Quantitative analysis of the working area and angle of attack for the retrosigmoid, combined petrosal, and transcochlear approaches to the petroclival region

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Object. The authors quantitatively assessed the working areas and angles of attack associated with retrosigmoid (RS), combined petrosal (CP), and transcochlear (TC) craniotomies.

Methods. Four silicone-injected cadaveric heads were bilaterally dissected using three approaches progressing from the least to the most extensive. Working areas were determined using the Optotrak 3020 system on the upper and middle thirds of the petroclivus and brainstem. Angles of attack were studied using the Elekta SurgiScope at the Dorello canal and the origin of the anterior inferior cerebellar artery (AICA).

The TC approach provided significantly greater (p < 0.001) working areas at the petroclivus (755.6 ± 130.1 mm²) and brainstem (399.3 ± 68.2 mm²) than the CP (354.1 ± 60.3 and 289.7 ± 69.9 mm²) and RS approaches (292.4 ± 59.9, 177.2 ± 54.2 mm², respectively). The brainstem working area associated with the CP approach was significantly larger (p < 0.001) than that associated with the RS route. There was no difference in the petroclival working area comparing the CP and RS approaches (p = 0.149). The horizontal and vertical angles of attack achieved using the TC approach were wider than those of the CP and RS at the Dorello canal and the origin of the AICA (p < 0.001).

Conclusions. The CP approach offers a more extensive working area than the RS for lesions involving the anterolateral surface of the brainstem, but not for petroclival lesions. The TC approach provides the widest corridor, improving the working area and angle of attack to both areas, but hearing must be sacrificed and the facial nerve is at risk.

KEY WORDS • petroclival region • petrosal approach • quantitative anatomical study • retrosigmoid approach • transcochlear approach

Before the advent of microsurgery, lesions in the petroclival region were considered formidable, untreatable, or both. Mortality rates associated with the resection of such lesions, especially meningiomas, were greater than 50%. After the 1970s refinements in neurosurgical instruments, improvements in neuroanesthesia with neuromonitoring, developments in neuroradiology, and the advent of skull base surgery as a discipline allowed lesions to be resected with acceptable morbidity and mortality rates.1,2,4,7,8,10,12–14,16–18

In the 1980s various approaches were popularized for the treatment of lesions involving the skull base.2,3,10,14,17 The most popular was a group of transtentorial petrosal approaches and their variations. These approaches provided considerable exposure of the petroclival area through extensive temporal bone drilling. The additional bone removed, however, increased approach-related risks, including cerebrospinal fluid fistulae and injury to cranial nerves, arteries, veins, and venous sinuses.2,4,7,8,10,13,14,17 Choosing an appropriate skull base approach that provides adequate exposure while avoiding unnecessary exposure that can entail significant concomitant risks can be key to successful resections and outcomes. The selection of an approach to the petroclival region usually depends on a surgeon’s experience and subspecialty. Currently, few quantitative data have been published to support the choice of an approach in terms of comparative anatomical exposure or angles of attack.6,11,19

To gain insight into the benefits of skull base approaches in the petroclival region, we quantitatively assessed exposures related to the extended removal of temporal bone. We evaluated and compared the three most common approaches: the conventional RS, CP (that is, the anterior petrosal approach and retrolabyrinthine presigmoid transtentorial approach), and TC approach. The parameters calculated for each surgical avenue included the working area, defined as the exposed area on the brainstem and petroclival region, and the angles of attack to predefined anatomical sites.

Abbreviations used in this paper: AICA = anterior inferior cerebellar artery; CP = combined petrosal; IAC = internal acoustic canal; RS = retrosigmoid; TC = transcochlear.
Materials and Methods

Four cadaveric heads with colored silicone-injected arterial and venous systems and no known brain pathological entity were used to obtain bilateral measurements, yielding eight data sets. The three approaches were performed progressing from least to most extensive dissection. The first-stage dissection consisted of the RS approach: the second stage, the CP approach; and the third stage, the TC approach. These approaches have been previously described in detail, and are reviewed here only briefly.

Retrosigmoid Approach

The cadaveric specimens were placed in a 90° lateral position with rigid fixation. The standard suboccipital RS incision was followed by a craniotomy to expose the sigmoid sinus laterally, the transverse sinus superiorly, the lateral two thirds of the cerebellar hemisphere medially, and the rim of the foramen magnum inferiorly. The mastoid bone was drilled to partially unreof the sigmoid sinus. The dura mater was opened to form a triangular flap base on the sigmoid sinus. Two more radial incisions starting from the apex of the triangle were cut to expose the craniotomy site completely.

