“Lazy” far-lateral approach to the anterior foramen magnum and lower clivus

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Until the development of modern skull base surgery and microsurgical techniques, lesions of the anterior/anterolateral foramen magnum and lower clivus were generally considered inoperable.12,29,34 In a review of case series published before 1976, Yaşargil and Curcic found an overall mortality rate of approximately 13%; in some series, rates are as high as 45%.42 In 1986, Heros19 introduced the far-lateral approach (FLA) for the management of aneurysms of the vertebral artery (VA), the vertebral artery (VA) is both a critical anatomical structure and a barrier that limits access to this region. The most important nuance of this FLA technique is the management of this critical vessel. When the lazy FLA is used, the VA is reflected laterally, encased in its periosteal sheath and wrapped in the dura, greatly minimizing the risk for vertebral injury while preserving a wide working space. To accomplish this step, drilling is performed lateral to the point where the VA pierces the dura. The dura is incised medial to the VA entry point by using a slightly curved longitudinal cut. Drilling of the condyle and the C-1 lateral mass is performed in a manner that preserves cranio-cervical stability. The lazy FLA is a true FLA that is based on manipulation of the VA and lateral bone removal to obtain excellent exposure ventral to the spinal cord and medulla, yet it is among the most conservative FLA techniques for management of the VA and provides a safer window for bone work and lesion management. Among 44 patients for whom this technique was used to resect 42 neoplasms and clip 2 posterior inferior cerebral artery aneurysms, there was no surgical mortality and no injury to the VA.

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KEY WORDS far-lateral approach; foramen magnum; meningioma; vertebral artery

ABBREVIATIONS FLA = far-lateral approach; VA = vertebral artery.


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anced between a conservative approach that can limit the extent of resection and a more aggressive approach that can place the VA at greater risk for injury. We also present our experience with a series of patients who underwent surgery via the lazy FLA for various conditions.

Surgical Technique and Clinical Experience

Surgical Technique

This modification of the FLA was developed in an anatomy laboratory in which cadaver heads were used. The surgery itself is performed after induction of general anesthesia and involves use of an operating microscope and microsurgical techniques, high-speed drills, and microinstruments. Intraoperative monitoring of motor and somatosensory evoked potentials and the lower cranial nerves is indicated for cases in which the cranial nerves are manipulated during surgery. Key steps of the lazy FLA and tumor removal are shown in Video 1.

VIDEO 1. Clip showing key steps of the lazy FLA and tumor removal. Copyright Sergey Spektor. Published with permission. Click here to view with Media Player. Click here to view with Quicktime.

Patient Positioning

Until 2004, selected patients were placed in the sitting position for surgery; however, patients are now operated on in a 3/4 prone decubitus position (Fig. 1). Several positioning details are noteworthy. The leg lying on the table is bent at the knee to provide stability while the pelvis and thighs remain vertical to prevent overrotation of the patient during surgery. A silicon roll is placed beneath the axilla and the chest of the patient, and the arm on the table is stretched forward in supine rotation, providing vascular access in the wrist, forearm, and elbow. The upper arm is placed low, on a small pillow, naturally pulling the upper shoulder forward and downward to the floor and facilitating rotation of the chest up to 30°–45°, depending on the patient’s body type. To prevent cervical plexus damage, we allow gravity to work and avoid any traction in the higher shoulder. We also use supports in the sacral area to prevent the patient from falling when the table is rotated backward, and in the lower sternal area to prevent chest overrotation and to keep the patient stable when the table is rotated forward.

The patient is securely taped to the table; care is taken to prevent damage at compression points. The head is fixed in a 3-pin Mayfield head holder, parallel to the floor in the anteroposterior dimension, without any rotation, and bent slightly toward the floor to open the condylar C-1 facet joint. The head is then flexed forward to the maximal extent while avoiding disruption to the airway/endo- tracheal tube angulation. This head position (bent forward, parallel to the floor with minimal tilt to the pendant shoulder) provides excellent surgical access without interference from the patient’s upper shoulder, which is placed to fall forward.

At this step, all electrodes for neurophysiological monitoring are placed. Last, the operating table is maximally tilted and rotated to ensure that the patient is absolutely secure.

Skin Incision and Soft-Tissue Dissection

A lazy-S skin incision is created, beginning in the retroauricular area, descending vertically through the midpoint between the inion and mastoid, and curving in its lower part to the midline of a spinal process between C-4 and C-7. The inferior reach of the incision depends on the extent of disease below the level of the foramen magnum and C-1 lamina and on the patient’s neck shape and width (Fig. 2).

