Analysis of the uncinate processes of the cervical spine: an anatomical study

Laboratory investigation

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Object. Although the uncovertebral region is neurosurgically relevant, relatively little is reported in the literature, specifically the neurosurgical literature, regarding its anatomy. Therefore, the present study aimed at further elucidation of this region’s morphological features.

Methods. Morphometry was performed on the uncinate processes of 40 adult human skeletons. Additionally, range of motion testing was performed, with special attention given to the uncinate processes. Finally, these excrescences were classified based on their encroachment on the adjacent intervertebral foramen.

Results. The height of these processes was on average 4.8 mm, and there was an inverse relationship between height of the uncinate process and the size of the intervertebral foramen. Degeneration of the vertebral body (VB) did not correlate with whether the uncinate process effaced the intervertebral foramen. The taller uncinate processes tended to be located below C-3 vertebral levels, and their average anteroposterior length was 8 mm. The average thickness was found to be 4.9 mm for the base and 1.8 mm for the apex. There were no significant differences found between vertebral level and thickness of the uncinate process. Arthritic changes of the cervical VBs did not necessarily deform the uncinate processes. With axial rotation, the intervertebral discs were noted to be driven into the ipsilateral uncinate process. With lateral flexion, the ipsilateral uncinate processes aided the ipsilateral facet joints in maintaining the integrity of the ipsilateral intervertebral foramen.

Conclusions. A good appreciation for the anatomy of the uncinate processes is important to the neurosurgeon who operates on the spine. It is hoped that the data presented herein will decrease complications during surgical approaches to the cervical spine.

Key Words • anatomy • vertebra • joint • cervical spine • uncovertebral joint • Luschka

The uncovertebral joints (Fig. 1) consist of the lateral margins of the superior surface of the VB known as the uncinate processes, located in the cervical spine from vertebrae C-3 to C-7, and their articulations with the adjacent superior VB at its echancrure (anvil). This articulation forms the medial wall of the intervertebral foramen in the cervical region below C-2 and, rarely, may be seen on the first thoracic vertebra.9

Neurosurgically, a thorough knowledge of the uncinate process is important for uncinectomy and uncoforaminotomy procedures. However, morphological studies of the uncinate process are lacking in the neurosurgical literature. Therefore, the present study was performed for a better elucidation of the anatomy of these structures.

Methods

The cervical spines of 40 human adult skeletons were used for the present study. The approximate age range of

Abbreviations used in this paper: AP = anteroposterior; VB = vertebral body.
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These specimens was 40–80 years old. Twenty-five male and 15 female specimens were used. Measurements were made of the uncinate processes and included the height, AP length, and thickness. Additionally, the angle of the uncinate from the midline in the coronal plane was measured for each level. All measurements were made using an electronic digital caliper accurate to 0.1 mm (Mitutoyo Corp.). Angles were measured with a goniometer.

Uncinate processes were classified (Types I–III) based on both their inclination and degree of effacement of the adjacent intervertebral foramen. The differences in various parameters between vertebral levels were analyzed using ANOVA, and differences between sides and the sex of donors with the Student t-test, with significance set at p < 0.05. Observations were also made of the motion of the uncovertebral joints (with artificial intervertebral discs in place in the subaxial cervical spine) during lateral flexion, extension, and flexion and axial rotation of the cervical spine. The artificial discs used were made of 3-mm-thick × 17-mm-long pieces of felt. These were held in place with glue, and manual motions of the articulated cervical spine were made with the C-7 VB held in a neutral position.

Results

An uncinate process was found bilaterally on all specimens between C-3 and C-7 vertebrae. No specimen was found to have an uncinate process on the T-1 vertebra. The height of these processes ranged from 2 to 6.1 mm (mean 4.8 mm). We observed that the taller the uncinate process, the more likely that it decreased the size of the intervertebral foramen; that is, there was an inverse relationship between height of the uncinate process and the size of the intervertebral foramen. Degeneration of the VB did not correlate with whether the uncinate process effaced the intervertebral foramen in the sagittal plane (that is, no matter what the degeneration of the surrounding spinal elements, this did not have an obvious effect on the vertically oriented uncinate process, resulting in intervertebral foramen effacement.

