Morphologic and Radiologic Anatomy of the Occipital Bone

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Summary: Several diseases may cause craniovertebral instability warranting occiput–cervical fusion. As occipital screw and rod constructs are becoming more popular, requiring that screws be placed either medially or laterally in the occipital bone, the need for clearer anatomical and computed tomography (CT)-confirmed data regarding the relative thickness of the occiput in its various localities has become more critical. In 18 cadaveric specimens, the occipital bone was divided into 35 measurable segments. Transversely, the occipital bone was divided into five lines starting at the level of the inion; horizontal lines then proceeded inferiorly in 1-cm segments, 1, 2, 3, and 4 cm below the level of inion. In a comparable fashion, the occipital bone was divided vertically, starting at the midline, and proceeding laterally also in 1-, 2-, and 3-cm segments. Anatomical measurements of thickness were directly performed using a Vernier caliper. Results were directly correlated with axial CT measurements of bony thickness. Anatomical and CT measurements closely correlated within the same specimen, but there was significant interspecimen variability. The marked differences in the occipital bone anatomy noted between specimens indicates that patients undergoing occipital screw placement for cranial–cervical instability would benefit from preoperative occipital CT evaluations. Key Words: Morphometry—Occipital bone—Occipitocervical fixation.

INTRODUCTION

A variety of craniocervical disorders warrant occipital cervical fixation using medial or lateral occipital screw placement along with rod or plate placement (1–6). This study, correlating both direct anatomical with CT measurements of occipital bone thickness, was undertaken to determine the thickness of the occipital bone where many of these screws would be placed to avoid inadvertent intradural penetration during surgery. Although a close correlation between anatomical and CT measurements within specimens was assumed to be present, a significant amount of interspecimen variability was also anticipated.

MATERIAL AND METHODS

The occipital bones from 18 cadavers were used in this study. The occiput was divided by a grid into five trans-
verse lines beginning at the inion and extending by 1 cm increments to 4 cm inferiorly, and by horizontal lines beginning at the midline and extending 3 cm laterally. The grid yielded 35 separate measurements (Fig. 1). The occipital bone was measured manually by a Vernier caliper accurate to 0.1 mm, and radiologically by computed tomography. Anatomical measurements of the occipital bone were taken by an anatomist and a neurosurgeon, and spiral CT data were defined by a radiologist. Both measurements were performed in a blind fashion. Besides the bone thickness measurement, the distance between the inion and the rim of the foramen magnum, as well as the location of the inferior nuchal line, were also measured.

### Anatomical Definitions

The inion was defined as the prominence located an average of 1 cm below the apex of the internal occipital.
protuberance. The superior nuchal line radiates laterally from the protuberance. The inferior nuchal line runs laterally from the midpoint of occipital crest, extending from external occipital protuberance to the posterior margin of the foramen magnum.

**Data Analysis**

The results were analyzed using the Wilcoxon matched-pairs signed-ranks test. A p value of less than 0.05 was accepted as significant. The results of anatomical and radiologic measurements were correlated. An $r$ value of 0.5–1.0 was evaluated as a good correlation, whereas an $r$ value of 0.0–0.49 was evaluated as a poor correlation.

**RESULTS**

The results of both measurements are listed in Table 1. The distance between the inion and rim of foramen magnum was found to be 46 mm (range: 39–55 mm). The inferior nuchal line was found to be on line 3 (i.e., 2 cm below to inion) in 8 specimens (44%), and between lines 3 and 4 in 10 specimens (56%).

Tables 2 and 3 combine the thickness of the 35 points of the occipital bone and the position of these points in the measurement. The comparison of anatomical and radiologic measurements revealed significant differences in 8 points (22.8%). Anatomical and radiologic analyses demonstrated poor correlations in the 8 points, and good correlations between the 27 points, respectively.

The thickest point of the occipital bone was found to be in the midline—level 1 (inion).

The inion, measured anatomically and on CT, was 14.22 ± 4.02 mm, and 12.69 ± 4.10 mm, respectively. The thickest vertical points were on the midline, and the thickest transverse points were on line 1. The second thickest points were in the first paramedian vertical lines. The occipital bone thickness decreased rapidly below the inferior nuchal line and 2 cm lateral to the midline (Tables 2 and 3).

**DISCUSSION**

Anatomical and CT data from this and other studies document the thickness of the occipital bone and the optimal placement of screws for occipital–cervical fusion. The thickness of the occipital bone confirmed anatomically by Oliver et al., and Ebraheim et al., and CT by Grob (3,7,8). In this study, the thickness of the same target points were measured both anatomically and by CT.

Based on these data, there are five “safe” and five “moderately safe” locations for screw placement when performing occipital–cervical fixation. The five “safest points” include: L1–L1 (level, 1 cm left to the midline), L1 ML (midline), L1 +1 (level 1, 1 cm right to the midline), L2 ML, and L3 ML. There are five additional points where placement of 8 mm screws may be considered “moderately safe”: L1 −2, L1 +2, L2 −1, L2 +1, and L4 ML. Other points were considered inappropriate for screw placement (Fig. 2).

**TABLE 3. Thickness of the different points of the occipital bone measured on computed tomography scan**

<table>
<thead>
<tr>
<th></th>
<th>−3</th>
<th>−2</th>
<th>−1</th>
<th>ML</th>
<th>+1</th>
<th>+2</th>
<th>+3</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>6.78 ± 2.39</td>
<td>7.19 ± 2.49</td>
<td>8.72 ± 3.30</td>
<td>12.69 ± 4.10</td>
<td>8.86 ± 2.04</td>
<td>7.71 ± 2.18</td>
<td>6.53 ± 1.67</td>
</tr>
<tr>
<td>L2</td>
<td>5.39 ± 1.63</td>
<td>5.00 ± 1.64</td>
<td>5.81 ± 2.31</td>
<td>8.07 ± 3.01</td>
<td>5.06 ± 1.67</td>
<td>4.19 ± 1.20</td>
<td>4.50 ± 1.50</td>
</tr>
<tr>
<td>L3</td>
<td>3.75 ± 1.41</td>
<td>3.50 ± 1.26</td>
<td>3.86 ± 1.19</td>
<td>7.81 ± 1.82</td>
<td>4.03 ± 1.41</td>
<td>3.19 ± 1.15</td>
<td>3.72 ± 1.34</td>
</tr>
<tr>
<td>L4</td>
<td>2.42 ± 0.84</td>
<td>2.62 ± 0.79</td>
<td>3.64 ± 1.08</td>
<td>6.19 ± 1.88</td>
<td>3.83 ± 1.20</td>
<td>2.58 ± 0.75</td>
<td>2.81 ± 1.10</td>
</tr>
<tr>
<td>L5</td>
<td>2.06 ± 0.95</td>
<td>2.69 ± 0.75</td>
<td>4.72 ± 1.43</td>
<td>5.06 ± 2.19</td>
<td>4.50 ± 1.25</td>
<td>3.15 ± 1.73</td>
<td>2.81 ± 1.66</td>
</tr>
</tbody>
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L, level; −, left side; +, right side; ML, midline.

FIG. 2. The map of safe zones for placement of 8 mm screw. The black squares represent the safest areas for monocortical 8 mm screw placement. The white squares represent the moderately safe areas that may be risky for 8 mm screw placement. The other unmarked areas are not proper for 8 mm screw placement.
CONCLUSIONS

Because there is great variability between individuals in occipital bone thickness, preoperative CT examinations are warranted to determine optimal screw placement before performing occipital–cervical fusions. In general, the safest points for screw insertion are in the midline and first paramedian regions above the inferior nuchal line.

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REFERENCES