The Nuchal Lines as Anatomic Landmarks to Dissect the Muscles in the Far Lateral Approach

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■ BACKGROUND: **A critical step in the far lateral approach (FLA) is exposure of the V3 segment of the vertebral artery, located deep in the suboccipital triangle (SOT). Safe exposure of the SOT is achieved by means of a plane-by-plane dissection, which carries the risk of devascularization. A suitable alternative is to lift a cutaneous muscle flap including the 3 first muscle planes and leave the deepest plane (SOT) attached to the skull base. To achieve this, it is necessary to have superficial anatomic landmarks to help identify the cleavage site. We describe the use of the nuchal lines as a safe, effective, and reproducible method to dissect the muscles to expose the SOT and vertebral artery.**

■ METHODS: **Eight adult cadaveric heads, fixed with formaldehyde and injected, were studied. On both sides, FLA was simulated by using the nuchal lines as anatomic landmarks to expose the SOT. This technique was later applied on 10 patients requiring FLA.**

■ RESULTS: **Anatomic dissections confirmed identification, by means of the nuchal lines, of a cleavage site, which made it possible to separate the deepest muscle plane from the rest of the flap. This technique was successfully applied in 10 patients undergoing FLA.**

■ CONCLUSIONS: **The nuchal lines allow dissection of muscles in 2 groups, one superficial and the other deep (SOT), which remains attached to the skull base. The V3 segment of the vertebral artery is easily exposed.**

INTRODUCTION

The far lateral approach (FLA) was designed to treat neoplastic, vascular, and inflammatory lesions located in the foramen magnum.[1-3] A crucial aspect of the FLA is adequate exposure of the vertebral artery (VA).[4] The V3 segment of the VA runs behind the articular facet of C1, between the transverse foramen of the atlas laterally and the dural entrance medially.[5,6] The V3 segment of the VA lies deep in the suboccipital triangle (SOT).[7] This triangle is formed by the rectus capitis posterior major muscle and the inferior oblique and superior oblique muscles, which belong to the deepest plane of the neck muscles.[8]

The neck muscles are organized into 4 planes.[8] Therefore, safe exposure of the SOT involves dissecting these muscles plane by plane.[9] However, a serious risk of applying this technique is devascularization of the skin and subcutaneous tissue, possibly resulting in skin necrosis. An alternative is to lift the skin flap and subcutaneous tissue with the first 3 muscle planes and leave the deepest plane attached to the skull base, achieving exposure of the SOT and VA.[8,10] To achieve this, it is necessary to have superficial anatomic landmarks to guide surgeons where to make the separation. The objective of the present study is to describe the use of the nuchal lines as a safe, efficient, and reproducible method to dissect the muscles and expose the SOT and VA.

MATERIALS AND METHODS

Eight adult cadaveric heads, fixed with formaldehyde and injected with colored silicone, were studied. In both sides, an FLA was simulated with the patient in semisitting position, using the nuchal lines as anatomic landmarks to dissect the muscles and expose the SOT. Between 2005 and 2017, the

Key words
- Far lateral
- Foramen magnum
- Landmarks
- Nuchal lines
- Suboccipital triangle
- Vertebral artery

Abbreviations and Acronyms
FLA: Far lateral approach
INL: Inferior nuchal line
SNL: Superior nuchal line
SOT: Suboccipital triangle
VA: Vertebral artery

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senior author (A.C.) used this technique to expose the SOT and VA in 10 patients diagnosed with foramen magnum meningiomas who required an FLA for resection.