The wound is opened in a linear fashion, and the splenius capitis and semispinalis capitis muscles are transected longitudinally with diathermia and retracted to the side. Similar to a pterional approach, as the temporalis muscle is elevated and separated from the superior temporal ridge, the semispinalis capitis muscle is detached from the superior nuchal line to enable wider retraction and wider wound opening. Beneath the superficial muscular layer, the fat pad is bluntly dissected to open the deep muscular layer that forms the suboccipital triangle, which comprises the rectus capitis major and minor muscles, the superior and inferior oblique muscles, and the posterior belly of the

FIG. 1. Photograph showing the patient’s head fixed in a 3-pin Mayfield head holder, parallel to the floor in the anteroposterior dimension, without any rotation, and bent slightly toward the floor in the vertex-sacral axis to open the craniovertebral junction/condylar C-1 facet joint. The head is then flexed forward to the maximal extent while avoiding disruption of the airway/endo- tracheal tube angulation.

FIG. 2. Photographs showing how the inferior reach of the lazy-S skin incision varies according to the inferior extent of the lesion as well as the shape and width of the patient’s neck.
Suboccipital/Retrosigmoid Craniotomy

The size of the craniotomy depends on the inferior intracranial extent of the tumor; usually, the craniotomy resembles a retrosigmoid craniotomy for cerebellopontine angle access. First, a fluted steel bur and then a diamond bur are used to perform a narrow strip craniectomy that exposes the edge of the sigmoid sinus. Next, the footplate of the craniotomy attachment is inserted, and the bone flap in the posterior fossa is elevated. If mastoid bone air cells are violated while drilling, they must be meticulously obliterated with a bone wax–bone dust mixture. Sometimes it is possible to include the posterior foramen magnum rim in the craniotomy flap; sometimes the rim of bone stays behind and will be removed with a high-speed drill during the next step (Fig. 4).

Removal of the Rim of the Lateral Foramen Magnum and Drilling of the Condyle

The lateral edge of the foramen magnum rim is drilled away. Drilling continues laterally into the condylar fossa and the condyle. Only the posteromedial part of the condyle must be removed to provide direct access to the anterior foramen magnum area and clivus. A condylar emissary vein is usually found in the condylar fossa, and it should be identified on preoperative CT and MR images before surgery because it can be large and its perforation can cause massive venous bleeding. Any bleeding that occurs is controlled with bone wax obliteration, and drilling continues directly along this channel through the bone wax. The deep border of drilling is compact bone of the posterior wall of the hypoglossal canal; the upper border is the inferior wall of the sigmoid sinus on its way to the jugular bulb and jugular foramen. Together with the inferomedial part of the condyle, a superomedial part of the C-1 facet is also drilled away at this stage (Figs. 4 and 5).

Hemostasis is achieved by bone wax packing to the bone, application of Surgicel (Ethicon), and bipolar coagulation of the venous plexus vessels, if needed. The goal is to remove as much bone as possible lateral to the point of the penetration of the VA through the atlantooccipital membrane without jeopardizing craniovertebral stability or the VA as it passes through the transverse foramen of C-1 and curves around the condylar process.

Dural Opening

The dura is opened in a C-shaped fashion. The upper point in the incision begins as far lateral as possible, near the sigmoid sinus; the incision then curves caudally and medially to the VA and continues beneath the VA obliquely through the cervical area, as far lateral and inferior as possible, providing a dural flap. The medial part of the flap contains the VA as it passes extra/intradurally (Fig. 6 left). The lower extension of the flap is determined by the inferior extension of the tumor and can include hemilaminectomy at C-2, C-3, or even C-4, if needed. The flap is reflected laterally, together with the VA as it pierces the dura, and is tacked with sutures and rubber rings to permit constant lateral traction (Fig. 6 right). Care must be taken to avoid kinking of the extradural VA, and uninterrupted flow should be confirmed with an intraoperative Doppler device. With sufficient removal of the bone of the condylar fossa and the posteromedial part of the condylar process, lateral traction of the dural flap along with the VA provides wide exposure of the anterior part of the upper spinal canal, foramen magnum, and clivus (Fig. 7).

