Best cutoff score of cervical-pedicle thickness as a morphological parameter for predicting cervical central stenosis

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Abstract
There are various factors for the cause of cervical central stenosis (CCS), such as osteophyte, cervical-disc degeneration, and cervical ligamentum flavum hypertrophy. However, the pedicle of the cervical vertebra has not yet been analyzed for its relationship with CCS. We created a new morphologic parameter called the cervical-pedicle thickness (CPT) to assess the association between CCS and the cervical pedicle.

We obtained morphological cases involving the CPT from 82 patients with CCS. There were also 84 in the normal group who underwent cervical spine magnetic resonance imaging (CS-MR) as part of routine health screening. We obtained the T2-weighted CS-MR axial images from group members, and assessed the CPT at the level of the C6 vertebra on CS-MR.

The mean CPT was 3.46 ± 0.57 mm in the normal group, 4.97 ± 0.75 mm in the CCS group, which thus had a significantly higher CPT ($P < .01$) than did the normal group. For the prognostic value of the CPT as a predictor of CCS, ROC analysis indicated that the best cutoff score for the CPT was 4.18 mm, with 93.9% sensitivity, 92.9% specificity, and AUC 0.97.

Greater CPT was highly associated with a possibility of CCS. This conclusion will be helpful for assessing the CCS patients.

Abbreviations: AUC = area under the curve, CCS = cervical central stenosis, CPT = cervical-pedicle thickness, CS-MR = Cervical spine magnetic resonance imaging.

Key Words: cervical central stenosis, cervical pedicle, cervical-pedicle thickness

1. Introduction

Cervical spinal stenosis is a common degenerative disease defined as a narrowing of the cervical spinal canal by both soft tissues and bone, which can cause mechanical compression of the cervical spinal nerve roots. It results from degenerative changes, including intervertebral disc bulging or herniation, ossification of the posterior longitudinal ligament, and osteophytes.[1–4] It frequently causes pain in the upper extremities and the posterior neck. Patients with cervical spinal stenosis frequently experience reduced quality of life and functional ability.[5,6] Degenerative cervical spinal stenosis can be divided, anatomically into the cervical central stenosis (CCS), foraminal stenosis, or a combination of both. CCS is defined as a central narrowing of the spinal canal in the cervical vertebrae.[7,8] This narrowing causes cervical spinal nerve irritation, which can result in chronic and painful neurologic symptoms. Previous research has

indicated that morphologic analysis, including the cervical spinal-canal area, cervical dural-sac thickness, and cervical lateral masses, are associated with aging, disc degeneration, and CCS.[9] However, few studies have investigated how the cervical-pedicle affects CCS. Moreover, no studies have established the most suitable optimal cutoff point of the cervical spinal-canal area for diagnosing CCS. Kayalioglu et al demonstrated that the anatomic variations in the thickness of the cervical pedicles are frequently observed. They also insisted that left-right differences for the pedicle diameter differ at C6.[10] These morphological differences demonstrated that the cervical pedicle width is not always the same.[10] Thus, we think that the thickness of the cervical pedicle is a major morphologic feature in the assessment of irregular hypertrophy. In order to analyze the correlation between CCS and the thickness of the cervical pedicle, we created a new morphological parameter called the cervical-pedicle thickness (CPT). The CPT has not yet been evaluated for

its relationship with CCS. We assumed that the CPT is one of the adjuvant morphologic parameters in the diagnosis of CCS. Therefore, we used cervical spine magnetic resonance imaging (CS-MR) to compare the CPT between the CCS group and the normal group.

2. Methods

2.1. Patients

The Catholic Kwandong University College of Medicine, Incheon, South Korea, Institutional Review Board (IRB) checked and approved this original research. We reviewed patients who had visited the International St. Mary's Hospital Pain Clinic and Spine Center between March 2017 and January 2019 and were diagnosed with CCS. Inclusion criteria were

- a diagnosis of CCS with or without cervical foraminal stenosis,
- being over 50 years and with a past clinical history of upper extremity pain and chronic function-limiting neck pain of at least a 4 on a numerical rating scale of 0 to 10,
- cervicalgia for at least 10 weeks, and
- having had CS-MR imaging done within 10 weeks of the CCS diagnosis.

