# The Surgical Anatomy of Six Variations of The Extreme Lateral Approach

## Uzak Lateral Yaklaşımın Altı Varyasyonunun Cerrahi Anatomisi

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**Abstract:** The extreme lateral transcondylar approach (ELA) is used to access lesions that are located or extend superior to the middle clivus, inferior to the upper cervical spine, and lateral to the foramina jugulare. Different combinations of drilling of several bone structures, including the occipital condyle, the C1 and C2 facets and laminae, and the jugular tubercle and process, coupled with suboccipital craniotomy, equip the surgeon with different ways of approaching the region of interest. In order to fully understand the options for ELA, it is useful to clarify the variations of this approach. This study involved the bilateral use of 10 complete cadaveric head specimens and includes the description and discussion of six different variations of ELA relative to lesion location and the need for subsequent occipito-cervical fusion. The ELA options are as follows:
1. Retrocondylar approach (RCA)
2. Partial transcondylar approach (PTCA)
3.Transtubercular approach (TTA)
4. Transcondylar approach (TCA)
5. Transjugular approach (TJA)
6. Transfacetal approach (TFA)

**Key Words**: clivus, cranio-cervical junction, extreme lateral approach, foramen magnum, tuberculum jugulare, transcondylar approach

**Özet:** Uzak lateral yaklaşım (ELA), yukarıda orta clivus, aşağıda üst servikal spinal bölge ve yanlarda da foramen jugulareye uzanan lezyonlar için kullanılmaktadır. Occipital condyle, C1 ve C2 faset ve laminaları, tuberculum jugulare ve processus jugularis gibi farklı kemik oluşumların alınmasının değişik kombinasyonlarına suboksipital kranyotominin de eklenmesi ile birlikte uygun bölgelere farklı yaklaşımlar yapmak mümkündür. Bu çalışmada, ELA'nın modifikasyonlarının daha iyi kavranması amacı ile, on kadavra (çift taraflı) kullanılmak ve lezyonunun yeri ve uzanımı da göz önünde bulundurulmak sureti ile altı farklı varyasyon, oksipital-servikal füzyon endikasyonları ile birlikte tarif edilmekte ve tartışılmaktadır:
1. Retrokondüler yaklaşım (RCA)
2. Kısmi transkondülar yaklaşım (PTCA)
3.Transtüberküler yaklaşım (TTA)
4. Transkondüler yaklaşım (TCA)
5. Transjuguler yaklaşım (TJA)
6. Transfasetal yaklaşım (TFA)

**Anahtar Kelimeler:** clivus, foramen magnum, kranyo-servikal bileşke, transkondüler yaklaşım, tuberculum jugulare, uzak lateral yaklaşım

### INTRODUCTION

The extreme lateral transcondylar approach (ELA) is used to access the ventral surface of the cervicomedullary junction, lower clivus, and foramen magnum, and is the preferred technique of numerous authors (1,2,3,4,5,8,10,11,12,13,14,16,17,18, 19). This approach is useful for managing aneurysms of the vertebrobasilar junction and vertebral artery, meningiomas and hypoglossal neurilemomas at the

foramen magnum, and chordomas of the lower clivus (2,17,18). Drilling of different combinations of bone structures, including the jugular tubercle and process, the occipital condyle, and the articular facets and laminae of C1 and/or C2, allows optimal surgical exposure of normal anatomical structures and pathological lesions (2,3,5,6,7,14). The purpose of this study was to impart a better understanding of the indications for, and surgical anatomy involved in, six variations of ELA. The need for occipito-cervical fusion relative to each option is also discussed.

## MATERIALS AND METHODS

For this study, we used 10 complete cadaveric head specimens that were fixed with Formalin and injected with Microfil. We made an inverted U-shaped incision on the occipital region and then dissected and reflected the muscles layer by layer. The vertebral artery was exposed in the suboccipital triangle. After removing the bone tissue from the lateral process and hemilaminectomy of C1, we performed a suboccipital craniotomy and drilled the appropriate bone structures. The dura was opened, either leaving a cuff around the vertebral artery or in linear fashion. We then exposed the normal anatomical structures around the lower clivus, the foramen magnum, and the anterior part of the upper cervical spine.