The taller uncinate processes tended to be located below C-3 vertebral levels, and with greater degeneration of the VB, there was usually a taller uncinate process. The AP length ranged from 5 to 8.3 mm (mean 8 mm), and in general this length decreased from the C4/5 to C-7 vertebral levels. Regarding the thickness of the uncinate process, for the base this measurement ranged from 3 to 6 mm (mean 4.9 mm), and for the apex this distance ranged from 1 to 2.1 mm (mean 1.8 mm). These distances for each level are detailed in Table 1. There were no significant differences found between vertebral level and thickness of the uncinate process. No significant differences were noted between the lengths measured or the thickness of the uncinate processes between sides or sex of the donor. Arthritic changes of the cervical VBs did not necessarily deform the uncinate processes, although this sometimes did occur. The overall morphological features (thickness, height, and so on) of the specimens were more or less the same for younger versus older skeletons. The angle of the uncinate process from midline ranged from 10° to 15° (mean 13°), with wider angles generally seen on older vertebrae, with more degeneration of the VB.

We classified the uncinate process with regard to the degree of impingement of the ipsilateral intervertebral foramen. Processes that were vertical, with no encroachment of the intervertebral foramen, were classified as Type I (80%) (Fig. 2); processes that inclined in a postero-lateral manner and decreased the diameter of the adjacent intervertebral foramen were classified as Type II (12%) (Fig. 3); and processes that at their base blended with the ipsilateral facet joint to compress the intervertebral foramen, but were not inclined, were classified as Type III (8%) (Fig. 4).

With axial rotation of approximately 5°, the artificial intervertebral discs were noted to be driven into the ipsilateral uncinate process, primarily at the junction of its base with the plateau of the VB. This movement was not

<table>
<thead>
<tr>
<th>VB</th>
<th>Height (mm)</th>
<th>AP Length (mm)</th>
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<tbody>
<tr>
<td>C-3</td>
<td>4.5–6.1 (4.8)</td>
<td>6.5–8.3 (8.1)</td>
</tr>
<tr>
<td>C-4</td>
<td>3–5.5 (5)</td>
<td>6–8 (7.5)</td>
</tr>
<tr>
<td>C-5</td>
<td>3–5.1 (4.9)</td>
<td>5.5–8.2 (7.1)</td>
</tr>
<tr>
<td>C-6</td>
<td>2.5–5.3 (5.1)</td>
<td>5–7.9 (7.2)</td>
</tr>
<tr>
<td>C-7</td>
<td>2–5 (4.9)</td>
<td>5.5–6.9 (6)</td>
</tr>
</tbody>
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* Values are expressed in millimeters—as the range, with the mean in parentheses.
restricted by the uncinate processes, but rather by the facet joints. With lateral flexion, the ipsilateral uncinate processes aided the ipsilateral facet joints in maintaining the integrity of the ipsilateral intervertebral foramen (Fig. 5). No restriction of movement by the uncinate processes was found during flexion or extension of the cervical spine.

**Discussion**

*Differing Opinions Regarding the Uncovertebral Joints*

The idea that the uncovertebral joints are synovial joints remains controversial. The dimensions for this joint range from 2 to 6 mm. Luschka hypothesized that through a degenerative origin, a synovial membrane was formed and created the joint. Years later, Hadley had a difficult time showing that these joints were synovial. However, he noticed that the outwardly protruding lips of the superior surfaces of each VB are separated from one another by less than one-third the normal height of the disc (Fig. 6). He concluded that this significant decrease in the height of the disc was due to its degeneration and the formation of osteophytes.