Exclusion criteria were as follows:

(1) the cervical spinal-cord signal change (cervical myelopathy) on CS-MR;
(2) infection in the cervical spine;
(3) previous surgical history on the cervical vertebrae;
(4) congenital spine defect; and
(5) incomplete chart data.

After the CCS was confirmed by an experienced, board-certified radiologist, 82 patients were enrolled. In the CCS group, there were 50 (60.98%) men and 32 (39.02%) women with a mean age of 59.04 ± 7.57 years (range, 50–81 years) (Table 1). To compare the CPT between the normal and CCS groups, a control group was also enrolled. The normal individuals had undergone CS-MR as part of a detailed medical checkup. Subjects in the normal group had no CCS-related symptoms. The normal group consisted of 84 patients (37 men and 47 women) with an average age of 57.32 ± 6.63 years (range, 50–79 years) (Table 1). The CPT in the normal group was also analyzed at the C6 vertebra.

2.2. Imaging parameters

We did CS-MR imaging with 3T (Siemens Medical, Erlangen, Germany) Avanto with 1.5 T (Philips Healthcare, Best, The Netherlands) scanners. For CS-MR imaging, we acquired T2-weighted axial images with an intersection gap = 0.9 mm, slice thickness < 3.0 mm, repetition time = 714 ms, echo time = 15 ms, 160 × 160 field of view, 320 × 224 matrix. All CS-MR data were transferred to an image-analysis software program (INFINITT PACS, Seoul, South Korea).

2.3. Image analysis

We obtained the T2-weighted axial CS-MR imaging at the C6 vertebra for an individual data, used an image-analysis software program to measure the CPT at the most thickened C6 pedicle level on CS-MR, and measured the CPT linearly at the C6 pedicle level (Fig. 1).

2.4. Statistical analysis

All variables are presented as means ± standard deviations. We used unpaired t-tests to compare the CPT between the normal and CCS groups, and estimated the validity of CPT for diagnosis of CCS by receiver operator characteristics (ROC) curves. We accepted a $P < .05$ as being statistically significant. We analyzed the association between the CPT and age-related changes by using 1-way ANOVA, and used SPSS version 22.0 for Windows (IBM SPSS, IBM Corp., NY) for all statistical analyses.

3. Results

Age and gender were not significantly different between the 2 groups (Table 1). The mean CPT of the control group was 3.49 ± 0.59 mm in persons aged 50 to 59, 3.47 ± 0.48 mm in person in the 60 to 69 age group, and 2.91s ± 0.62 mm in persons in the 70 to 79 age group (Table 2). In the normal group, we found no statistically significant associations between the CPT and age-related changes in the 1-way ANOVA ($F = 2.055$; $df = 2$; $P = .135$). The mean CPT of the CCS group measured 5.01 ± 0.78 mm in patients aged 50 to 59, 4.78 ± 0.44 mm in patients in the 60 to 69 age group, and 5.14 ± 1.02 mm in patients in the 70 to 81 age group (Table 3). In the CCS group, we also not find a statistically significant association between the CPT and age-related changes ($F = 0.952$; $df = 2$; $P = .390$). The mean CPT was 3.46 ± 0.57 mm in the normal group, and 4.97 ± 0.75 mm in the CCS group. The CCS patients had a significantly higher CPT ($P < .01$) than did the normal group
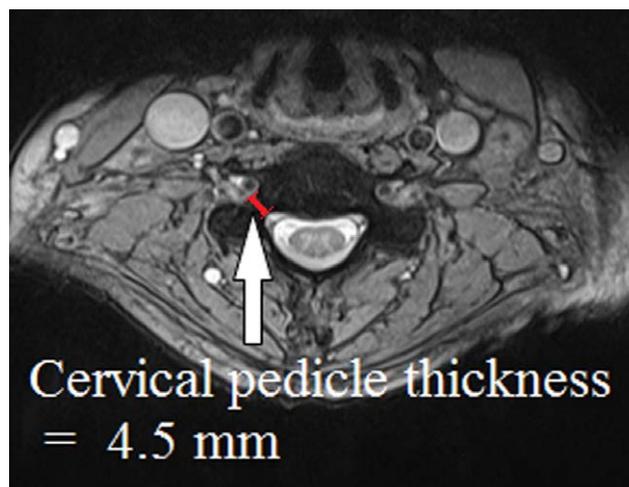
Figure 1. Measurement of cervical-pedicle thickness was carried out at the C6 vertebra on T2-weighted cervical MR images. MR = magnetic resonance.