### Surgical - Anatomical Dissection and Description

After positioning the head specimen and making an inverted U-shaped incision on the occipital region (Figure 1A), the skin flap was reflected posteriorly to expose the bone landmarks and muscles. The important bone landmarks for the extreme lateral transcondylar approach are the mastoid tip and the mastoid body, the asterion, and the superior nuchal line. The transverse process of C1 is inferior to the mastoid tip, and no more than 10 to 15 mm away. The location and bone insertions of the lateral neck muscles are easily recognized, and these should be separated and reflected to allow adequate surgical exposure. The muscles are grouped in three layers. The superficial muscle layer contains the sternocleidomastoideus and trapezius muscles. The sternocleidomastoideus covers the C1 transverse process, and is the only muscle group that should be reflected anteriorly. All the other muscles should be reflected posteriorly or inferiorly. The splenius capitis, splenius cervicis, and longissimus capitis muscles constitute the middle layer. The semispinalis capitis muscle is located posterior to the splenius capitis (Figure 1B). The occipital artery can be identified in a plane deep to the splenius capitis but superficial to the longissimus capitis and semispinalis capitis muscles. The splenius cervicis muscle is one of the important landmarks for exposing the vertebral artery (VA). This artery courses between the transverse processes of C1 and C2 close to this muscle. The levator scapulae muscle is another important landmark for locating the VA. The deep muscle layer contains the superior obliquus capitis, the inferior obliquus capitis, the rectus capitis major, and the rectus capitis minor muscles. The first three muscles constitute the suboccipital triangle, where the extradural VA can be safely exposed (Figures 2A&B). The artery is covered with fat tissue and a

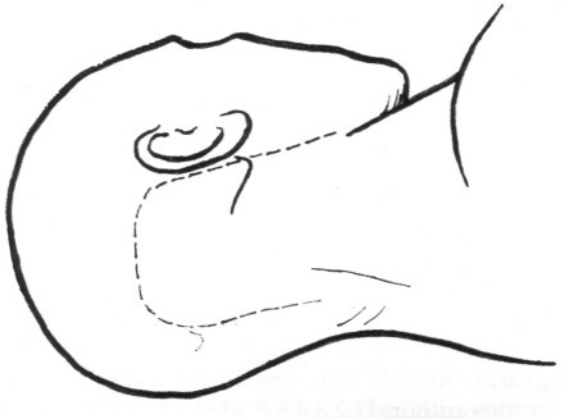

Figure 1A: The schematic drawing shows the position of the head specimen and the inverted U-shaped incision for ELA on the occipital region.


Figure 1B: The middle muscle layer was exposed beneath the sternocleidomastoideus and trapezius muscles, which constitute the superficial muscle layer. (Abb: SCM: sternocleidomastoideus T: trapezius, SC: splenius capitis, SSC: semispinalis capitis).