RESULTS

Anatomic Considerations

Nuchal Muscles. There are 4 muscular planes in the nuchal region, which from surface to depth are 1) sternocleidomastoid and trapezius muscles; 2) splenius capitis muscle; 3) semispinalis capitis and longissimus capitis muscles; and 4) rectus capitis posterior minor, rectus capitis posterior major, inferior oblique, and superior oblique muscles. The muscles forming the first 3 muscle planes have their upper main insertion at the level of the superior nuchal line (SNL), whereas the muscles in the deepest plane (rectus and obliques) have their main superior insertion at the level of the inferior nuchal line (INL). The rectus capitis posterior minor muscle inserts superiorly on the most medial part of the INL and below on the C1 spinous process. The rectus capitis posterior major muscle inserts superiorly on the medial part of the INL and inferiorly on the C2 spinous process. The superior oblique muscle inserts superiorly on the lateral part of the INL and inferiorly on the C1 transverse process. Finally, the inferior

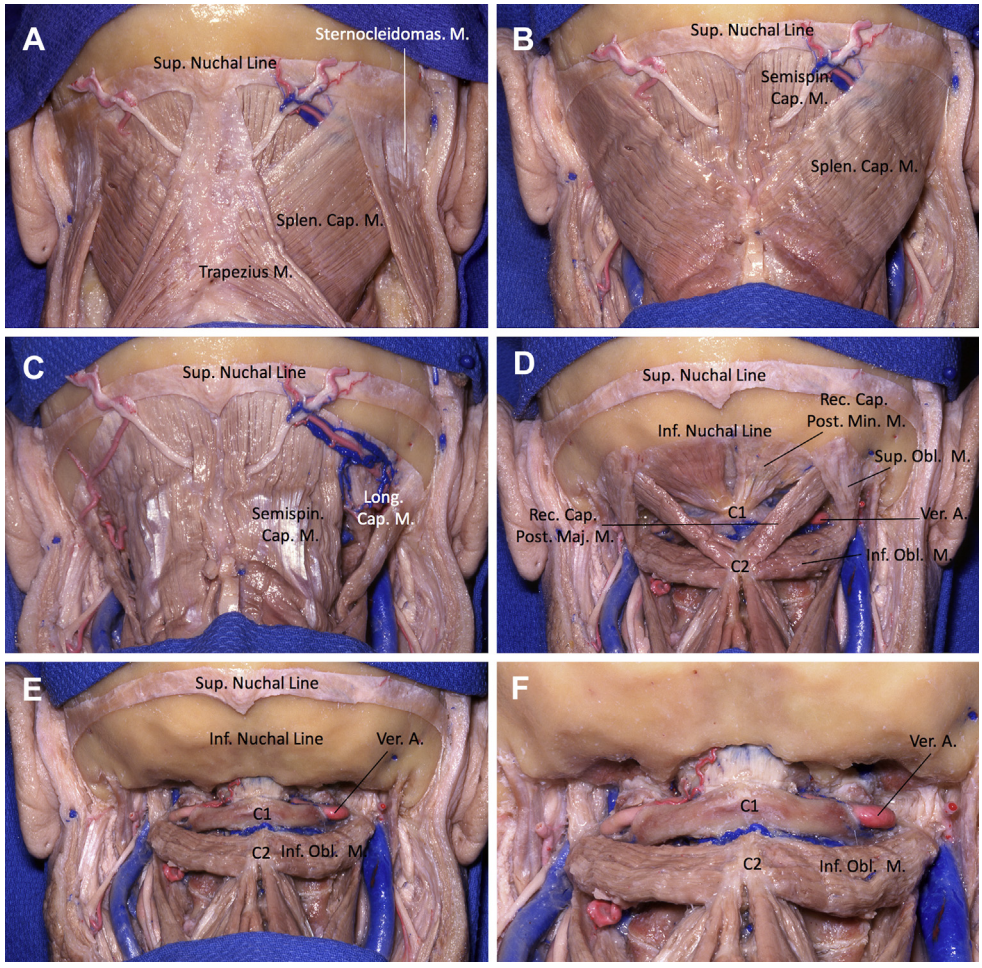

Figure 1. Cadaveric stepwise dissection of the suboccipital region muscles. (**A**) The muscles of the first layer are trapezius and sternocleidomastoid; both have their main occipital insertion on the superior nuchal line. (**B**) The muscle of the second layer is the splenius capitis; its main occipital insertion is the superior nuchal line. (**C**) The muscles of the third layer are semispinalis capitis and longissimus capitis; both have their main occipital insertion on the superior nuchal line. (**D**) The muscles of the fourth layer are rectus capitis posterior minor, rectus capitis posterior major, superior oblique, and inferior oblique. The V3 segment of the vertebral artery, in the depth of the suboccipital triangle, was exposed. (**E** and **F**) The rectus and oblique muscles have been removed to expose the entire V3 segment of the vertebral artery, the posterior arch of C1, the occipitoatlantal junction, and the foramen magnum. Sternocleidomas., sternocleidomastoid; M., muscle; Sup., superior; Splen, splenius; Cap., capitis; Semispin., semispinalis; Long., longissimus; Rec., rectus; Post., posterior; Min., minor; Inf., inferior; Obl., oblique; Ver., vertebral; Maj., major; A., artery.

oblique muscle inserts medially on the C2 spinous process and laterally on the C1 transverse process (Figure 1A–D).

Suboccipital Triangle. The SOT is formed by 3 of the 4 muscles of the deepest plane: medially by the rectus capitis posterior major, laterally by the superior oblique muscle, and inferiorly by the inferior oblique muscle. The V3 segment of the VA is deep in the SOT, accompanied by the C1 nerve. The VA is located above a channel formed in the upper surface of the arch of the atlas, and it is surrounded by a venous plexus (Figure 1D–F).

Surgical Considerations

Skin Positioning and Marking. The patient is placed in a semisitting position, with the head bent 10° toward the side of the lesion. It is important not to bend the neck too much to prevent poor venous return. In addition, during positioning we tried pulling the head upward to increase the separation surface between the

