Surgical Anatomy and Morphometric Analysis of the Occipital Condyles and Foramen Magnum

By

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Summary: Surgical anatomy that provides the basis for dealing with lesions arising in the lower clivus and ventral foramen magnum was reviewed in 8 adult cadaver heads and 76 dry skulls. The extreme lateral transcondylar approach was performed in cadavers; the morphometric analysis was studied in both the cadavers and the skulls. The landmarks, distances and structures were selected in order to guide the surgical operations in this area. In the paper, surgical approaches to this region are reviewed, and the results are discussed from the standpoint of surgical importance.

There are many kinds of pathological processes that involve the craniovertebral junction. These lesions include intradural tumors such as meningiomas, neurinomas or vascular lesions such as aneurysms and arteriovenous malformations of the vertebral artery and vertebrobasilar junction, extradural tumors such as chordomas, basilar invagination and other congenital anomalies, non-traumatic (rheumatoid) and traumatic entities with C1–C2 subluxation. Anterior cranial base approaches are appropriate for surgical management of extradural lesions which are localized strictly to the midline. Basilar invagination and congenital anomalies, rheumatoid compression of the craniovertebral region, and some traumatic lesions can be treated successfully using the transoral and transmaxillary procedures or the mandibular swing-transcervical approach. For intradural lesions, the transoral, transmaxillary and transmandibular approaches can still be utilized, but are suboptimal because of the lack of proximal and distal vascular control, limited lateral exposure and the possibility of contamination of the cerebrospinal fluid with oral flora resulting in life-threatening meningeal infection. Suboccipital approach, with or without upper cervical vertebral laminectomy, is the traditional approach used for intradural lesions of the posterior fossa and craniovertebral junction, but in case the lesion is placed ventrally, this approach provide very poor exposure and required retraction of the brainstem.

The extreme lateral transcondylar and transjugular approach (ELTCA) offers a very lateral view of the structures located at the lower clival area and craniovertebral junction. This lateral cranial base approach permits a controlled resection or reconstruction of the lesions in this area through direct view of the vertebral artery, lower cranial nerves, and the interface between the lesion and the brainstem. It is also possible to achieve an occiput-to-C1-3 fusion during the same operation, if necessary. Furthermore, because there is a well-vascularized muscle covering of this area, reconstruction of the operative field is perfect and infectious or vascular complications in the postoperative period oftenly can be managed with good results. Surgical anatomy of the occipital condyles (OC) is critical for ELTCA, and this study aims to study surgical anatomical and morphometric details of the relevant region.
Material and Methods

The surgical anatomy and morphometric analysis of this area was studied using eight adult human cadavers, embalmed with formalin, and seventy-six adult human dry skulls. All observations and measurements were recorded in a specially designed software. The landmarks were identified and the distances were measured using standard calipers in millimeters.

The bony landmarks and structures (Fig. 1) selected for the study included:
1. anterior end of the OC
2. posterior end of the OC
3. medial side of the OC
4. lateral side of the OC
5. basion
6. opisthion
7. hypoglossal canal
8. posterior condylar canal
9. inferior condylar canal

These bony landmarks and structures were easily identifiable in all specimens. The following measurements (Fig. 2), thought to be of help during ELTCA, were then taken on each specimen, and the necessary statistical analysis was worked out.
1. anterior-posterior diameter of the OC
2. width of the OC
3. distance between the basion and the opisthion
4. distance between the anterior ends of the OC
5. distance between the basion and the anterior end of the OC
6. distance between the posterior ends of the OC
7. distance between the opisthion and the posterior end of the OC
8. distance between the posterior end of the OC and hypoglossal canal
9. features of the posterior condylar canal
10. features of the inferior condylar canal
11. angle of the anteroposterior direction of the OC to the sagittal plan
12. angle between the OC (sagittal condylar angle)
13. angle of the mediolateral direction of the OC to the horizontal plan
14. frontal condylar angle (the angle between the joint surfaces of the OC to the horizontal plan)

Results and Observations

The data from the measurements of our material are given in Table 1.

Posterior condylar canal was identified in most of the cases on gross observations. Out of the material, 46 skull had posterior condylar canal bilaterally, and 22 unilaterally. Inferior condylar canal was present in about half of the cases, usually asymmetric in size.

Discussion

Surgical management of the lesions located at the ventrolateral lower clivus and ventral foramen magnum is a challenging neurosurgical technical problem that in the past has been associated with high mortality rates and incomplete removal. If the literature of the last two or three decades is considered with regard to the approach to this region, then reports on a bilateral or unilateral suboccipital approach with or without cervical laminectomy predominate, but the surgical results were disappointing for ventrally situated lesions. Owing to the disappointing results of surgery of ventrally located tumors in this area carried out via the suboccipital approach, the transoral approach recommended for extradural tumors by Mullan et al. has recently also been applied in occasional cases with intradural lesions. Heros described a very lateral suboccipital approach for