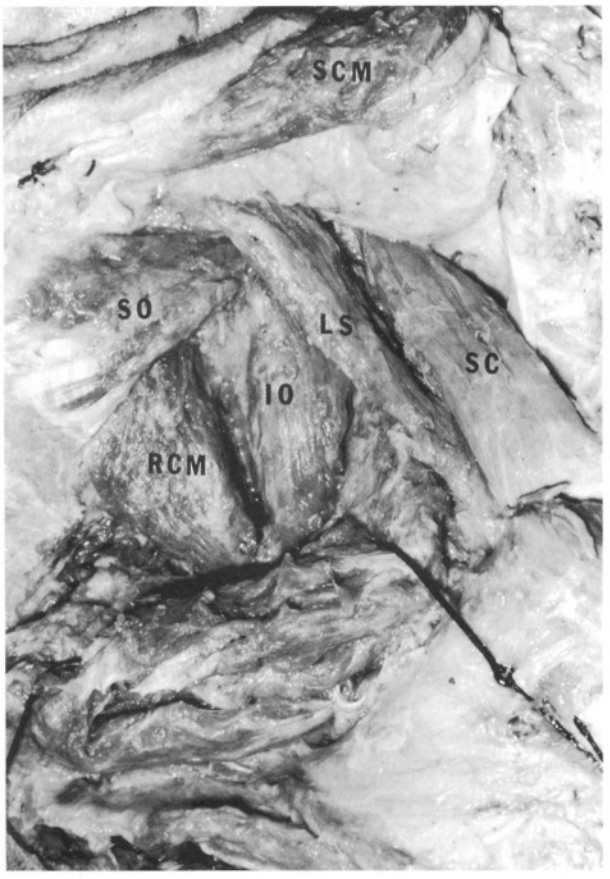


Figure 2A: After reflection of the muscles in the superficial and middle layers, the deep muscles were exposed. The superior obliquus capitis, the inferior obliquus capitis, and the rectus capitis major muscles constitute the suboccipital triangle. (Abb: LS: levator scapulae, SC: splenius cervicis, SCM: sternocleidomastoideus, SO: superior obliquus capitis, IO: the inferior obliquus capitis, RCM: rectus capitis major).

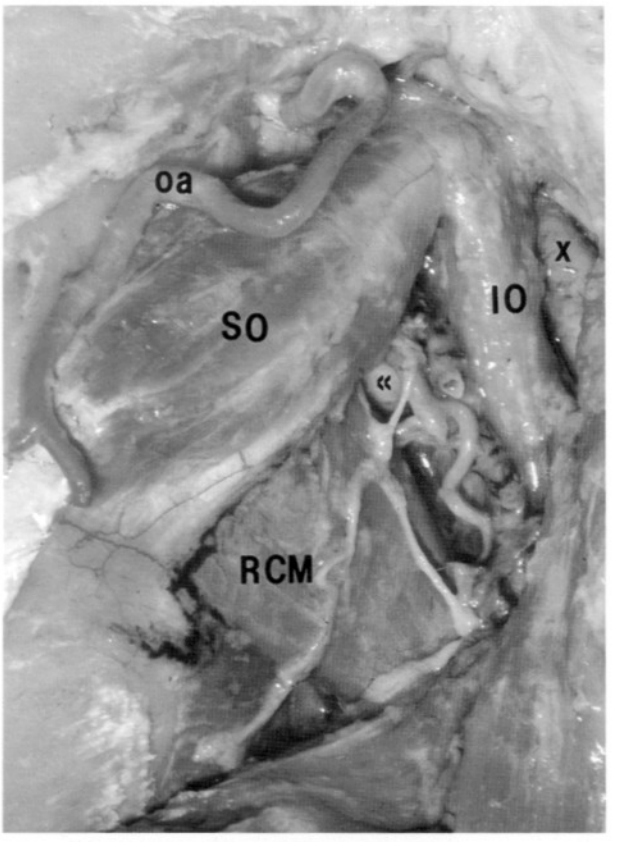


Figure 2B: The extradural vertebral artery was exposed in the suboccipital triangle (double arrow) and between C1-C2 (x). (Abb: oa: occipital artery SO: superior obliquus capitis, IO: the inferior obliquus capitis, RCM: rectus capitis major).

dense venous plexus in this triangle. The rectus capitis lateralis muscle extends from the transverse process of the atlas to the jugular process. This muscle is a good landmark for identifying the posterior portion of the jugular bulb. The VA courses under the lamina of C1 from medial to lateral in an L shape (Figure 3). We removed the transverse process and lamina of C1, and performed a suboccipital craniotomy. The vertebral artery was transposed posteromedially, and then the occipital condyle was exposed for partial or total resection. We then studied six variations of the extreme lateral transcondylar approach (Table 1).