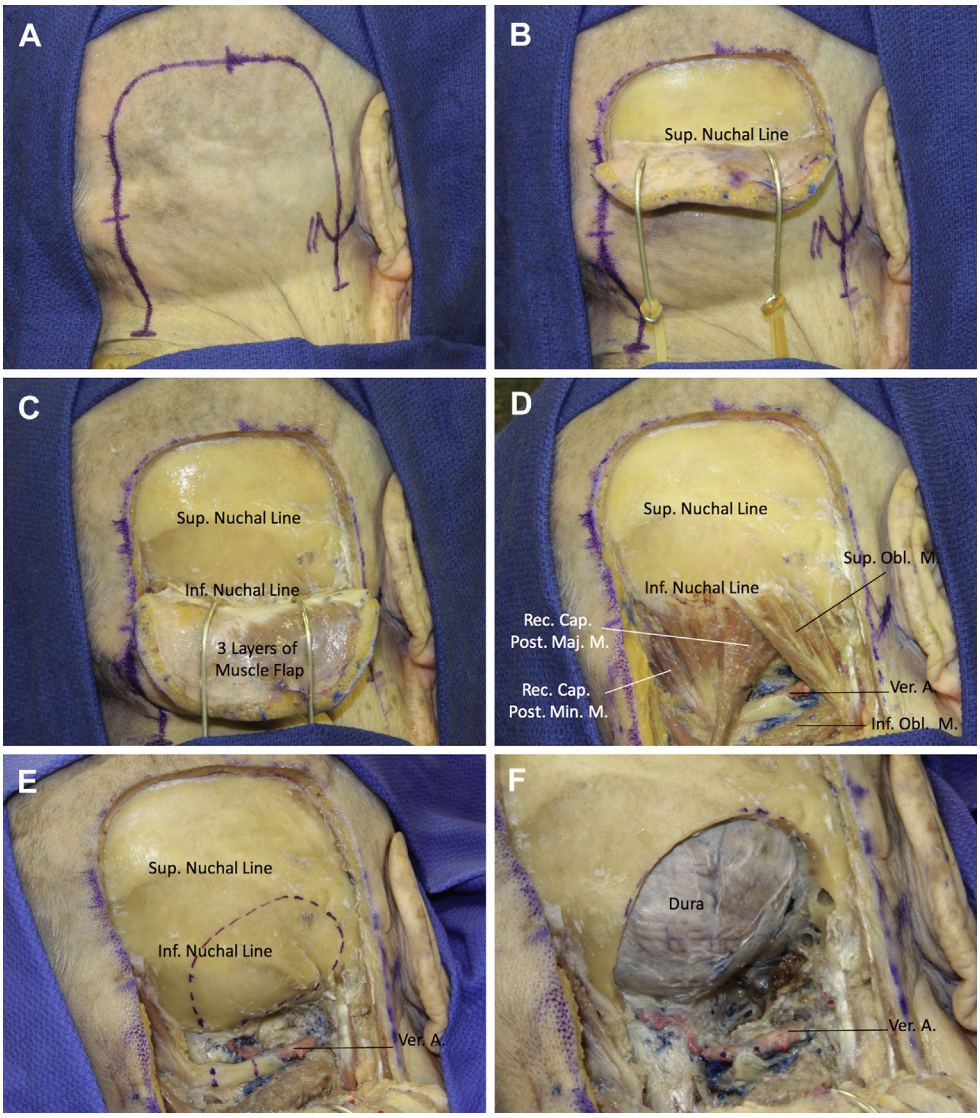

Figure 2. Cadaveric dissection simulating far lateral approach. (**A**) A horseshoe-shaped incision was demarcated, with the base directed downward. (**B**) The incision was initiated in the upper branch of the horseshoe, going deeper to the osseous plane. Subperiosteally, the flap was lowered until the superior nuchal line was reached. (**C**) Subperiosteal dissection continued downward until the inferior nuchal line was reached. (**D**) From the inferior nuchal line, rectus and oblique muscles are left attached to the skull base. The suboccipital triangle was exposed as well as the V3 segment of the vertebral artery. (**E**) Muscles of the suboccipital triangle were dissected; *dotted line* marks the craniotomy area. (**F**) Dura mater and vertebral artery were exposed. Sup., superior; Inf., inferior; Obl., oblique; M., muscle; Rec., rectus; Cap., capitis; Post., posterior; Maj., major; Ver., vertebral; A., artery; Min., minor.