Tumor Removal

Microsurgical removal is achieved in the usual manner,
by use of cavitronic ultrasonic surgical aspiration, microbipolar coagulation, and microsurgical instruments. Usually, the tumor is detached ventromedially to the ipsilateral VA; ventral to the spinal cord and medulla; and between cranial nerves IX–XII, the VA, and the posterior inferior cerebral artery. The denticulate ligament is transected, releasing the spinal cord and facilitating arachnoid dissec-

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tion. Retraction is not needed because the entry into the tumor is very lateral. After the tumor has been debulked and detached, its periphery is gently pulled out from beneath the medulla, while the arachnoid plane is preserved.

Our surgical goal was to excise tumors to the maximum extent possible while preserving neurological function; thus, a small remnant of tumor was sometimes left along the cranial nerves or vasculature. When indicated, residual tumor was managed with stereotactic radiosurgery or fractionated radiosurgery.

In patients with posterior inferior cerebral artery aneurysms, this approach provides an excellent direct view of the aneurysmal neck, facilitating safe aneurysmal clip placement.

Closure

After the tumor is removed and hemostasis is achieved, the dura is closed. Tenting sutures are transected, and the dural flap, containing the VA, is reflected back from lateral to medial. We prefer watertight suturing when possible; when watertight suturing is not possible, we fill gaps in the dura with dural substitutes such as Duragen (Integra) or TachoSil (Baxter), or stitch in a dural patch. The occipital bone fragment is replaced and fixed with CranioFix clamps (Aesculap) or miniplates. The ends of the superior and inferior oblique muscles are reconnected, and the semispinalis and splenius capitis muscles are sutured in layers, after which watertight sutures are applied to the aponeurosis, the subcutaneous tissue is sutured, and the skin is closed with sutures or staples.
Postoperative Management

Because this approach does not jeopardize atlantooccipital stability, patients are usually mobilized on the first postoperative day. Depending on the pathology of the neoplasms and the size and behavior of any residual tumor, additional stereotactic radiosurgery or fractionated stereotactic radiotherapy is performed when necessary.

Clinical Experience

From our skull base database, which has been prospectively maintained since 1998, we selected patients in whom pathology involved the area of the anterior/antero-lateral foramen magnum and lower third of the clivus. We defined the foramen magnum as described by George et al., corresponding to a zone delineated anteriorly by the lower third of the clivus to the upper edge of the body of C-2, laterally by the jugular tubercles to the upper aspect of the C-2 lamina, and posteriorly from the anterior edge of the squamous occipital bone to the C-2 spinous process. We excluded from the study those patients who had tumors involving primarily the posterior aspect of the foramen magnum or originating elsewhere and extending into this area, those who had tumors involving primarily the superior two thirds of the clivus, and those who had undergone an alternative surgical approach.

Tumor resection was defined as total when the tumor was removed grossly, subtotal when a remnant remained on cranial nerves or relevant vasculature of the region, and partial when a bulk of tumor remained. Aneurysm closure was defined as total or with a remnant.

We recorded data regarding patient demographics, clinical presentation, surgical details, tumor pathology, surgical complications, surgical morbidity and mortality (death within 30 days of surgery), and long-term outcomes. The hospital’s institutional review board approved the study design and waived the requirement for informed consent.

Preoperative MR imaging, computed tomography, and (in selected cases) angiography were used to determine the exact location and characteristics of the lesions and to localize critical neurovascular structures with respect to the tumors. Postoperative MR and CT images were used to assess the extent of tumor resection or aneurysm closure, to rule out postoperative bleeding and ischemic changes, and to detect any recurrence. All patients were followed up in our outpatient clinics. Imaging studies were performed 3 months after surgery and annually thereafter.

Results

The lazy FLA was used for 44 surgeries (Fig. 8; Table 1). In all cases, the approach provided excellent exposure, enabling appropriate tumor removal or clipping of posterior inferior cerebral artery aneurysms. Selected surgical details are shown in Table 2.
There were no patient deaths, no damaged VAs, no vascular complications, and no new neurological deficits resulting from long tract/brainstem manipulation or cerebellar damage. In 1 patient, cranial nerve XI was transected intentionally and anastomosed because of tumor encasement; this patient recovered well.

Of the 44 patients, 3 elderly patients (6.8%) with preoperative neurological deficits resulting from en plaque meningiomas involving the lower cranial nerves developed permanent lower cranial nerve palsy after manipulation of nerves encased in their tumors; no cranial nerves were transected in these patients. Transient neurological deficits were seen in 5 patients (11.4%) (Fig. 9). Surgical complications and neurological outcomes are summarized in Table 3.