Table 1

Comparison of the demographic data of control and CCS group.

Variable	Control group n = 84	CCS group n = 82	Statistical significance
Gender (male/female)	37/47	50/32	NS
Age (yrs)	57.32 ± 6.63	59.04 ± 7.57	NS
CPT (mm)	3.46 ± 0.57	4.97 ± 0.75	$P < .001$

Data represent the mean ± standard deviation (SD) or the numbers of patients.
CCS = cervical central stenosis, CPT = cervical-pedicle thickness, NS = not statistically significant ($P > .05$).

Table 2

Age distribution of subjects with mean CPT of normal group.

Age distribution (yrs)	Total (N)
50–59	3.49 ± 0.59 mm (60)
60–69	3.47 ± 0.48 mm (20)
70–79	2.91 ± 0.62 mm (4)

CPT = cervical-pedicle thickness.

(Table 1). For the prognostic value of the CPT as a predictor of CCS, ROC analysis indicated that the best cutoff score of the CPT was 4.18 mm, with 93.9% sensitivity, 92.9% specificity, and AUC 0.97 (95% CI: 0.94–0.99) (Table 4; Fig. 2).

4. Discussion

Cervical vertebrae are important for protecting the neurovascular structure. However, recurrent chronic neck and shoulder pain in the elderly is common because of degenerative changes of cervical vertebrae. The 1-year prevalence is 40%; intense disability and pain are seen in 14% of the elderly.[1,8,11] Common etiologies include cervical-disc herniation, cervical spondylosis, cervical discogenic abnormalities, cervical facet-joint arthritis, and cervical foraminal stenosis.[12,13] CCS is also a common cervical disorder that results in considerable disability and morbidity. Degenerative cervical anatomic change is the most frequently seen of CCS and can result from osteophyte formation, bulged disc, and cervical facet hypertrophy.[14,15] Previous research has found that the relationships between the cervical dura- sac thickness, narrowed spinal canal, and cervical lateral masses are closely associated with disc aging, degeneration, and CCS.[16] Kayalioglu et al have reported that the pedicles of cervical vertebrae are strong structural anatomic elements of the cervical vertebrae and offer the strength of attachment to the cervical spine.[10] Wasinpongwanich et al noted that overall mean pedicle height was 6.9 mm at C6. They observed that there was no statistically significant difference between right and left pedicle height.[17] Farooque et al observed that mean PTA was 43.22 degrees at C6.[18] However, few studies have investigated how degenerative hypertrophy of the cervical-pedicle affects CCS. Although some morphological analyses of the cervical pedicle have been done by measurements on plain cervical spin X-rays, computed tomography of cervical vertebrae, and measurements on cadaveric research,[19,20] there is no previous research on an association between CCS and the cervical pedicle as a morphological parameter on CS-MR. To our knowledge, this research is the first to propose a best cutoff score of CPT to predict CCS. Kayalioglu et al demonstrated that anatomic differences in the cervical-pedicle sizes are frequently observed. They also insisted that right-left differences for the cervical-pedicle diameter differ at C6. These morphologic features suggest that the cervical-pedicle width is not always the same.[10] However, an association between CCS and the cervical pedicle as a
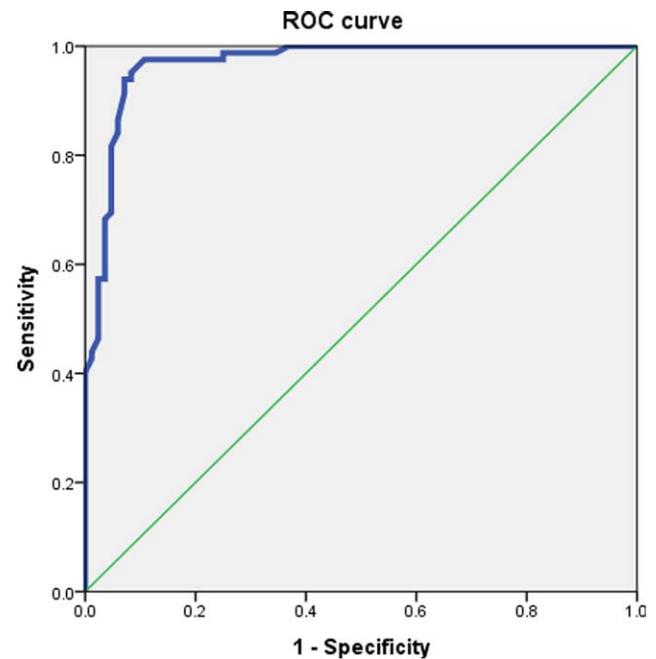