Table I: Variations of the Extreme Lateral Approach.

| Variations of ELA | Indications |
|---|---|
| 1. Retrocondylar Approach (RCA) | Laterally located lesions above the atlanto-occipital joint |
| 2. Partial Transcondylar Approach (PTCA) | Midline intradural lesions located above the atlanto-occipital joint |
| 3. Transtubercular Approach (TTA) | Large and giant aneurysms of the VA and vertebrobasilar junction |
| 4. Transcondylar Approach (TCA) | Extradural lesions involving the occipital condyle |
| 5. Transjugular Approach (TJA) | Extensive lesions involving the jugular foramen |
| 6. Transfacetal Approach (TFA) | Lesions below the atlanto-occipital joint |

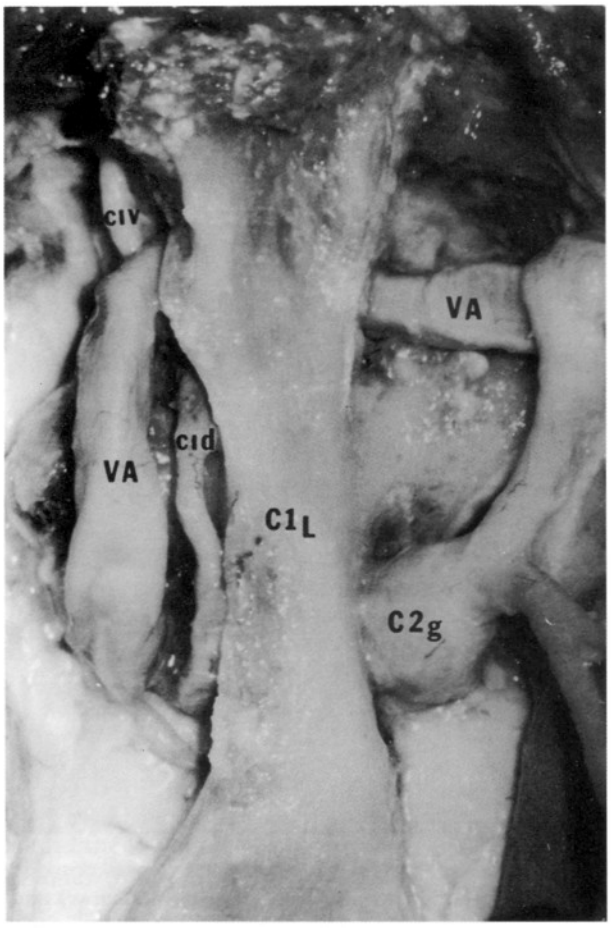


Figure 3: The extradural vertebral artery courses under the lamina of C1 from medial to lateral in an L shape. The C1 dorsal root and ventral root are superior, and the C2 ganglion is inferior to the lamina (Abb: VA: vertebral artery, C1L: lamina of C1, CID: C1 dorsal root, CIV: C1 ventral root, C2g: C2 ganglion)

**Six Different Variations of ELA:**

1. Retrocondylar approach (RCA): The retrocondylar approach is the method of choice for intradural lesions that are located anterolateral to the craniocervical junction. Removal of the transverse process and the lamina of C1, and suboccipital craniotomy without drilling the occipital condyle achieve the desired exposure (Figure 4). The dura should be opened in linear fashion.

2. Partial transcondylar approach (PTCA): Midline intradural lesions that are located anterior and above the atlanto-occipital joint can be exposed using this approach. After the VA is moved posteromedially, the posterior third of the occipital


Figure 4: Retrocondylar Approach (RCA): The transverse process and the lamina of C1 were removed, and a suboccipital craniotomy was performed. The occipital condyle was not drilled. (Abb: VA: vertebral artery, OC: occipital condyle, CID: C1 dorsal root, CIV: C1 ventral root, C2g: C2 ganglion).

condyle and the superior facet of C1 are drilled. The landmark for the limit of condyle drilling is the hypoglossal canal. The dura should be opened leaving a cuff around the VA (Figure 5).