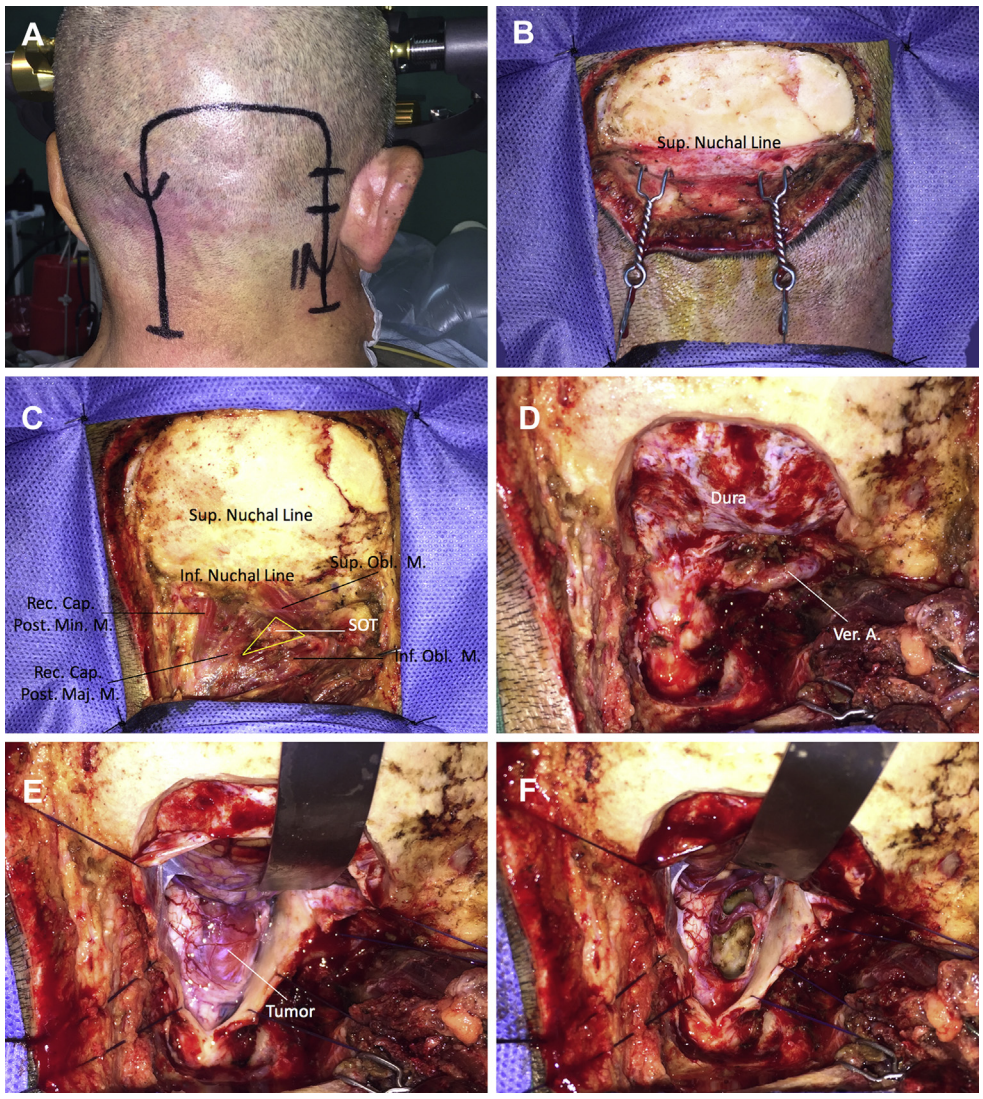

Figure 3. Far lateral approach in real surgery. (**A**) Horseshoe-shaped incision was demarcated with the base directed downward. (**B**) The incision was initiated in the upper branch of the horseshoe, going deeper to the osseous plane. Subperiosteally, the flap was lowered until the superior nuchal line was reached. (**C**) The suboccipital triangle was exposed (*yellow lines*). (**D**) Craniotomy was performed, and C1 and C2 laminae were resected. (**E**) Dura mater was opened, and the tumor was exposed. (**F**) Operative view after tumor resection. Sup., superior; Inf., inferior; Obl., oblique; M., muscle; Rec., rectus; Cap., capitis; Post., posterior; Min., minor; SOT, suboccipital triangle; Maj., major; Ver., vertebral; A., artery.

occipital condyle and C1 facet joint. A park-bench or lateral decubitus position could also be used.

After confirming correct positioning, the skin is marked. A horseshoe-shaped incision is performed, with the base directed downward, as follows: 1) medial branch, along the midline, from C4 spinous process below to 1 cm above the inion; 2) upper branch, the line continues from medial to lateral, approximately 1 cm above the upper edge of the ear; and 3) lateral branch, the incision descends just behind the ear to 1 cm below the tip of the mastoid process (**Figures 2A** and **3A**).

Soft Tissue Incision and Dissection. For stage 1 (from the upper part of incision until the SNL), we begin our incision in the upper branch of the horseshoe, going deeper to reach the osseous plane. Subperiosteally, we begin to lower the flap, until we reach the SNL (the first stop). At this level, it will be difficult to continue the superiosteal dissection because of muscle insertions of the first 3 superficial muscle planes; therefore, it is necessary to perform sharper maneuvers to liberate the SNL muscle insertions. The aim is to leave the first 3 muscle planes attached to the flap, thus preserving their vascularization and vitality.

Figure 4. (**A**–**H**) Surgical cases. (**A**, **C**, **E** and **G**) Preoperative T1 enhanced magnetic resonance imaging of foramen magnum meningiomas operated using far lateral approach and nuchal lines technique. (**B**, **D**, **F** and **H**) Postoperative T1 enhanced magnetic resonance imaging.

For stage 2 (from the SNL until the INL), after we pass the SNL, subperiosteal dissection continues, and the separation of the flap from the osseous plane is easy to make; thus, we continue downward to the INL (the second stop). At this level, the separation of the soft tissue flap and the osseous plane becomes difficult again as the insertions of the fourth muscle plane appear. At this stage of the approach, the fourth muscle plane is left attached to the skull base.