**Discussion**

The most important nuance of our lazy FLA technique is management of the VA. Reflecting the VA laterally, encased in its periosteal sheath and wrapped in the dura,

**TABLE 1. Demographics and primary lesions for 44 patients who underwent surgery via the lazy FLA**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic</strong></td>
<td></td>
</tr>
<tr>
<td>Age (yrs)</td>
<td></td>
</tr>
<tr>
<td>Mean 52</td>
<td></td>
</tr>
<tr>
<td>Range 14–77</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
</tr>
<tr>
<td>Female 32</td>
<td></td>
</tr>
<tr>
<td>Male 12</td>
<td></td>
</tr>
<tr>
<td><strong>Lesion</strong></td>
<td></td>
</tr>
<tr>
<td>Anterior &amp; anterolat foramen magnum meningioma (6 en plaque)</td>
<td>25 (57)</td>
</tr>
<tr>
<td>Foramen magnum–jugular tuberculum meningioma (1 en plaque)</td>
<td>8 (18)</td>
</tr>
<tr>
<td>Foramen magnum epidermoid cyst, ventral</td>
<td>4 (9)</td>
</tr>
<tr>
<td>Other (chordoma, choroid plexus papilloma, fibroxanthoma, liponeurocytoma, rhabdomyosarcoma)</td>
<td>5 (11)</td>
</tr>
<tr>
<td>PICA aneurysm</td>
<td>2 (5)</td>
</tr>
</tbody>
</table>

PICA = posterior inferior cerebral artery.

**TABLE 2. Surgical details for 44 surgeries in which the lazy FLA to the anterior foramen magnum and lower clivus was used**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient position</strong></td>
<td></td>
</tr>
<tr>
<td>Lateral</td>
<td>34</td>
</tr>
<tr>
<td>Sitting</td>
<td>10</td>
</tr>
<tr>
<td><strong>Extent of resection (n = 42 tumors)</strong></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>20 (48)</td>
</tr>
<tr>
<td>Subtotal</td>
<td>11 (26)</td>
</tr>
<tr>
<td>Partial</td>
<td>11 (26)</td>
</tr>
<tr>
<td><strong>Aneurysm closure (n = 2 PICA aneurysms)</strong></td>
<td></td>
</tr>
<tr>
<td>Complete</td>
<td>2 (100)</td>
</tr>
</tbody>
</table>
“Lazy” FLA to the anterior foramen magnum and lower clivus

Strategies for managing the VA in these procedures range from the most aggressive to conservative. In 1990, Sen and Sekhar described their technique for removing intradural lesions of the cervical spine and foramen magnum. They exposed the VA from C-2 to its dural entry. Citing its propensity for troublesome bleeding, they also removed the venous plexus surrounding the VA. Margalit et al. later provided a more explicit explanation of the dural incision, which lies at the lateral aspect of the spinal cord and medulla and extends anteriorly toward the VA entry point. Especially in patients with extradural tumors, this technique completely liberates the VA from its dural attachment, and it can then be moved freely. It is noteworthy that for 4 patients in the Margalit et al. series, the VA was injured.

Bertalanffy et al. reflect the VA while preserving its dural attachment; however, they free it from as much of the surrounding alveolar tissue as possible and coagulate or pack the venous plexus so that the course of the artery is more completely revealed.

According to George et al., the team at Lariboisière prefers to leave the VA in its protective sheath with the obvious exception of procedures performed with the objective of VA revascularization. In a comment within the Margalit et al. article, Dr. George notes that incising the dura at the point where it is pierced by the VA is useful only in cases in which a meningioma insertion directly involves the dura at this point.

The extent of condyle bone removal is one of the most widely discussed issues with regard to this approach because of the risks of craniocervical instability, hypoglossal injury, condylar vein injury, and increased surgical time. In clinical and anatomical studies, some classifications for the FLA were even determined primarily by the extent of condylar drilling. Generally, no more than one-third of the occipital condyle must be removed; Nanda et al. have presented a technique with no drilling of the condyle. Resection of more than 50% of the condyle has been shown to cause craniocervical instability. In our experience, drilling of up to one-third of the condyle enables mobilization of the VA and thus provides good exposure of the surgical field. More extensive drilling is generally required to achieve total resection of aggressive tumors with extensive bony involvement.