3. Transtubercular approach (TTA): Large and giant aneurysms of the VA and the vertebrobasilar junction are exposed using the TTA. The bone above the hypoglossal canal corresponds to the jugular tubercle, and drilling this provides access to the middle clivus. The posteromedial third or half of the occipital condyle-C1 facet joint is drilled. The jugular tubercle is removed extradurally to allow enough space for intradural exposure (Figure 6). The deepest part of the tubercle should be drilled intradurally and the dura should be opened leaving a cuff around the VA.

4. Transcondylar approach (TCA): The transcondylar approach is usually used for extradural lesions that involve the occipital condyle and lower clivus. The posterior half of the occipital condyle is drilled, and the hypoglossal canal is exposed (Figure 7). Depending on the extent of the extradural lesion, the whole condyle may have to be drilled. It is usually not necessary to open the dura during this approach. Occipito-cervical fusion is necessary after this procedure.

5. Transjugular approach (TJA): This method is preferred for extensive extradural lesions that involve the jugular foramen and for simple glomus jugulare

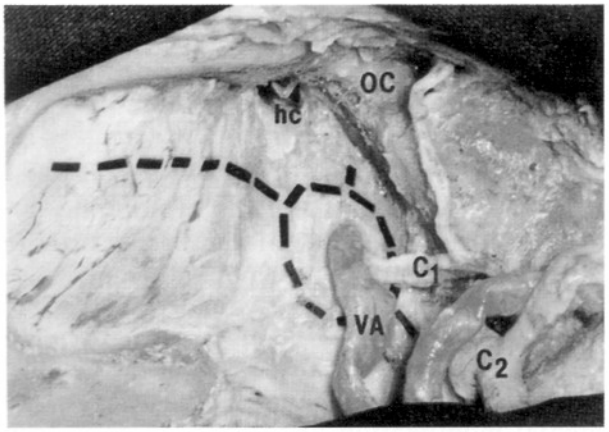


Figure 5: Partial Transcondylar Approach (PTCA): The vertebral artery was mobilized posteromedially. The posterior third of the occipital condyle and the superior facet of C1 were drilled. The landmark for the condyle drilling limit is the hypoglossal canal. The dura should be opened leaving a cuff around the VA (dotted lines). (Abb: VA: vertebral artery, OC: occipital condyle, hc: hypoglossal canal, C1: C1 roots, C2: C2 roots).

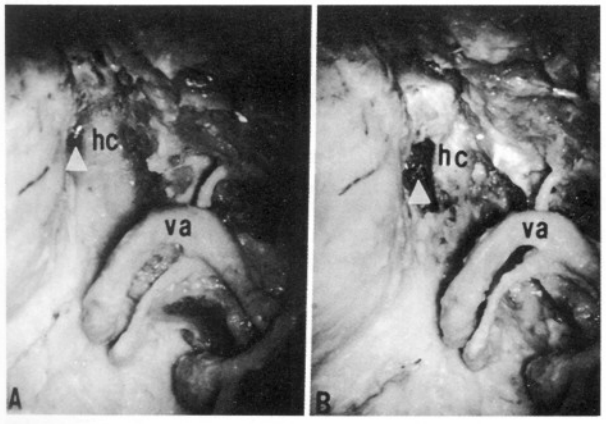


Figure 6: Transtubercular Approach (TTA): After drilling the posterior third or half of the occipital condyle-C1 facet joint, the hypoglossal canal was exposed. The jugular tubercle (white arrow) is above the hypoglossal canal and medial to the jugular foramen. It was removed extradurally to allow adequate space for intradural exposure. Limited (A) and extensive (B) drilling of the jugular tubercle is shown. The deepest part of the tubercle should be drilled intradurally. The dura should be opened leaving a cuff around the vertebral artery. (Abb: hc: hypoglossal canal, va: vertebral artery).

tumors. This approach requires total mastoidectomy with anterior mobilization of the mastoid segment of the facial nerve from the fallopian canal, and the

