Anatomical basis of approaches to foramen magnum and lower clival meningiomas: comparison of retrosigmoid and transcondylar approaches

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Object. Meningiomas of the lower clivus and foramen magnum are among the most challenging of all neurosurgical lesions. Debate continues regarding the most appropriate approach to this eloquent anatomical region. This anatomical study was undertaken to measure and compare the area of surgical exposures of the lower clivus achieved using the retrosigmoid and the extreme-lateral transcondylar (ELT) approaches.

Methods. Thirteen embalmed cadaveric heads were dissected bilaterally via the retrosigmoid approach on one side and the ELT approach on the other. The circumference of the area of exposure was delineated using beaded pins placed into the dura. After removal of the brain, the longest longitudinal and transverse axes of the pinned areas were measured and surface area calculated. The area of surgical exposure was also expressed as a percentage of the total area of the lower clivus. Normalized and adjusted surface areas were calculated using the bimastoid diameter. The areas of exposure were compared using the two-tailed paired Student t-test.

The mean area of exposure required using the retrosigmoid approach was 19.8 ± 14.7 mm² (range 6–49 mm²) and that using the ELT approach was 27.8 ± 22.8 mm² (range 10–90 mm²). The mean percentage of the lower clivus exposed by the retrosigmoid approach was 14.9 ± 3.6% (range 10–22%) and that exposed by the ELT approach was 20.5 ± 4.9% (range 10–25%). The ELT approach provided significantly greater area of operative exposure and allowed a significantly higher percentage of lower clivus and foramen magnum exposure than did the retrosigmoid approach (p < 0.05). Normalized and adjusted surface areas, taking into consideration the bimastoid diameter, were also statistically significant in favor of the ELT approach.

Conclusions. The ELT approach provided a significantly greater area of exposure than did the retrosigmoid approach.

KEY WORDS • meningioma • clivus • foramen magnum • retrosigmoid approach • extreme-lateral transcondylar approach • skull base

Abbreviations used in this paper: CCJ = craniocervical junction; ELT = extreme-lateral transcondylar; SD = standard deviation; VA = vertebral artery.
edge, no other study has addressed this issue. Therefore, the purpose of this study was to measure and compare the area of surgical exposures of the lower clivus and foramen magnum provided by the retrosigmoid and the ELT approaches.

MATERIALS AND METHODS

Thirteen embalmed cadaveric heads (26 sides) were dissected using the retrosigmoid approach on one side and the ELT approach on the other; an operating microscope was used. An electric drill with cutting and diamond burs as well as and macro- and microsurgical instruments were used as necessary.

Operative Approaches

Retrosigmoid. The technique for the retrosigmoid approach has been previously described. Briefly, a reverse U-shaped incision was made in the suboccipital area. Skin and subcutaneous tissues were reflected inferiorly as a single layer. A suboccipital craniectomy was then performed with its superior extent just below the transverse sinus and its lateral extent just medial to the sigmoid sinus. The dura was opened in a cruciate fashion, and the occipital lobe was maximally retracted.

Extreme-Lateral Transcondylar. The technique for the ELT approach has been described by Sen, et al. The incision is extended along the upper third of the anterior border of the sternocleidomastoid muscle, to just above the lateral part of the superior nuchal line, to the midline, and then down the midline to C-4. After elevation of the skin flap along with the subcutaneous tissue, the posterior C-1 arch and posterior portion of the C-1 lateral mass were removed using a cutting burr on a high-speed drill. The VA as well as its encircling venous plexus was then freed and mobilized from the C-1 transverse process. A standard suboccipital craniectomy was then performed. A partial mastoidectomy up to the vertical part of the facial nerve was conducted, and the sigmoid sinus was unroofed up to the level of the jugular bulb. The inferior extension of the craniectomy includes the foramen magnum and, laterally, the craniectomy includes drilling of the posterior half of the occipital condyle. The dural incision was made longitudinally, the dural edges tented up with sutures, and the occipital lobe retracted.