The most frequently recommended configurations

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. (%)</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical complication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DVT w/ PE, IC hemorrhage</td>
<td>1</td>
<td>Conservative management, full recovery</td>
</tr>
<tr>
<td>PE</td>
<td>1</td>
<td>Conservative management, full recovery</td>
</tr>
<tr>
<td>CSF leak</td>
<td>1</td>
<td>Via mastoid, 3 yrs postop, surgical obliteration</td>
</tr>
<tr>
<td>Drop foot</td>
<td>1</td>
<td>Position-related (patient in sitting position during op)</td>
</tr>
<tr>
<td>Neurological outcome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permanent LCN deficits</td>
<td>3 (6.8)</td>
<td>Surgical manipulation of LCN during removal of en plaque meningiomas; tracheostomy &amp; gastrostomy for 2, conservative management for 1</td>
</tr>
<tr>
<td>Transient LCN deficits</td>
<td>5 (11.4)</td>
<td>Temporary gastrostomy for 2, temporary tracheostomy for 1, full recovery for 2 (including 1 case of deliberate transection of CN XI w/ anastomosis)</td>
</tr>
</tbody>
</table>

CN = cranial nerve; DVT = deep vein thrombosis; IC = intracranial; LCN = lower cranial nerve; PE = pulmonary embolism.
for the skin incision are the inverted hockey stick (or L-shaped)\textsuperscript{7,24,25} or C-shaped incisions.\textsuperscript{8,26} Others recommend linear paramedian incisions, arguing that they reduce the risk for CSF leakage.\textsuperscript{8,24,26} Our choice of incision, a lazy-S incision, provides excellent retraction and wide angle exposure in the transverse axis, creates a deep surgical field, and reduces trauma to the musculature.\textsuperscript{7} In our experience, this type of soft-tissue incision also seems to reduce the risk for skin necrosis, pseudomeningoceles, and fluid collection.

Broadly speaking, the steps in this approach are positioning, skin incision, soft-tissue dissection, VA management, suboccipital/retrosigmoid craniotomy, lateral foramen magnum rim removal and drilling of the condyle, dural opening, intradural microsurgery, and closure. In the extensive literature about FLA, authors describe various philosophies ranging from conservative to aggressive at each step.

A broad spectrum of benign and malignant neoplasms, as well as vascular pathology, is found in the foramen magnum and lower clivus. Although various authors have described a range of modifications to surgical approaches for the management of these lesions, there is consensus that the surgical strategy should take into account the characteristics of a specific lesion. Resection of these pathologies is demanding, especially when the lesion is anterior or anterolateral with a broad-base insertion. Among the larger series of patients who have undergone surgery performed by experienced skull base surgeons using variants of the FLA over the past 20 years, mortality rates ranging from 2\% to 17\% and new permanent deficits ranging from 8\% to 22\% have been reported.\textsuperscript{4,6,15,26,30,32} As a result, lateral approaches to anterior and anterolateral lesions in the area of the foramen magnum have been discussed extensively in the literature.

Authors have used diverse terminology to refer the general approach: extreme lateral, extreme lateral inferior transstubercular exposure, extreme lateral inferior transcondylar exposure, posterior lateral approach and its modifications, conventional posterior suboccipital approach, lateral suboccipital, far-lateral, far-lateral suboccipital, posterolateral, supracondylar, dorsolateral suboccipital transcondylar, extreme lateral transcondylar with variations, and extreme lateral craniovertebral with 6 variations.\textsuperscript{1–3,5,8,10,12,15–23,25,28,31,33,35,37,38} The heterogeneity of lesions and surgical strategies makes direct comparisons of outcomes difficult.

Conclusions

In summary, we consider our modification of this surgical technique as a lazy FLA. On the one hand, it is a true FLA based on manipulation of the VA and lateral bone removal to obtain excellent exposure ventral to the spinal cord and medulla. On the other hand, it is rather conservative with respect to the management of the VA, which is reflected together with its periosteal sheath and surrounding dura mater, providing a safe and sufficient route to the anterior foramen magnum and area of the lower clivus.

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References


Author Contributions
Conception and design: Spektor, Moscovici. Acquisition of data: all authors. Analysis and interpretation of data: Spektor, Moscovici. Drafting the article: Spektor, Moscovici. Critically revising the article: Spektor, Moscovici. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Spektor. Administrative/technical/material support: Spektor. Study supervision: Spektor.

Supplemental Information
Videos

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