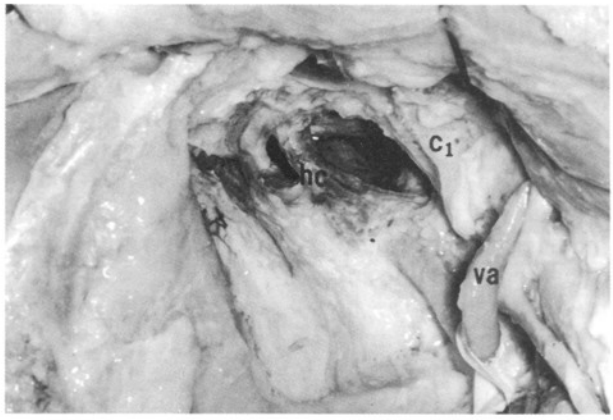


Figure 7: Transcondylar Approach (TCA): The posterior half of the occipital condyle was drilled, and the hypoglossal canal was exposed. Depending on the extent of the extradural lesion, the whole condyle may need to be drilled. Usually, the dura does not need to be opened during this approach. Occipito-cervical fusion is necessary after this procedure. (Abb: hc: hypoglossol canal, va: vertebral artery, cıv: C1 ventral root, cıd: C1 dorsal root).


Figure 8: Transjugular Approach (TJA): This approach requires total mastoidectomy, with anterior mobilization of the mastoid segment of the facial nerve from the fallopian canal and exposure of the lateral aspect of the jugular bulb and jugular vein. The jugular process of the occipital bone, which forms the posterior and inferior wall of the jugular bulb, was then drilled away. (Abb: va: vertebral artery, hc: hypoglossal canal, VII: facial nerve, IX: glossopharyngeal nerve, jb: jugular bulb).

exposure of the lateral aspect of the jugular bulb and jugular vein. This allows dissection of the lesion from the internal carotid artery. The jugular process of the occipital bone, which forms the posterior and inferior wall of the jugular bulb, is drilled away (Figure 8).

The sigmoid sinus may be ligated to achieve wider exposure with the TJA. After unroofing the CNs IX, X, XI, and XII extradurally, a lower clival tumor can be removed superior to the internal auditory canal and inferior to C2. The removal of the posterolateral third of the occipital condyle exposes the entire hypoglossal canal. Drilling the lateral portion of the jugular tubercle, which is above the hypoglossal canal and medial to the jugular foramen, exposes the medial wall of the jugular bulb. CN IX courses anterior to the connection of the inferior petrosal sinus with the jugular bulb, and CNs X and XI posteriorly. A linear dural incision should be made approximately 1 cm posterior to the sigmoid sinus.

6. Transfacetal approach (TFA): Lesions located anterior or anterolateral to the upper cervical spine are exposed via the TFA. The first step is C1 and C2 hemilaminectomy without a mastoidectomy. The VA is mobilized posteromedially. The posterior half of the C1 and C2 facet joint and the occipital condyle are drilled until the C1 and C2 nerve roots are exposed. The dura should be opened in linear fashion anterior to the cervical nerve roots, and should be divided posteriorly as two flaps. Occipito-cervical fusion is often necessary following this approach (Figure 9).

Through the use of these six approaches, the intradural VA, the posterior inferior cerebellar artery (PICA), the lower cranial nerves, and the brainstem can all be safely exposed (Figure 10).

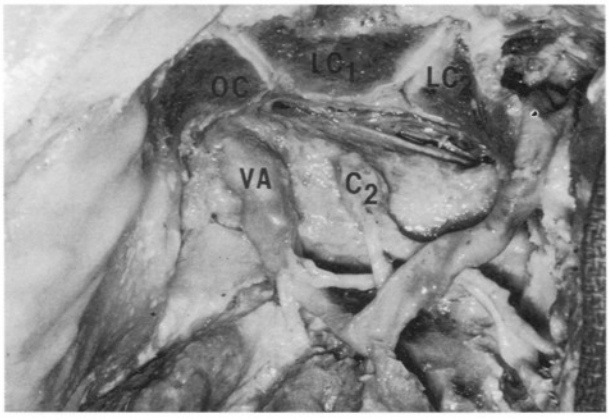


Figure 9: Transfacetal Approach (TFA): After C1 and C2 hemilaminectomy without a mastoidectomy, the vertebral artery was mobilized posteromedially. The posterior half of the C1 and C2 facet joint and the occipital condyle were drilled until the C1 roots and C2 roots were exposed. Occipito-cervical fusion is often necessary following this approach. (Abb: LC1: C1 hemilaminectomy, LC2: C2 hemilaminectomy, VA: vertebral artery, OC: occipital condyle, C2: C2 roots)