Delineation of the Area of Exposure

The area of surgical exposure was delineated by placing beaded pins into the dura around the circumference of the exposed area (Fig. 1). After removal of the brain, the longest longitudinal and transverse axes of the pinned areas were measured in millimeters. The area of exposure was then determined by multiplying the length of the two axes. The area of surgical exposure was expressed as a percentage of the total area of the lower clivus. The boundaries of the lower clivus were delineated, as detailed by Sekhar, et al., as follows: the upper border is a line joining the two jugular foramina; the lower border is a line running through the anterior margin of the foramen magnum; and each lateral border is formed by a line joining the jugular foramen and the hypoglossal canal.

RESULTS

Comparison of the Surface Area

A summary of surface areas of exposure provided by the retrosigmoid and the ELT approaches is provided in Table 1 and Fig. 2. The mean surface area of exposure provided by the retrosigmoid approach was 19.8 ± 14.7 mm² (range 6–49 mm²), and that provided by the ELT approach was 27.8 ± 22.8 mm² (range 10–90 mm²). The surface area of exposure provided by the ELT approach was significantly greater than that provided by the retrosigmoid approach (p = 0.024). The ELT approach provided a greater area of exposure of the lower clivus in 12 of 13 cadaveric heads examined. The areas of exposure created by both the retrosigmoid and ELT approaches were highly correlated with bimastoid diameter (r = 0.86 and 0.88, respectively). Normalized surface area (p = 0.036) and adjusted surface area (p = 0.016) were also significantly greater for the extreme-lateral approach.

Percentage of the Lower Clivus Exposed

The percentage of the lower clivus exposed by the retrosigmoid and the ELT approaches are summarized in Fig. 1. Photograph of the clivus, posterior fossa, and foramen magnum. The area outlined by the orange pinheads demarcates the exposure provided by the ELT approach. The area demarcated by the blue pinheads on the left was provided by the retrosigmoid approach. The brainstem and inferior cerebellum have been resected. The cerebellar folia can be seen at the upper right corner. The ruler marks the location of the foramen magnum and is placed between the VAs.
Retrosigmoid and extreme-lateral approaches

<table>
<thead>
<tr>
<th>Area Exposed</th>
<th>Method</th>
<th>ELT</th>
<th>Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>total surface area</td>
<td>Retrosigmoid</td>
<td>19.8 ± 14.7 mm²</td>
<td>27.8 ± 22.8 mm²</td>
</tr>
<tr>
<td></td>
<td>ELT</td>
<td>(6–49 mm²)</td>
<td>(10–90 mm²)</td>
</tr>
<tr>
<td>normalized surface area</td>
<td>Retrosigmoid</td>
<td>2241 ± 1878 mm²</td>
<td>3144 ± 2895 mm²</td>
</tr>
<tr>
<td></td>
<td>ELT</td>
<td>(540–5978 mm²)</td>
<td>(1030–11070 mm²)</td>
</tr>
<tr>
<td>adjusted surface area</td>
<td>Retrosigmoid</td>
<td>0.18 ± 0.11 mm²</td>
<td>0.25 ± 0.18 mm²</td>
</tr>
<tr>
<td></td>
<td>ELT</td>
<td>(0.07–0.40 mm²)</td>
<td>(0.10–0.73 mm²)</td>
</tr>
<tr>
<td>% total surface area of clivus</td>
<td>Retrosigmoid</td>
<td>14.9 ± 3.6 %</td>
<td>20.5 ± 4.9 %</td>
</tr>
<tr>
<td></td>
<td>ELT</td>
<td>(10–22%)</td>
<td>(10–25%)</td>
</tr>
</tbody>
</table>

* Determined by performing the two-tailed paired Student t-test.
† The bimastoid diameter multiplied by the total surface area of exposure.
‡ The total surface area of exposure divided by the bimastoid diameter.

