Surgical Anatomy of Nuchal Ligament in the Lower Cervical Spine; Cadaver and Clinical Study

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Introduction
Problems of the posterior surgical approach for the cervical spine include postoperative axial pain, such as posterior cervical pain, shoulder pain and stiffness. In previous studies, it was reported that the incidence of postoperative axial pain was lower in C3-C6 laminoplasty than in C3-C7 laminoplasty, emphasizing the effectiveness of the former procedure where discission of the nuchal ligament that is attached to the C7 spinous process is avoided. It has been reported that this method was effective in minimizing postoperative axial pain. In addition, it has also been reported that the nuchal ligament attaches to not only the C7 spinous process but also the C6 spinous process strongly when the C6 spinous process is long.

The current study was conducted on cadavers to investigate the anatomical details of the attachment of the nuchal ligament to the spinous process, and the relationship between the length of spinous process of the lower cervical spine and the morphology of the spinous process attachment of the nuchal ligament. In addition, the relationship between the length of C6 spinous process and the attachment of the nuchal ligament to the spinous process was investigated from preoperative CT and MRI in cases undergoing surgery for cervical myelopathy. The significance of paying attention to the length of C6 spinous process was examined.

1. Cadaver study
Materials and Methods
Thirty-five Japanese adult cadavers (21 males and 14 females) with no history of cervical spine surgery were used for anatomical study. The mean age was 81.9 years (range, 56-100 years). These cadavers had been donated to the Department of Anatomical Science at Hiroshi University Graduate School of Medicine for teaching and research purposes.

Subcutaneous tissue was removed at the posterior of the cervico-thoracic spine to expose the area extending from C3 to T2 and vertebral arches from C3 to T2 while keeping the nuchal ligament extracted and separated lengthwise in the middle of the spinous process. The length of the C6 and C7 spinous processes was measured in the sectioned surface using a digital caliper, which determines the ratio of C6 spinous process length and C7 spinous process length (C6 spinous process length / C7 spinous process length; C6/C7 ratio). In addition, the anatomical details of the attachment of the nuchal ligament to the spinous process tip of C5, C6 and C7 were observed and classified into the following three groups: Grade 1, no anatomical union between the spinous process tip and the nuchal ligament; Grade 2, coarse union between the spinous process tip and the nuchal ligament; Grade 3, dense and closely adherent union between the spinous process tip and the nuchal ligament.

The relations between the above three types of morphology of the spinous process attachment of the nuchal ligament and the C6/7 ratio were investigated.

Results
In the morphology of the spinous process attachment of the nuchal ligament, all cases were Grade 1 at C5, and Grade 3 at C7. On the other hand, individual differences were recognized at C6 with Grade 1 found in 42.9%, Grade 2 in 14.3% and Grade 3 in 42.9%. The mean C6/7 ratio was 0.79±0.15 (0.46-0.99). In the relations between the morphology of the spinous process attachment of the nuchal ligament at C6 and C6/7 ratio, the C6/7 ratio was less than 0.8 (15 cases), and 0.80±0.07 (0.53-0.83) in the Non-attached group. The C6/C7 ratio was significantly higher in the Attached group.

In the Attached group, there was only one case (3.3%) in which the C6/C7 ratio was less than 0.8, and C6/C7 ratio was 0.78. In the Non-attached group, there were two cases (6.7%) in which the C6/C7 ratio was more than 0.8, and those C6/C7 ratio were 0.80 and 0.83. There was no significant difference between gender, CSM and OPLL.

Discussion
Recently, cervical laminoplasty via the posterior approach has been the main mode of therapy for the surgical treatment of myelopathy in patients with cervical spondylisis and OPLL. As for the shortcomings of this procedure, however, so-called postoperative axial pain, such as posterior cervical pain, should pain and stiffness, have been reported. In particular, it has been reported that this axial pain was more acute in those patients who exhibited exaggerated atrophy of the nuchal muscles after surgery. As a method to minimize the surgical invasion of the nuchal muscles, changing the area of decompression from “C3 to C7” to “C3 to C6” to preserve the C7 spinous process has been reported as a new procedure. According to this procedure, the C7 spinous process is preserved together with the nuchal ligament that is attached to it, thus reducing the surgical invasion of nuchal muscles. It has also been reported that this method was effective in minimizing postoperative axial pain. Further, it is known for the morphology of the cervical spinal spinous process that there is individual difference in the length of the C6 spinous process. In our previous studies using cadavers, we reported the relationship between the length of spinous process of the lower cervical spine and the morphology of the spinous process attachment of the nuchal muscles was attached to the C6 spinous process. The relations between the above three types of morphology of the spinous process attachment of the nuchal ligament and the C6/7 ratio were investigated.

2. Clinical study
Materials and Methods
Preoperative CT and MRI from 60 cases (47 males and 13 females, mean age 62.6 years) that underwent surgery for cervical myelopathy were used. The diagnosis was CSM in 46 and OPLL in 14. The length of the C6 and C7 spinous process was measured with the sagittal images of the CT, and the C6/C7 ratio was calculated. The sagittal and axial images of the MRI were used to determine whether or not the nuchal ligament was attached to C6 spinous process. The relations between C6/7 ratio and the morphology of the spinous process attachment of the nuchal ligament was investigated.

Three spine surgeons evaluated each of the MRI two times, and the interobserver and intraobserver reliability was examined with Cohen’s kappa values. Interpretation of the strength of agreement determined with the kappa values was assessed by adopting the criteria of Landis and Koch: >0.81; Almost perfect, 0.61-0.80; Substantial, 0.41-0.60; Moderate, 0.21-0.40; Fair, 0-0.20; Slight. For statistical analysis, Mann-Whitney U-test was used. The level of significance was set at P< 0.05.