Figure 2. ROC curve of CPT for prediction of CCS. The best cutoff point of CPT was 4.18 mm, with sensitivity 93.9%, specificity 92.9% and AUC 0.97. CPT AUC (95% CI) = 0.97 (0.94–0.99). AUC = area under the curve, CPT = cervical-pedicle thickness, CCS = cervical central stenosis, ROC = receiver operating characteristic.

morphologic parameter on CS-MR has not been reported previously. Moreover, there are no objective morphologic parameters to indicate a thickened cervical pedicle. We thought that the thickness of the cervical pedicle is an objective, precise, clear measurement parameter to evaluate CCS. In this study, the CPT was measured from T2-weighted axial CS-MR. In our opinion, this measurement skill has not been reported previously. Our research first demonstrated correlations between the CPT and CCS. The CCS group had significantly greater CPT values than did the normal group.

The positive association between the CPT and the CCS could be explained if the high CPT value is associated with the increase rate in CCS. In this research, the most suitable cutoff score for CPT was 4.18 mm, with 93.9% sensitivity, 92.9% specificity, and AUC of 0.97 (95% CI: 0.94–0.99). We newly reported that CPT is the objective, precise, adjuvant diagnostic parameter for predicting CCS. Our interpretation of this result is that a thickened CP is related to mechanical friction, which might increase the rate of the CCS prevalence; so we strictly controlled for individual age to reduce this age bias. We included only subjects above 50 years old, because previous research had reported that CP morphology at young ages is not evidence of degenerative change.

This original research has some limitations. First, several different methods for assessing CCS, such as cervical spinal-canal area, cervical dural-sac area, lateral mass, morphologic grading, and cervical ligamentum flavum hypertrophy, have been proved to be effective at diagnosing CCS.[21–27] However, we analyzed only the measurement of CPT.

Second, there might be some measurement bias associated with measuring the CPT on CS-MR. Even though we tried to analyze these image parameters in the best that showed the cervical pedicle at the most stenotic level of the C6 vertebral body, the axial images we investigated to measure the values could not be homogeneous, because of differences in the cutting level in CS-MR resulting from anatomic differences and technical cause.

The fourth limitation is that the CPT was measured only to the C6 level in this research. The fifth limitation of our study

Table 3	
Age distribution of patients with mean CPT of CCS group.	
Age distribution (yrs)	**Total (N)**
50–59	5.01 ± 0.78 mm (53)
60–69	4.78 ± 0.44 mm (19)
70–81	5.14 ± 1.02 mm (10)

CCS = cervical central stenosis, CPT = cervical-pedicle thickness.

Table 4		
Sensitivity and specificity of each cutoff point of the CPT.		
CPT (mm)	**Sensitivity (%)**	**Specificity (%)**
2.17	100	1.2
3.25	100	31.0
3.69	98.8	65.5
4.18*	93.9	92.9
4.78	53.7	97.6
5.59	17.1	100

*The most suitable cutoff score on the ROC curve.

CPT = cervical pedicle thickness, ROC = receiver operating characteristic.

is that the participants in this study were only Asians. Despite these limitations, this research is the first to prove that the CPT is associated with CCS.

5. Conclusions

We demonstrated that CPT is a sensitive measurement parameter for evaluating CCS. For CCS, the best cutoff point was 4.18 mm, with 93.9% sensitivity 92.9% specificity, and AUC of 0.97. Greater CPT was highly associated with a possibility of CCS. This conclusion will be helpful for assessing CCS patients.

Acknowledgments

Author contributions

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