## DISCUSSION

Since the first attempt of Hammon and Kempe, who described a suboccipital craniotomy for aneurysms of the vertebral and basilar arteries including removal of the posterior rim of the foramen magnum (9), other authors have added new ways of approaching the lower clivus and the occipito-cervical junction. Partial resection of the occipital condyle (3), drilling of the jugular tubercle (14), and medial mobilization of the VA (5) have been described by several authors. ELA involving medial mobilization of the VA from C2 to the dural entry point, and partial or total resection of the occipital condyle and lateral mass of C1 have also been described (3,5,6,7,17,18,19). Sen and Sekhar described an ELA variation for anteriorly located extra- and intradural lesions (17,18). This approach exposes the middle clivus superiorly, the upper cervical spine inferiorly, and the jugular foramen laterally. The various ELA techniques involve single or combined removal or drilling of several bone structures, including the occipital condyle, jugular tubercle, jugular foramen, occipito-cervical joint, and bones of the C1-C2 joint (2,3,5,6,10,13,14,17,18,19). Salas and Sekhar have recognized six variations of ELA which are very useful inpractive (16).

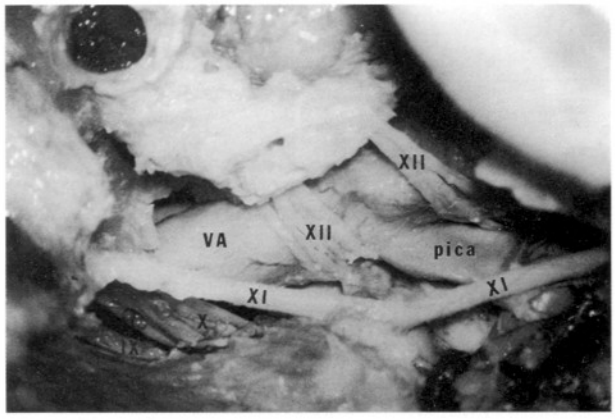


Figure 10: The dura was opened leaving a cuff around the vertebral artery. The intradural vertebral artery, the lower cranial nerves, and the brainstem were exposed. The posterior inferior cerebellar artery arises from the intradural VA and courses between the rootlets of cranial nerve XII. (Abb: VA: vertebral artery, IX, X, XI and XII: lower cranial nerves, pica: posterior inferior cerebellar artery)

In this paper, we describe and discuss these six variations of ELA that equip the neurosurgeon with specific and practical anatomical knowledge and surgical technique. For the RCA, a lateral suboccipital (retrosigmoid) craniotomy with resection of the foramen magnum provides adequate exposure. To reach ventral lesions of the foramen magnum and the craniocervical junction, Sen and Sekhar advised drilling the posterior third of the occipital condyle (17,18). To visualize the ventral part of the lower brainstem, Bertalanffy preferred to use the PTCA, drilling the posteromedial third of the condyle without a mastoidectomy (3). The removal of the posterior third or half of the condyle allows wide-angle visualization of the anterior aspect of the lower brainstem. We prefer to drill the posterior third of the condyle and the mastoid process, which exposes the contralateral VA and the hypoglossal nerve. Hosoda et al. also prefer to drill the posterior third of the condyle, and combine this with partial mastoidectomy (11).

