Morphometric analysis of the uncinate processes of the cervical vertebrae

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Background: Uncinate processes (UPs) are distinct features unique to cervical vertebrae. They are consistently found on posterolateral aspect of the superior end plate of 3rd to 7th cervical vertebrae. In this study, we investigated the morphology of the UPs with a particular emphasis on the regional anatomy and clinical significance.

Materials and methods: The study included 63 vertebrae. The width, height and length of UPs were measured with a digital calliper. We also assessed inclination angle of UP relative to sagittal plane, angle between medial surface of UP and superior surface of vertebra, angle between long axis of the UP and frontal plane, angle between long axis of UP and sagittal plane.

Results: Average width of the UPs ranged from 4.25 mm at C3 to 6.33 mm at T1; average height ranged from 4.88 mm at T1 to 7.54 mm at C4; and average length ranged from 6.88 mm at T1 to 11.46 mm at C4. We measured the inclination angle of UP relative to sagittal plane, and found it to be relatively constant with T1 having the largest value. The average angle was 41.39°, and the range was 17° to 85°. The angle between the long axis of the UP and the sagittal plane was increasing significantly from C5 to T1. The average angle was 20.74° and the range was 6° to 65°.

Conclusions: Anatomy of UPs is significant for surgeon who operates on the cervical spine. Hopefully, the information presented herein would decrease complications during surgical approaches to the cervical spine. (Folia Morphol 2017; 76, 3: 440–445)

Key words: uncinate process, uncovertebral joint, Luschka joint, cervical spine

INTRODUCTION

In 1834, Rathke [see 3] has defined the uncinate process (UP) as a bony protuberance that extends from posterior margin of vertebral body. In 1858, Von Luschka [see 25] introduced the description of uncovertebral joint between the UP and vertebra.

The localisation of UP on vertebral column anteriorly extends up to the third cervical vertebra, and posteriorly down to the second thoracic vertebra [30]. They are mostly found between segments C3 to C7 [1, 4, 29]. UPs are further defined as bony protuberances, protuberentia, prominentia, bridges or lips extending from lateral or posterolateral segments of cervical vertebral bodies [1, 4, 7, 8, 11, 12, 14, 18, 31, 32]. They have an anterior slope, an apex and a posterior slope besides a medial articular surface [4]. In addition, UPs deliver a concave appearance to the upper tips of vertebral bodies on the coronal plane [14, 28]. They have a more posterior location on lower vertebral segments [30].

The purpose of this study was to define the morphology of UPs in Turkish population with an...
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C5) were excluded due to destruction probably due to osteoporosis or bony degeneration. Hence, 63 vertebrae with intact UPs were involved in measurements. The width, height and length of UPs were measured (Fig. 1).

Furthermore, the distance of the apex of the UP to intervertebral foramen (IVF) and foramen transversarium (FT) was studied (Fig. 2). We also assessed inclination angle of UP relative to sagittal plane (B), angle between medial surface of UP and superior surface of vertebra (A+B), angle between long axis of UP and sagittal plane (C), angle between long axis of the UP and frontal plane (C+D) (Fig. 3). All measurements were made using an electronic digital calliper accurate to 0.1 mm. Angles were measured with a goniometer.

Statistical analysis

Statistical analysis was done with SPSS (Chi., IL, USA) software. Descriptive statistics were presented as mean ± standard deviation. Pearson correlation analysis was performed to determine the linear association between morphometric parameters in C3–T1 vertebrae; p < 0.05 was accepted as statistically significant.

RESULTS

Foramina transversaria of vertebrae C3, C4, C5 and C6 had bifid spinous process while FT of vertebra C7 had smaller, non-bifid and obvious spinous processes. Vertebra T1 had no FT, and joint surfaces for ribs on their bodies were notable. The width, height and length of UPs on vertebrae C3–T1, as well as the distances of their apex to the IVF and the FT are presented in Table 1.

emphasis on their relevance to the regional anatomy, and their clinical significance.

MATERIALS AND METHODS

A total of 75 vertebrae were used in this study. Of them, 20 were C3 vertebrae, 20 were C4, 9 were C5, 6 were C6, 8 were C7, and 12 were T1. Adult vertebrae present in the anatomy laboratory, of ages between 65 and 75 years were used. No gender classification was made. Twelve vertebrae (4 from C3, 7 from C4 and 1 from C5) were excluded due to destruction probably due to osteoporosis or bony degeneration. Hence, 63 vertebrae with intact UPs were involved in measurements. The width, height and length of UPs were measured (Fig. 1).