For stage 3 (from the INL until C2), we continue our dissection from the INL downward, separating the first 3 muscle planes (attached to the flap) from the fourth muscle plane (attached to the skull base) until we achieve full exposure of C1 and C2. It is important to respect the muscle fibers of the rectus and oblique muscles to correctly identify the SOT.

For stage 4 (VA exposure), when the SOT attached to the skull base has been identified, we position the surgical microscope and search for the VA in the fatty tissue. The V3 segment of the VA is surrounded by a venous plexus, which will become even more evident if the position is not correct and if the patient's venous return is poor. Once the VA has been exposed, the rectus capitis posterior minor and major muscles are detached together with the superior oblique muscle to fully expose the VA, the foramen magnum, the articulation between the occipital condyle and C1, and the retrocondylar fossa (**Figures 2B–D** and **3B** and **C**).

Craniotomy and Bone Removal. Craniotomy type, drilling of occipital condyle, and removal of the posterior arch of C1 and/or C2 depend on the lesion to be treated. However, to apply any of these FLA variants, good exposure of the V3 segment of the VA is necessary. The next step is tumor resection (**Figures 2E** and **F** and **3D**).

Tumor Resection. Durotomy is performed. The exposure achieved allows direct access to the tumor, increasing the possibility of an adequate resection (**Figures 3E** and **F** and **4A–H**).

DISCUSSION

The area around the foramen magnum and the craniocervical junction is the site of various different vascular, neoplastic, and degenerative lesions. Lesions that are posterior to the plane of the dentate ligament and medial to the VA can be reached by a midline posterior approach; lesions that are lateral and/or anterior to the neuraxis require a more extensive approach such as the FLA. The FLA was originally designed to treat these types of lesions and has proved to be very helpful in the management of most lesions.[1,3,11]

There are several names for the FLA and a large variety of modifications.[12-16] Many different incisions have been used to gain access to the posterior and lateral craniocervical junction. The classic is the reverse hockey stick incision, but a C-shaped incision has been also described.[1-3,16] We prefer a horseshoe-shaped incision as described by Wen et al.[7]

The basic FLA does not include removal of the posterior part of the occipital condyle. The transcondylar extension, by drilling the condyle, allows a more lateral view and provides access to the lower clivus and premedullary area.[7] There are many different opinions regarding how much condyle needs to be drilled[17-19]; we agree with Lancino et al.[20] that the lesion dictates how much removal of the condyle is necessary.

Beyond the multiple variants of the FLA (e.g., incision, amount of bone removed), a critical step when performing the FLA is the exposure of the V3 segment of the VA.[4,21] Although there are reports of the FLA without VA exposure,[22] we consider VA exposure to be essential for adequate surgical management of the lesion. Youssef et al.[9] argued that exposing the VA is a true neurosurgical challenge for several reasons: 1) variable course, 2) deep location in the SOT, and 3) presence of a surrounding venous plexus. Similarly, Bertalanffy et al.[23] affirmed that bleeding of this venous plexus may produce an adverse surgical field.[23] The main risk during exposure of the VA is to cause a lesion; therefore, it is necessary to have a method to allow surgeons to identify the VA safely.

The real anatomic landmark to find the V3 segment of the VA is the SOT.[9] Youseff et al.[9] developed a system to expose the VA in the SOT by means of a plane-by-plane dissection of the nuchal muscles. The main limitation of this technique is the high possibility of devascularizing the flap and the concomitant risk of producing necrosis. Therefore, we suggest the use of 2 superficial anatomic landmarks, the nuchal lines, with the aim to surgically separate the muscle layers of the nuchal region into 2 groups; the first 3 planes are left joined and attached to the skin and the subcutaneous tissue (thus preventing the risk of necrosis), and the fourth muscle plane remains attached to the skull base. Thus, exposure of the SOT is achieved. To our knowledge, an efficient and reproducible method that allows the identification and exposure of the SOT without performing a plane-by-plane dissection has not yet been described in the literature.

CONCLUSIONS

The nuchal lines allow dissection of the muscles in 2 groups, one superficial (first 3 muscle layers) and the other deep (SOT), which remains attached to the skull base. Thus, the V3 segment of the VA is easily and safely exposed during the FLA.

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