Table 1. Morphometric data from the measurements of the parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min-Max (mm²)</th>
<th>Average (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>right (12.1-31.2) left (16.0-31.9)</td>
<td>right (23.1) left (22.9)</td>
</tr>
<tr>
<td>2</td>
<td>right (8.5-14.2) left (8.0-14.5)</td>
<td>right (11.3) left (11.4)</td>
</tr>
<tr>
<td>3</td>
<td>27.8-43.2</td>
<td>36.6</td>
</tr>
<tr>
<td>4</td>
<td>15.1-31.4</td>
<td>22.8</td>
</tr>
<tr>
<td>5</td>
<td>right (7.2-21.2) left (6.9-19.3)</td>
<td>right (14.4) left (13.7)</td>
</tr>
<tr>
<td>6</td>
<td>24.6-39.8</td>
<td>30.2</td>
</tr>
<tr>
<td>7</td>
<td>right (19.0-33.2) left (20.1-32.3)</td>
<td>right (24.3) left (24.7)</td>
</tr>
<tr>
<td>8</td>
<td>right (9.8-19.3) left (10.1-20.5)</td>
<td>right (14.9) left (15.5)</td>
</tr>
<tr>
<td>9</td>
<td>right (21°-64°) left (23°-58°)</td>
<td>right (28.2°) left (29.7°)</td>
</tr>
<tr>
<td>10</td>
<td>47°-84°</td>
<td>57.8°</td>
</tr>
<tr>
<td>11</td>
<td>right (134°-157°) left (125°-158°)</td>
<td>right (148°) left (145°)</td>
</tr>
<tr>
<td>12</td>
<td>95°-132°</td>
<td>120°</td>
</tr>
</tbody>
</table>
vertebral and vertebrobasilar artery lesions. Seeger\textsuperscript{19} described the dorsolateral paracondylar approach with partial resection of the occipital condyle in an approach to the ventral surface of the brainstem. The approach, ELTCA was developed, with some modifications and improvements in technique, in the last decade, and accepted widely because of its excellent ventrolateral exposure of the region\textsuperscript{4,8,9,18,20–23}. The technical steps and details can be found in any of these mentioned papers, and it is beyond the scope of our paper.

The landmarks and distances used in this study were selected completely in order to improve the surgical orientation and to ease the surgical operation. Surgical anatomy of the occipital condyles and the region of the foramen magnum is critical for this approach, and should be known in detail. The OC form the articular surface for the atlas. The long axes of the OC converge in an anteromedial direction. The mean angle to the median sagittal plane is 35.5° in neonates and about 28° in adults\textsuperscript{12}. In our series we measured this angle as parameter 11, and we found that it was 28.2° (21°–64°) on the right side and 29.7° (23°–58°) on the left side. The angle formed by two OC is known as the “sagittal condylar angle”, and this angle (parameter 12) was found to be 57.8° on average (the range varied between 47°–84°) in our series. The coronal sections through the center of the occipital condyles and extension of the tangents of the joint surfaces forward yields the so-called “frontal condylar angle”. This angle was measured in the series as parameter 14, and found to be 120° on average (range 95°–132°). The angle of the mediolateral direction of the OC to the horizontal plan was 148° (134°–157°) on the right side and 145° (125°–158°) on the left. The width of the OC in the midline of the long axis (as parameter 2) was measured to be 11.3 (8.5–14.2) mm on the right side and 11.4 (8.0–14.5) mm on the left side. The length (anterior-posterior diameter) was found to be 23.1 (12.1–31.2) mm on the right side and 22.9 (16.0–31.9) mm on the left (parameter 1). The ratio between the length of the OC and its width was about 2 to 1. The observations demonstrated that the medial side of the condyle was at a lower level than the lateral side, and also the anterior-posterior length of the articular surface was greater on the medial side than on the lateral side. A variety of occipital condyle shapes have been described, including two semicircles type, oval type, rhombus type, bean-shaped, prismatic types, flattened types, convex types, flattened convex types, flat types, short and broad types, flat and long types, small and convex types.

The distance between the anterior ends of the occipital condyles (parameter 4) was measured 22.8 (15.1–31.4) mm. Parameter 5, the distance from the basion to the each anterior end of the OC, was found to be 14.4 (7.2–21.2) on the right side and 13.7 (6.9–19.3) mm on the left. This morphometric data are critical for the anterior cranial base approaches, which are usually limited laterally by hypoglossal canals.

The distance between the basion and the opisthion (parameter 3) was 36.6 mm on average, and the range varied between 27.8–43.2 mm. The tangential line to the posterior ends of the both occipital condyles crosses about the midline of the basion-opisthion line, and this line (parameter 6) was 30.2 (24.6–39.8) mm. The bone area between the opisthion and the posterior end of the OC forms a round margin, and in our material was measured to be 24.3 (19.0–33.2) mm on the right side and 24.7 (20.1–32.3) mm on the left (parameter 7). The relationship between the OC and the hypoglossal canal is important for not only the ELTCA but also the anterior cranial base approaches. In this sense, the distance between the posterior end of the OC and hypoglossal canal was measured and found to be 14.9 (9.8–19.3) mm on the right side and 15.5 (10.1–20.5) mm on the left (parameter 8).

Posterior and inferior condylar canals are among the largest emissary foramina in the human skull. The posterior condylar vein exits the skull through the posterior condylar canal, which is a communication between the jugular foramen and the condylar fossa, situated just posterior to the occipital condyles on either side of the foramen magnum. This canal permits for venous anastomosis between the jugular bulb and the suboccipital venous plexus. This canal was identified in most of the cases in our series, usually bilaterally. Inferior condylar canal was less constant, and usually asymmetric in size and location. These canals can be important in radiological assessment, and also surgically.

References

5) Canalis RF, Martin N, Black K, Ammirati M, Cheatham M, Bloch J and Becker DP. Lateral approach to tumors of the
craniovertebral junction. Laryngoscope 1993; **103**:343–349.


Explanation of Figures

Plate I

Fig. 1. The landmarks and structures selected in this study are shown in this figure.
Plate II

Fig. 2. The distances in this figure are measured to determine the three dimensional anatomy.