Orofino et al. agreed with Hadley’s conclusion of degenerative joint formation and thus went on to study the cervical spinal vertebrae of fetuses after the 11th week of gestation, which is known as the time period where synovial tissue is fully recognizable. These authors showed that the uncinate processes of fetuses are separated from each other by loose fibrous tissue, and no synovial membrane is present. Four full-term cervical spines also
Uncinate process

showed no signs of synovial membranes in the uncinate process region. In the investigation by Orofino et al.\textsuperscript{14} of the adult cervical spine, the area where loose fibrous tissue once remained was filled with fibrocartilage and new bone. The formation of fibrocartilage and new bone supported their conclusions that the changes seen in the uncinate process region of the cervical spine are due to reactive osteogenesis and thus degeneration. These authors believed that the new bone formation was in response to the stress of aging and may be hastened by trauma.

In 1985, Hayashi and Yabuki\textsuperscript{8} examined the cervical spines of donors whose ages ranged from preterm to 89 years old. These authors found that in the cervical spine, the neural arch that is part of the uncinate process formation is cephalad to the VB, thus leaving the uncinate process unable to articulate with the adjacent vertebrae. Caudally, the cartilage between the VB and neural arch also existed, but the arch was formed on the same plane as the VB, so that there was no uncinate process to articulate with part of the adjacent vertebra. Hayashi and Yabuki concluded that the intervertebral disc, which Hadley\textsuperscript{6} believed to be the site of degeneration, is formed in the area between the VBs in fetuses and has no impact on the neural arch forming the uncinate process, and thus the joint of Luschka cannot be formed by disc degeneration.\textsuperscript{8} However, the uncinate processes are not present in children younger than 10 years of age.\textsuperscript{1,18}

Uncinate Process of the Uncovertebral Joint

Resection of the uncinate process is usually performed 5–6 mm medial to the lateral margin of the superior aspect of the VB, and the distance between the medial and lateral margin of the uncinate process gradually increases from the C-3 to C-7 levels, as was found in the present study.\textsuperscript{11} We found that the height of the uncinate process was approximately 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 uncinate process, and this is comparable to the findings of Lu et al.\textsuperscript{11} These authors also found that the uncinate processes were significantly taller at C4–6 levels. As also observed in our study, the AP diameter of the medial margin of the uncinate process decreased from C-5 to C-7. Deformity of the uncinate process from degenerative changes often resulted in a posterolateral inclination of the process, thereby impinging the intervertebral foram (Fig. 3).

Proposed Functions of the Uncinate Processes and Uncovertebral Joints

The uncovertebral joint is thought to be responsible for a degree of stability and mobility of the cervical spine by limiting side-to-side movement of the cervical VBs. This may be due to the upper uncinate process of the uncovertebral joint being located more laterally, and the lower uncinate process being located more dorsally, allowing them to hold the lateral surfaces of the adjacent upper vertebrae between the upper and lower uncinate processes on both sides of the vertebrae.\textsuperscript{11} The overlapping effect of the uncovertebral joint is also thought to allow for axial rotation and lateral bending of the cervical vertebrae.\textsuperscript{10}

Hall\textsuperscript{7} hypothesized that the uncinate processes allow for rotational movement, whereas Penning and Wilmink\textsuperscript{16} theorized that the coupling motion seen in the lower cervical spine can be explained by the location and orientation of the uncinate processes. Using a C5–6 intact model, the importance of the uncovertebral joints and uncinate processes to coupled motions was confirmed. The uncinate processes and uncovertebral joints have varying degrees of influence on coupled motions, depending on the mode of loading.\textsuperscript{2} The uncinate processes reduce cervical motion in all loading modes, whereas the uncovertebral joints permit mobility, especially in axial rotation and lateral bending. Importantly, the uncinate processes may work together in accomplishing greater motion without over-stressing the intervertebral disc in younger spines, and provide stability during degeneration. Clausen et al.\textsuperscript{2} found that following resection of the uncinate processes, axial rotation was increased compared with lateral bending. Some have also likened these processes to guide rails for the translation that occurs in the cervical discs during flexion and extension.\textsuperscript{22} Another hypothesis is that the uncinate processes are associated with a facet joint orientation that favors axial rotation.\textsuperscript{15,16} We would hypothesize that the uncinate processes aid in maintaining the intervertebral disc in the coronal plane, especially in axial rotation of the cervical spine. This function is more or less performed in the thorax.