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In our cases, highest length was found in UPs of vertebrae C4–C6. In addition, height of UPs was reported in 10 studies, indicating an increasing pattern from C3 to lower cervicals. This pattern was not observed in the studies of Civelek et al. [6] and Pait et al. [18], and UPs of C5 were found to be shorter compared to those of the adjacent vertebra C4 and C6. Moreover, 4 of 10 studies revealed shorter UPs of C7 compared to those of the adjacent C6 [6, 13, 15, 23]. The length of UPs revealed a range of minimum 2 mm at C7 to maximum 10.5 mm at C6 [22, 29]. In our cases, highest UP was observed at vertebra C4 (7.54 ± 1.39 mm on the right side and 7.35 ± 1.17 mm on the left side) followed by the vertebra C6 (7.42 ± 1.34 mm on the right side and 7.04 ± 1.25 mm on the left side). Indeed, a declining pattern of height after the vertebra C6 is not surprising, because no UP is observed after vertebra C7 and T1. In vertebra T1, UPs height was found to be the shortest compared to all cervical vertebra (5.53 ± 0.85 mm on the right side and 4.88 ± 0.79 mm on the left side). Lower values at T1 confirm our hypothesis above. It should further be added that, such a variation in the height is probably due to different types of samples ranging from fresh cadavers to dry vertebrae underlying the morphometric data reported in this study.

Kotani et al. [11] and Snyder et al. [26] showed that the posterior segment of UPs provide more stability, compared to the anterior segment. Authors believed this finding was due to the wider and longer morphology of the posterior segment of UP compared to its anterior segment. The uncovertebral articulation was found to contribute in excess of 60% of the stability of the spinal motion segment in extension at C3–C4 [11].

Morphometric measurements of vertebrae C3–T1 reveal an average ($r = 0.536$) positive correlation in the width of UPs; however, a negative correlation in height ($r = -244$) and length ($r = -432$). While an increasing pattern is observed from C3 to T1, this is exactly opposite in height and length except for a few exceptions. An assessment of the height and length trend reveals that such pattern is reversed particularly in vertebra C4 and C5, and occasionally in vertebra C6.

The inclination angle of UP relative to sagittal plane (B) was relatively constant, with T1 having the largest value. The average angle B was 41.39°, and the range was 17° to 85°. The angle between the long axis of the UP and the sagittal plane (C) was increasing significantly from C5 to T1. The average angle C was 20.74°, and the range was 6° to 65°. An overall evaluation of these angular measurements reveals that angle C has the highest correlation within the range of vertebrae from C3 to T1 (10.00 ± 1.79°; $r = 0.794$, $p < 0.001$, on the right, and 9.56 ± 1.52°; $r = 0.750$, $p < 0.001$, on the left). Similarly, the angle C+D displayed a high correlation within the same range at an angle of 100.00 ± 1.79° ($r = 0.795$, $p < 0.001$) on the right side, and 99.56 ± 1.55° ($r = 0.759$, $p < 0.001$) on the left side.

**DISCUSSION**

The UP is a phylogenetic residue of the costovertebral joint in reptiles and birds [1]. Tubbs et al. [29] found that the height of the UP was 5–6 mm at the C4–6 levels, making the anterolateral window for decompression of the neural foramen determinable by the height and width of the UP, and this is comparable to the findings of Lu et al. [13]. These authors also found that the UPs were significantly taller at C4–C6 levels [13, 29]. In our cases, highest length was found in UPs of vertebrae C4–C6.