Table 1 and Fig. 2 lower. The mean percentage of the lower clivus exposed via the retrosigmoid approach was 14.9 ± 3.6% (range 10–22%) and that exposed by the ELT approach was 20.5 ± 4.9% (range 10–25%). The percentage of the lower clivus exposed by the ELT approach was significantly greater than that by the retrosigmoid approach (p = 0.002).

**DISCUSSION**

Notoriously known for their association with a high surgery-related morbidity rate, ventrally located lesions in the CCJ have inspired various alternatives to the traditional retrosigmoid approach. The ELT approach has become increasingly more extensive in its area of exposure. In addition to the large occipital craniotomy,11 Sen and Sekhar39 drilled half of the occipital condyle and later Sen and Sekar,26 and Babu et al.,3 drilled the entire occipital condyle. George, et al.,7 and others24 recommended partial mastoidectomy, Bertalanffy and Seeger4 recommended drilling of the atlantal lateral mass, and ultimately George, et al.,8 and Sen and Sekar26 added sectioning of the sigmoid sinus. The approach has gained wide acceptance not only because it avoids entering the contaminated oral cavity, but also provides early visualization of the VA, and creates wider exposure, however, have to be weighed against the risk of compromising the stability of the CCJ that may result from resecting of the entire condyle.

In this study we found the mean difference between the surface area of exposure provided by the ELT and the retrosigmoid approaches to be 8 mm² (p < 0.05). The additional drilling of the occipital condyle and partial mastoidectomy provided by the ELT approach expanded the area of exposure of the retrosigmoid approach anteriorly and ventrally. The exposure provided by the ELT approach, when 50% of the occipital condyle is drilled, however, is limited to the midline. Further extension of the exposure across the midline may be achieved by drilling the entire occipital condyle.3 The benefits of such wide exposure, however, have to be weighed against the risk of compromising the stability of the CCJ that may result from resecting of the entire condyle.

In our specimens, the retrosigmoid approach exposed 14.9% of the lower clivus and anterior foramen magnum, whereas 20.5% of the region was exposed via the ELT approach (p < 0.05). Lower: Bar graph demonstrating the percentage of the area of the lower clivus exposed by the two approaches. Values represent mean percentage ± SD, respectively, of the exposure area created by each approach. The asterisk denotes significantly greater percentage area of exposure achieved using the ELT approach (p < 0.05).
iological retraction” and the creation of what the senior author (M.D.C.) calls a three-dimensional surgical corridor that not only provides access but also allows the instrument-related maneuverability. The surgical corridor thus created by larger lesions effectively allows an extreme-lateral exposure without the need to drill the condyle (Fig. 3). More extensive lesions, such as those that cross the midline, may require even wider exposure by removing the entire condyle. Although drilling of the jugular tubercle can also improve visualization of the lower clivus, this was not the object of our study. Clearly it is this concept of a surgical corridor that can explain differences in surgery-related philosophy concerning this region.8,20 In our experience, the surgical corridor is assessed on preoperative imaging, and the retrosigmoid approach is used in cases involving larger and more laterally located lesions that create a larger corridor and the transcondylar approach is used in cases involving smaller more ventral-ly situated lesions. Ultimately clinical studies cannot resolve the issue of surgical approach alone because lesions in this region are rare and randomization is unlikely. Clearly, the astute surgeon will individualize the approach to the specific anatomy of each lesion and patient.

CONCLUSIONS

The ELT approach provided a significantly greater area of exposure of the lower clivus and foramen magnum than the retrosigmoid approach.

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References


Fig. 3. Photographs showing the surgical corridor to anterior foramen magnum and lower clival meningiomas. A: Suboccipital craniotomy (red) with a narrow corridor does not allow effective exposure of the tumor for resection. CMJ = cervicomedullary junction. B: Tumor growth naturally widens the surgical corridor, allowing safe and effective removal via suboccipital craniotomy without drilling of the condyle. C and D: Transcondylar exposure (blue) widens the corridor by removing the medial condyle (red arrow represents very narrow corridor before condyle resection, green arrow represents adequate corridor after its removal) (C), thereby allowing access to much of the tumor (D).
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