Fig. 6. Reconstructed 3D CT of the head and upper spine, noting the normal appearance of the right uncinate processes (arrows).
by the heads of the upper 9 ribs. In the lower thoracic and lumbar regions, there is no comparable bony structure that would inhibit lateral movement of the intervertebral discs.

The Uncovertebral Joint and Radiculopathy

Surgically, knowledge of the boundaries of the uncinate processes in the cervical spine from C-3 to C-7 is important in resection of these structures for removal of osteophytes or posterolateral disc herniation. Moreover, incomplete removal of osteophytes from the uncinate process has been reported to contribute to a poor surgical outcome. Removal of the uncovertebral joints and bone spurs associated with them is crucial for treating patients with cervical radiculopathy, and thus, anterolateral decompression of the cervical spine is commonly performed to treat patients with this condition. Treatment may include anterior cervical discectomy to preserve the motion segment of the spine with anterior cervical foraminotomy, which allows for preservation of motion while resecting the uncinate process.

We classified the uncinate processes based on their encroachment into the ipsilateral intervertebral foramen. Those with no encroachment into the intervertebral foramen were classified as Type I (Fig. 2); those processes that inclined in a posterolateral manner and decreased the diameter of the adjacent intervertebral foramen were classified as Type II (Fig. 3); and processes that at their base blended with the ipsilateral facet joint to compress the intervertebral foramen but were not inclined were classified as Type III (Fig. 4).

Exposure of the Uncovertebral Joint

Surgeons often use the anterior cervical approach for access to the uncovertebral joints. When dealing with diseases for which total tumor removal is not required, lateral exposure of the uncovertebral joint is used to provide immediate spinal cord decompression and stability. The approach is valuable in treating diseases concerning the VB, and the main indication for this approach is ventral epidural disease. The anterior cervical approach to the uncovertebral joint is insufficient in certain circumstances. Because the vertebral artery is so close to the uncinate processes, caution must be exercised with bone removal in this area. Notably, the vertebral artery travels closer to the uncinate processes in the midcervical region compared with lower cervical regions.

In 1976, the anterior cervical approach allowing for lateral exposure to the uncovertebral joint was first reported, and seems to have remained an underused procedure that can be deemed useful in treating numerous diseases. Although the approach is inappropriate for certain cases, the lateral exposure of the uncovertebral joint is essential for spinal cord decompression and stability.

Mummaneni et al. have stressed the need for removal of the uncovertebral joints bilaterally when an artificial cervical disc is placed. These authors shared their operative experience with the PRESTIGE LP (Medtronic Sofamor Danek) cervical disc. Mummaneni et al. discussed the possibility of new postoperative radiculopathy exacerbated with extremes of flexion, extension, and rotation of the artificial disc when adequate removal of the uncovertebral joints is not performed.

Conclusions

Based on our study, the uncinate processes are most likely involved in maintaining the position of the intervertebral discs during axial rotation. We have classified these structures based on their relationship to the ipsilateral intervertebral foramen. It is our hope that the data presented herein will help in decreasing the morbidity of surgical procedures in the cervical spine, and add to our overall comprehension of the function of the uncinate processes.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Tubbs, Loukas. Acquisition of data: Tubbs, Rompala, Verma, Loukas. Analysis and interpretation of data: Tubbs, Chambers. Drafting the article: Tubbs, Rompala, Verma. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Tubbs. Statistical analysis: Tubbs. Administrative/technical/material support: Tubbs. Study supervision: Tubbs.

References

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