In addition, height of UPs was reported in 10 studies, indicating an increasing pattern from C3 to lower cervicals. This pattern was not observed in the studies of Civelek et al. [6] and Pait et al. [18], and UPs of C5 were found to be shorter compared to those of the adjacent vertebra C4 and C6. Moreover, 4 of 10 studies revealed shorter UPs of C7 compared to those of the adjacent C6 [6, 13, 15, 23]. The length of UPs revealed a range of minimum 2 mm at C7 to maximum 10.5 mm at C6 [22, 29]. In our cases, highest UP was observed at vertebra C4 (7.54 ± 1.39 mm on the right side and 7.35 ± 1.17 mm on the left side) followed by the vertebra C6 (7.42 ± 1.34 mm on the right side and 7.04 ± 1.25 mm on the left side). Indeed, a declining pattern of height after the vertebra C6 is not surprising, because no UP is observed after vertebra C7 and T1. In vertebra T1, UPs height was found to be the shortest compared to all cervical vertebra (5.53 ± 0.85 mm on the right side and 4.88 ± 0.79 mm on the left side). Lower values at T1 confirm our hypothesis above. It should further be added that, such a variation in the height is probably due to different types of samples ranging from fresh cadavers to dry vertebrae underlying the morphometric data reported in this study.

Kotani et al. [11] and Snyder et al. [26] showed that the posterior segment of UPs provide more stability, compared to the anterior segment. Authors believed this finding was due to the wider and longer morphology of the posterior segment of UP compared to its anterior segment. The uncovertebral articulation was found to contribute in excess of 60% of the stability of the spinal motion segment in extension at C3–C4 [11].
In the literature, it is reported that the width of UPS shows an increasing pattern from C3 to C7, similar to the height trend. Average widths are reported to be in the range of 4.6 mm at C3 to 7.4 mm at C7 [6, 13]. Next, two of six studies report a lower average width of UPS at C5 compared to C4, and one study reports a wider UPS at C5 compared to C6 [6, 13, 18]. Yilmazlar et al. [32] attributed the increased width of the UPS at C5 to spondylosis secondary to the increased cervical segmental motion at this level. In our cases, widest UPSs were found at vertebrae C7 (5.38 ± 0.82 mm on the right side and 5.38 ± 0.54 mm on the left side) and at vertebrae T1 (6.33 ± 1.32 mm on the right side and 6.23 ± 0.92 mm on the left side). In our study, average width of UPSs at vertebrae C4 (4.92 ± 1.26 mm on the right side, and 4.96 ± 1.27 mm on the left side) was found to be exceeding that of the adjacent vertebrae C3 and C5.

In the literature, also the anterior-posterior lengths of UPSs are assessed, revealing an overall pattern of increase towards C7 from C3. Average lengths are reported to be in the range of 6.0 mm at C3 to 13.0 mm at C7 [4]. However, 2 of 5 studies report longer UPSs of C7 compared to those of C6 [4, 19]. In our cases, measured lengths of UPSs were lower compared to that of vertebra C6. Indeed, length and height of UPSs display a gradually decreasing pattern towards lower cervicals, namely after C6. This is quite expectable, as these protuberances are not observed after T1. Therefore, they are very obvious throughout the C3–C6 range. After C6, we see a decline in the morphometric values of UPSs due to relative downsizing.

Table 1. Morphometric measurements of uncinate processes (n = 63)

<table>
<thead>
<tr>
<th>n</th>
<th>Vertebra</th>
<th>Width [mm]</th>
<th>Height [mm]</th>
<th>Length [mm]</th>
<th>IVF [mm]</th>
<th>FT [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
<td>Left</td>
<td>Right</td>
</tr>
<tr>
<td>16</td>
<td>C3</td>
<td>4.25 ± 1.10</td>
<td>4.28 ± 1.08</td>
<td>6.50 ± 2.16</td>
<td>6.11 ± 1.85</td>
<td>9.00 ± 1.33</td>
</tr>
<tr>
<td>13</td>
<td>C4</td>
<td>4.92 ± 1.26</td>
<td>4.96 ± 1.27</td>
<td>7.54 ± 1.45</td>
<td>7.35 ± 1.21</td>
<td>11.46 ± 1.56</td>
</tr>
<tr>
<td>8</td>
<td>C5</td>
<td>4.63 ± 0.52</td>
<td>4.75 ± 0.38</td>
<td>6.56 ± 1.18</td>
<td>6.44 ± 1.18</td>
<td>9.00 ± 1.51</td>
</tr>
<tr>
<td>6</td>
<td>C6</td>
<td>4.92 ± 0.20</td>
<td>5.50 ± 0.89</td>
<td>7.42 ± 1.46</td>
<td>7.04 ± 1.36</td>
<td>10.00 ± 1.26</td>
</tr>
<tr>
<td>8</td>
<td>C7</td>
<td>5.38 ± 0.88</td>
<td>5.38 ± 0.58</td>
<td>6.38 ± 1.09</td>
<td>6.13 ± 1.53</td>
<td>8.88 ± 2.63</td>
</tr>
<tr>
<td>12</td>
<td>T1</td>
<td>6.33 ± 1.32</td>
<td>6.23 ± 0.92</td>
<td>5.53 ± 0.89</td>
<td>4.88 ± 0.82</td>
<td>6.88 ± 1.09</td>
</tr>
</tbody>
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IVF — intervertebral foramen; FT — foramen transversarium