Combined Petrosal Approach

To perform the CP technique, we combined an anterior (Kawase) and a posterior transpetrosal retrolabyrinthine approach. The dura mater of the posterior fossa was tightly closed after performing the measurements for RS approach, and the craniotomy bone flap was firmly reattached.

The same head position as that in the RS approach was maintained. A temporal craniotomy was performed followed by a standard retrolabyrinthine mastoidectomy. First, the semicircular canal and vertical portion of the facial nerves were skeletonized. After bone was removed from the middle and posterior fossae, the dura of the middle fossa was retracted and elevated—posteriorly to anteriorly. Particular care was exerted to avoid damaging the lesser and greater petrosal nerves. The middle meningeal artery was divided at the foramen spinosum to improve mobilization of the subtemporal dura. The dura properia over the maxillary and mandibular nerves and the glossopharyngeal nerve exiting the brainstem was the upper variable landmark; B, the nasociliary nerve on the brainstem was the upper constant landmark; C, the maximal medial exposure of the uppermost brainstem was similarly mapped by assigning the following points in the trapezium: A, the apparent origin of the trigeminal nerve on the brainstem was the upper constant landmark; B, the glossopharyngeal nerve exiting the brainstem, the lower constant landmark; C, the maximal medial exposure of the uppermost brainstem at the level of the petrous ridge, the upper constant; and D, the maximal medial exposure of the lowest point on the brainstem, the lower variable (Fig. 2). The constant landmarks were marked for repeated use in assessments for the subsequent approaches.

The Optotrak 3020 system (Northern Digital, Waterloo, ON, Canada) with a six-marker digitizing probe was used to determine the constant and variable landmarks. The heads were immobilized in a rigid headholder clamped to an operating table, with the cameras positioned 1.5 m away. With the aid of an operating microscope, the researcher positioned the tip of the digitizing probe at each landmark while keeping the probe in view of the cameras. An assistant triggered data capture when the probe was positioned properly. Cartesian coordinates (x, y, and z) of the probe tip relative to the laboratory were recorded in millimeters.

Although almost planar, the four landmarks studied do not form a true trapezium. In the plane of interest, if the corners of an approximate trapezium are named in clockwise order (ABCD), one approximation of the surface area is the sum of the areas formed by the triangle ABC and ACD. A second approximation of the same area is the sum of the areas formed by triangles ABD and BDC. The mean of these values was used to represent the area of the trapezium. Areas of triangles were calculated as one half the magnitude of the vector cross product (for example, area of ABC = 1/2|AB × AC|).

Determining the Angle of Attack.

The angle of attack was determined using a robotic surgical microscope (SurgiscopE; Elekta Instruments, Inc., Atlanta, GA) moving in a spherical mode. The head was placed in rigid fixation so that the longitudinal axis of the clivus was parallel to one plane, and the midsagittal plane of the orbit was used to determine the vector of movement. The Dorello canal and the origin of the AICA were defined as the target points for assessment on the clival and brainstem sides. The target was identified and brought into focus by the laser beams from the microscope at a focal length of 300 mm. Keyhole-point fixation movement of the microscope enabled us to determine angles (Fig. 3). After this protocol was completed, the horizontal and vertical angles of attack at two target points in each of the three approaches were obtained.

Statistical Analysis

The working area and the angle of attack obtained from each approach were compared using one-way repeated-measures analyses of variance followed by the Holm–Sidak method of pairwise comparisons. When data failed a test of normal distribution, the Friedman repeated-measures analysis on ranks was used followed by the Dunn method. In all comparisons, a probability value of less than 0.05 was considered significant.

Results

The TC approach provided the greatest working area at both the petroclival region and brainstem (Table 1 and Fig. 4), followed by the CP approach and the RS approach. The
Quantitative analysis of three lateral skull base approaches

TC approach significantly increased (p < 0.001) the working area to the petroclival surface and brainstem, and the total working area compared with the CP and RS approaches. The brainstem working area and total working area afforded by the CP approach was significantly larger than that of the RS approach. There was no significant difference in the petroclival working area between the CP and RS approaches (p = 0.149).

The vertical and horizontal angles of attack to the Dorello canal achieved with the TC approach were significantly wider (p < 0.001) than those obtained with the CP and RS approaches (Table 2). In terms of the CP and RS approaches, there was no significant difference in the angle of attack to the Dorello canal in either the vertical (p = 0.811) or horizontal axis (p = 0.181).

Comparing the vertical and horizontal angles of attack to the origin of AICA, the TC approach allowed the maximal degree of movement (Table 2) significantly more than the CP or RS approaches (p < 0.05). Note, however, that there was no significant difference between the CP and RS approaches in the vertical and horizontal angles of attack.

