Postoperative axial bone window CT scan. **(K, L)** Postoperative 3D volume rendering CT angiography.

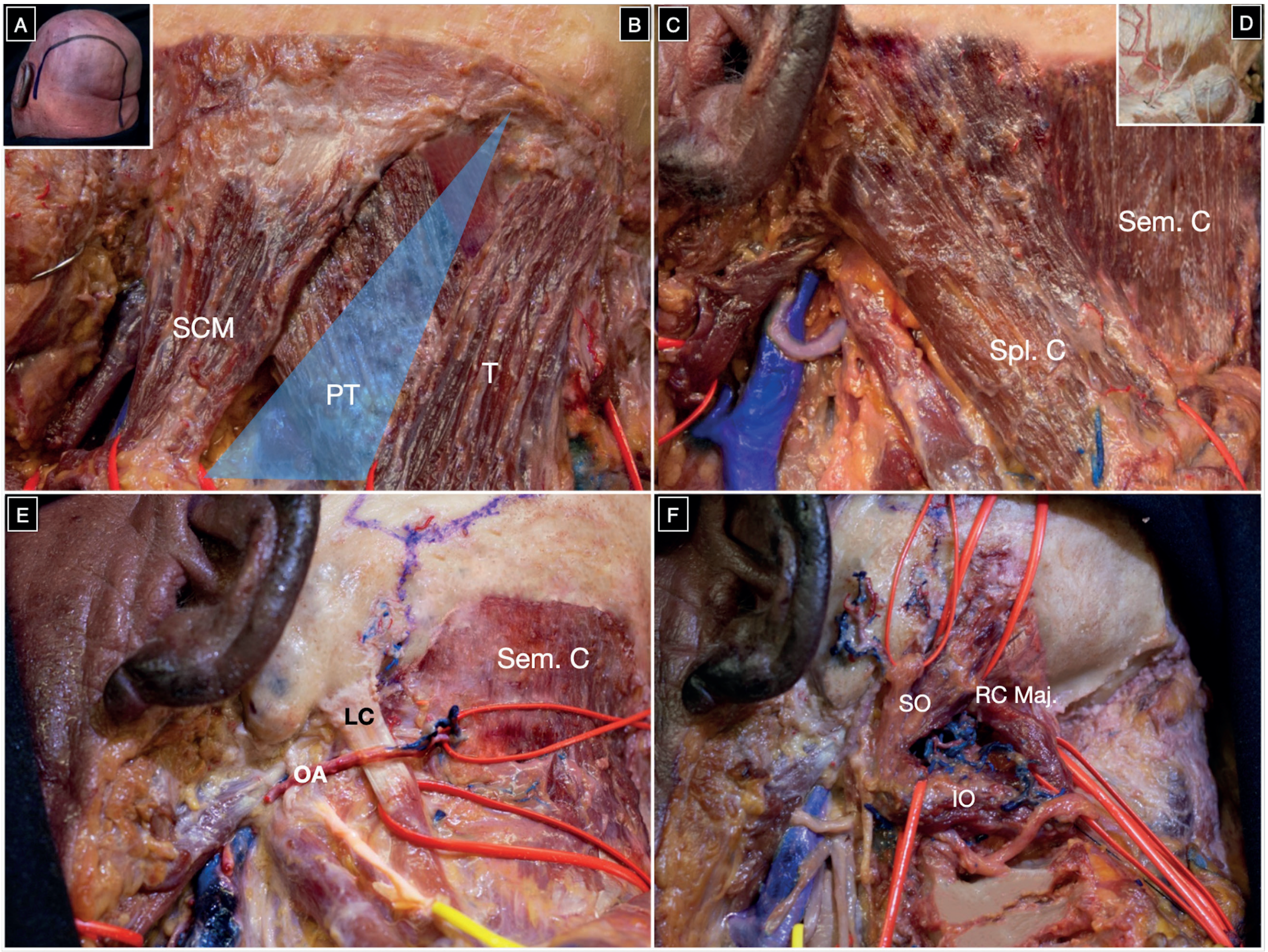

Figure 4: (A) Preoperative 3D volume rendering CT angiography; **(B)** Digital subtraction angiography of the left vertebral artery in the lateral projection; **(C)** Coronal contrast-enhanced MRI. **(D)** Patient in right modified park-bench position. **(E)** Neurophysiological monitoring. **(F)** Reverse hockey stick incision. **(G, H)** Clipping of the aneurysm. **(I)** Indocyanine green videoangiography after clipping. **(J)** Postoperative 3D CT scan. **(K)** Postoperative digital subtraction angiography of the left vertebral artery in lateral **(K)** and anterior–posterior **(L)** projection with the double catheter approach.

to evaluate preoperatively the size and shape of the condyle and JT to decrease the risk of neurovascular complications and mechanical instability (18, 35, 38, 40, 43, 45, 69-75).

Conclusion

The far lateral approach consists of an inferolateral extension of the lateral suboccipital approach.

In the far lateral approach, the more lateral suboccipital craniotomy and C1 hemilaminectomy significantly increase the angular exposure of those lesions lying anterior to the dentate ligament at the level of the anterior border of the FM and lower clivus.

The transcondylar, supracondylar, and paracondylar extensions confer a further versatility to the far lateral approach that can be tailored based on the different needs.

The far lateral approach is the approach of choice for most ventral FM meningiomas, schwannomas of the lower cranial nerves, aneurysms of the V4 segment of the VA, VBJ, VA-PICA junction, and proximal segments of the PICA, as well as cavernous hemangiomas and gliomas affecting the anterolateral aspect of the medulla oblongata and upper cervical cord.

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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