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the uncovertebral joint has its lateral surface being in proximity to the vertebral artery and its accompanying venous plexus [33]. The distance between the medial margin of the FT — in which the vertebral artery and veins travel — and the UP increases from C3 to C7 [9, 10, 17, 31]. The segment of the vertebral artery that is related to the UP is the portion located between the transverse processes of adjacent vertebrae. Nourbakhsh et al. [16] demonstrated that these segments demonstrate tortuosity in 13.4% of all intertransverse segments. Tortuosity was greatest at the third to fifth intertransverse spaces and was more likely to be present in segments demonstrating degeneration.

Panjabi et al. [19] measured the slope angle of UPs with the sagittal plane and found a relatively fixed angle peaking at C7. Average angle found was 40.3° [19]. In our study, this angle was found to be highest between cervical vertebrae, with 46.13 ± 15.6° on the right side and 47.25 ± 15.64° on the left side. However, an increase is noteworthy at C4 on the right side (48.08 ± 11.69°). Among all vertebrae with UP, maximum angle was 52.17 ± 8.02° on the right side and 47.67 ± 5.44° on the left side. Also in the literature, the angle between the long axis of UPs and the frontal plane was analysed, revealing a significant increase from C5 to C7, averaging 91.02°. In our study, such angle measured was highest between cervical vertebrae, with 114.63 ± 5.45° on the right side and 111.00 ± 3.81° on the left side in average. Again in our study, highest value was found in T1 as 138.75 ± 7.84° on the right side and 135.33 ± 10.53° on the left side. Saringer et al. [23] measured the angle between the long axis of UPs and the sagittal plane, and similarly reported an increasing pattern towards lower cervicals. Average angle measured was reported as 5.06°. And also in our study, there is an increase from C3 to T1.

Uğur et al. [31] and Bozbuga et al. [2] measured the angle between the medial surface of UPs and the upper surface of vertebrae, and reported a greatly varying value in the 90–162° range. In our study, this angle was calculated as 123.66 ± 8.11° on the right side and 123.38 ± 7.30° on the left side in C3, and 135.5 ± 14.05° on the right side and 137.25 ± 15.64° in the left side in C7. A positive, statistically significant correlation was found between the vertebra sequence (from C3 to T1) and angle C (the angle between long axis of UP and sagittal plane) ($r = 0.794, p < 0.001$).

**CONCLUSIONS**

As a conclusion; UPs are defined as critical structures in head and neck movements. Their interaction with the inferior side of vertebrae makes up the uncovertebral joints. These uncovertebral joints are in a lifetime development from a rudimentary joint up to a mature joint, and eventually degenerate. In some cases, these degraded joints become clinically visible due to the compressive effect of uncinate osteophytes. These compressive effects culminate in nerve root compression in IVF besides vertebral artery compression as osteophytes hand down onto the lateral. Due to this condition, pain, paraesthesia, reflex decay, muscle weakness and even symptomatic vertebrobasilar failures may occur. Besides being an injury site in patients with severe head and neck trauma, UPs and uncovertebral joints were mistaken for torticollis in acute cases in young people. Despite being often neglected due to their relatively small size; uncovertebral joints have major contributions to the stability of the cervical spine. In our study, also the UP of vertebra T1 was studied in addition to the literature.

While a positive correlation was observed in the width of these protuberances downwardly towards lower cervicals, a declining pattern, as suggested by some authors, was found in height and length after C6. We hope that, supporting morphometric studies with radiologic efforts to exhaustively study UPs in a wider sample population would serve as a guide for neurosurgeons conducting uncinecotomy and uncoforaminotomy.

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