**Discussion**

Horgan and coworkers\textsuperscript{11} first reported the quantitative assessment of surgical approaches to the upper and middle petroclival areas. They used a frameless stereotactic navigation system and applied the concept of a virtual cone and surgical freedom as described by Spektor, et al.\textsuperscript{19} Horgan and colleagues\textsuperscript{11} demonstrated the difference in the area of exposure (working area as defined by Gonzalez, et al.,\textsuperscript{9} and by us in the present study) of the clivus and the surgical freedom of the retrolabyrinthine, transcuscal, transotic, and TC avenues. They did not study the working area in the brainstem.

Chanda and Nanda\textsuperscript{6} published the angle of exposure and area of exposure associated with a partial labyrinthectomy petrous apicectomy and with the retrolabyrinthine and translabyrinthine approaches. The clival pit was used as the landmark for the angle of exposure, and only the horizontal angle was studied. The area of exposure proposed by Chanda and Nanda was the area of the surgical corridor and not the area at the target site associated with the surgical ap-
proaches. No anatomical study has been focused on the working area in both the brainstem and petroclival regions.

Surgical treatment for petroclival lesions requires consideration of their location on the petroclival surface as well as brainstem involvement. The latter may be different and independent. As data in our study show, the total working area and the brainstem working area were significantly different among the approaches. Nevertheless, the CP and RS approaches provided no difference in petroclival working areas.

This paradox is explained by the fact that the axis of approach via the RS approach is from a dorsal aspect and along the plane of the petrous bone. Conversely, although more bone was removed, the CP approach from the anterolateral aspect of the petrous bone and the bone drilling were not extensive enough to gain significantly more working area than that afforded by the RS approach. Note, however, that the anterolateral approach provided a greater anterolateral view and thus more working area to the brainstem.

Wider angles are important because they improve the surgical manipulation of working areas, ensuring a safer dissection and transforming the surgical corridor into a straighter and shallower avenue. Typically, maneuvers that augment angles are those that broaden the superficial area of surgical exposure, particularly bone removal. The angle of attack used in this study did not replicate the stepwise increment of bone removal in the same corridor as that used by Gonzalez, et al. We thought that by using the same target points we could compare the different windows of exposure. For all parameters, the angle of attack was widened significantly by using the TC approach rather than the CP or RS approach. For neither target was the angle of attack of the CP approach superior to that of the RS approach. The angle of attack to the Dorello canal and the origin of the AICA were limited not only by the widening of the osseous corridor but also by the brainstem, cerebellum, temporal lobe, and configuration of the petroclival bone, specifically, by the jugular tubercle and clival depression. During the TC approach, the extensive bone removal near the Dorello canal and the origin of the AICA overcomes obstruction from the structures above, which is not possible with the CP approach.

**Surgical Considerations**

The concept of approaching the upper and middle thirds of the petroclival region via the transpetrosal route to unlock
Quantitative analysis of three lateral skull base approaches

TABLE 2

Angles of attack afforded by three surgical approaches

<table>
<thead>
<tr>
<th>Surgical Approach</th>
<th>Dorello Canal</th>
<th>AICA Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vertical</td>
<td>Horizontal</td>
</tr>
<tr>
<td>RS</td>
<td>19 ± 5.5</td>
<td>10.2 ± 1.6</td>
</tr>
<tr>
<td>CP</td>
<td>18.2 ± 10.5</td>
<td>12.6 ± 4.7</td>
</tr>
<tr>
<td>TC</td>
<td>43.5 ± 4.9†</td>
<td>43.4 ± 6.4†</td>
</tr>
</tbody>
</table>

* Values are expressed in degrees.
† p < 0.001.

Study Limitations

Given that preserved cadaveric specimens without pathological entities were used in this study, the conditions of a living brain were not simulated. Furthermore, the effects of draining cerebrospinal fluid, brain swelling, and mass lesions, which are major considerations in the clinical setting, were not addressed in the study. The working area and angle of attack associated with the three approaches are not obtained by a single retraction of the brain but by different routes and approaches.

Conclusions

The RS approach can provide a working area and angles of attack for the petroclival surface similar to those offered by the CP approach. In considering the duration of surgery and approach-related risks, however, the RS approach should be the first choice. For lesions that dominate or invaginate the anterolateral surface of the brainstem, the CP approach should be considered. The TC approach allows maximal space to maneuver during surgery involving the petroclival region, but requires sacrifice of hearing and risks damage to the facial nerve; hence, this approach should be reserved for patients who are already without functional hearing.

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References


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