The TTA is useful for accessing large and giant aneurysms of the VA and the vertebrobasilar junction (4,12). In this approach, it is very important to keep under control the VA through medial transposition after drilling the jugular tubercle. The transposition of the proximal VA clears the accessory nerve, the PICA, and the spinal and perforating arteries from the surgical corridor. This also makes it possible to interpose a vascular graft or reimplant the PICA. In vertebrobasilar aneurysms that are in higher locations and if a proximal-distal VA anastomosis is necessary, the combination of TTA and a retrolabyrinthine approach should be done. The division and reanastomosis of the sigmoid sinus may be required (2).

Al- Mefty et al. pointed out that the TCA provides access to lesions located lateral to the hypoglossal canal, and they used this approach in a series of eight patients with extradural nonneoplastic lesions of the craniocervical junction (1). This approach is also useful for radical resection of chordomas. The resection of the inferior wall of the jugular foramen for TJA may require drilling of the lateral part of the condyle. Drilling the bone above the condyle, which corresponds to the posteromedial side of the jugular foramen, is also useful. The superior wall should be drilled once the mastoid segment of the facial nerve is exposed (5,6) which requires a mastoidectomy. Wen et al. also pointed out the need for mastoidectomy and anterior mobilization of the facial nerve during TCA. They reported using a paracondylar approach to expose the jugular foramen, without drilling the condyle (20). The opening of the hypoglossal canal and drilling of the medial wall of the jugular foramen is very important when removing CN X and XII schwannomas (8). When the tumor extends anteriorly through the carotid canal, it is necessary to combine this approach with a subtemporal infratemporal approach (2). If the tumor has a large intracranial extension, combination TJA with a transpetrosal retrolabyrinthine approach may be necessary. This approach can be also combined with division of the nondominant sigmoid sinus.

George et al. reported the TFA, dividing this approach into the three subgroups of anterolateral, posterolateral, and posterior (6). They opened the dura posterior to the cervical roots using various types of dural flaps. We preferred to make the dural opening anterior to the cervical roots, in order to be able to retract the neural structures and expose the anterior aspect of the spinal cord.

Midline meningiomas originating from the dura of the clivus or the foramen magnum extend bilaterally. In these cases, the surgical site should be on the side where the tumor is largest. Drilling of the posterior third or half of the condyle is very important to achieve good exposure of the contralateral side. To expose and remove the dural attachment of midline meningiomas that also extend into the middle clivus, it is important to drill the jugular tubercle. To remove lesions that originate in the bone itself, such as chordomas, chondrosarcomas, or metastatic carcinomas, it is essential to totally remove the condyle. In order to drill the condyle safely, the extradural segment of the VA should be reflected posteromedially. An anatomical variation, the extradural PICA, should always be kept in mind (15).

After removing the bone in each approach, the dura is opened, either leaving a dural cuff around the VA or in linear fashion. The former prevents injury to the branches of the VA that are close to the dural opening. Medial mobilization of the intradural segment of the VA exposes the vertebrobasilar junction and the anterior aspect of the foramen magnum. The rootlets of the hypoglossal nerve are the only neural structures that cross the surgical corridor. If the VA is encased by the tumor, working around the artery will help mobilize the artery.

The ELA may require occipito-cervical fusion, depending on the extent of bone removal that is

required (1,3,18). The most important element of preventing occipito-cervical junction instability is preservation of the portion of the condyle that lies anterior to the hypoglossal canal. If more extensive bone removal is needed, occipito-cervical fusion must be done to maintain adequate stability. The TCA and TFAusually require fusion. If unilateral TCA is performed, the fusion may be done either during the same surgery or the following day. If both condyles are invaded by the tumor, fusion should be done at the end of the first stage of tumor removal to stabilize the craniocervical junction and avoid sigmoid sinus thrombosis (2,17,18). The RCA, PTCA, TJA, and TTA do not require occipito-cervical fusion. The maximum bone removal that can be done without occipito-cervical fusion is drilling of the posterior third, and sometimes even half, of the condyle.

In conclusion, the ELA has been described for lesions located anterior and anterolateral to the foramen magnum. Each variation of the ELA should be chosen in accordance with the exact location and nature of the pathology involved. The appropriate choice will help the surgeon achieve complete removal of the tumor with minimal complications, morbidity, and mortality.

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