

# Anterior Cervical Discectomy and Fusion Versus Conservative Treatment for Cervical Angina Conservative Treatment

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**Study Design:** This study employed a retrospective study design.

**Objective:** This retrospective cohort study aimed to compare the outcomes of anterior cervical discectomy and fusion (ACDF), and those of conservative treatment for patients with cervical angina.

**Summary of Background Data:** Cervical angina is typically characterized by intolerable and paroxysmal angina-like precordial pain, which is caused by cervical disk degeneration in patients without definitive cardiovascular abnormalities. Diagnosis is either delayed or neglected because of its various clinical manifestations. Whether conservative or surgical treatment is appropriate remains controversial because of the lack of comparative studies.

**Materials and Methods:** From 2009 to 2016, 163 patients with cervical angina with advanced chest pain, tightness, or palpitation were retrospectively studied. Twenty-three patients underwent ACDF, and the other 140 patients were treated nonsurgically by medication, physical therapy, collar immobilization, or stellate ganglion block. Japanese Orthopedic Association (JOA) score and 20-point autonomic nervous system (ANS) score were assessed pretreatment and posttreatment. Patients' satisfaction was assessed using the Odom criteria.

**Results:** The average age of the patients was 50 years, and most of them were females. The average follow-up was 25.5 months. The pretreatment JOA and 20-point ANS scores in the conservative and ACDF groups were 13.3 versus 11.7 ( $P=0.110$ ) and 13.0 versus 13.3 ( $P=0.928$ ), respectively. Generalized esti-

mating equation analysis showed that posttreatment JOA and ANS scores at each observation interval improved significantly in the ACDF group ( $P<0.001$ ). Angina-like symptoms also improved significantly in the ACDF group ( $P<0.001$ ). During an average 2-year follow-up, good or excellent results were obtained in 78.2% of surgical patients and 35% of nonsurgical patients.

**Conclusions:** Compared with conservative therapy, surgical treatment with ACDF for cervical angina provided better and more consistent relief from angina-like symptoms and overall sympathetic symptoms.

**Level of Evidence:** Level III.

**Key Words:** cervical angina, autonomic nervous system, anterior cervical discectomy, fusion

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Cervical angina, or pseudoangina pectoris, was first described by Phillips<sup>1</sup> in 1927 followed by Nachlas<sup>2</sup> in 1934. The typical clinical picture of cervical angina includes intolerable, paroxysmal angina-like symptoms presenting with anterior chest pain, retrosternal pain, or epigastric pain.<sup>3,4</sup> The pain may be exacerbated by exertion and relieved by rest.<sup>5</sup> These symptoms are associated with cervical spondylosis but not with cardiovascular abnormalities.<sup>3–6</sup> Studies showed that chest pains or palpitations of > 50% of the patients who are referred to a heart clinic or emergency department were not related to a cardiac diagnosis.<sup>4,7,8</sup> Moreover, patients with cervical angina often experience other sympathetic symptoms, such as headache, vertigo, dyspnea, tinnitus, or blurred vision.<sup>3,5</sup> The clinical presentation of cervical angina varies among patients, and the diagnosis remains delayed or neglected.<sup>9–12</sup> In our clinical practice, we noticed that, compared with patients presenting with radicular or myelopathic symptoms, those with cervical angina endured longer symptom duration because of the discordance between imaging studies and symptoms.

Conservative treatment with medication, physical therapy, collar immobilization, or stellate ganglion block has shown to be effective in several studies.<sup>13–15</sup> Studies about surgical treatment with discectomy and interbody fusion to treat cervical spondylosis with sympathetic

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symptoms have also shown good outcomes, specifically in alleviating symptoms, by resecting the posterior longitudinal ligament (PLL).<sup>16,17</sup> However, no comparative study on the effects of surgical versus conservative treatments specifically on patients with cervical angina has been conducted.

We hypothesize that anterior cervical discectomy and fusion (ACDF) is more effective than conservative treatment for both cervical angina and other associated sympathetic symptoms. The purpose of this retrospective study was to compare the clinical outcomes between ACDF and conservative treatments for cervical angina in a cohort of patients with cervical spondylosis.

## MATERIALS AND METHODS

### Study Population

From 2009 to 2016, a total of 1655 patients presented to the orthopedic department in our institution with chief complaints of either neck pain with typical myeloradicular symptoms (ICD-9 code 721.0) or neck pain with atypical sympathetic symptoms (ICD-9 code 723.2); they were retrospectively reviewed. Seven hundred seven patients without chest discomforts or angina-like complaints were excluded first. Subsequently, patients who underwent ACDF to relieve their myeloradicular symptoms or sympathetic symptoms other than angina-like symptoms were also excluded. Moreover, 73 patients were excluded because their chest discomforts were due to other illnesses, such as heart disease, gastritis, peptic ulcer, gastroesophageal reflux, or thyroid dysfunction, after further assessments and studies. The severity and frequency of angina-like symptoms was classified by the 20-point autonomic nervous system (ANS) score.<sup>17,18</sup> Patients with mild angina-like symptoms were also excluded. The inclusion criteria were as follows: (1) patients confirmed with diagnosis of cervical spondylosis, and reported chest wall pain, tightness, or palpitation in the past 3 months at least; (2) they had normal EKG presentation, patent coronary angiography, and normal cardiac enzyme level; (3) they had associated autonomic symptoms such as headache, dizziness, vertigo or blurred vision, etc.; (4) the chest pain or tightness was not responsive to nitroglycerins; (5) they also had radicular pain or myelopathic symptoms which resulted from cervical disk herniation or stenosis as shown on x-rays, computed tomography, or magnetic resonance imaging (MRI).

Thus a total of 169 patients with advanced cervical angina [chest pain score (CPS)  $\geq 2$ ] were enrolled in this comparative analysis. Nineteen patients chose ACDF due to prolonged history of disabling symptoms which were irresponsive to nonsurgical managements for at least 3 months elsewhere or in our hospital. Although some patients also fit the criteria for surgical treatment, they just declined surgery and we respected their will. Only 4 of the 150 patients who initially chose conservative treatment eventually turned to surgery due to intractable or relapsing symptoms. Six patients in the conservative group were lost to follow-up. Overall, 140 patients received conservative

treatments, and 23 patients underwent ACDF (Fig. 1). Approval of the study was obtained from the institutional review board and the ethics committee of the Buddhist Dalin Tzu Chi Hospital, Taiwan (No. B10901021).

### Treatment Protocol

#### Conservative Treatment

One hundred forty patients with advanced cervical angina were followed up every 3 months in the outpatient department. The conservative treatment included administration of medications, such as nonsteroidal anti-inflammatory drugs, COX-2 inhibitor, tramadol, acetaminophen, physical therapy, and soft collar immobilization. Patients with recurrent sympathetic symptoms received stellate ganglion blocks using the paravertebral technique, as described in previous studies.<sup>19–21</sup>

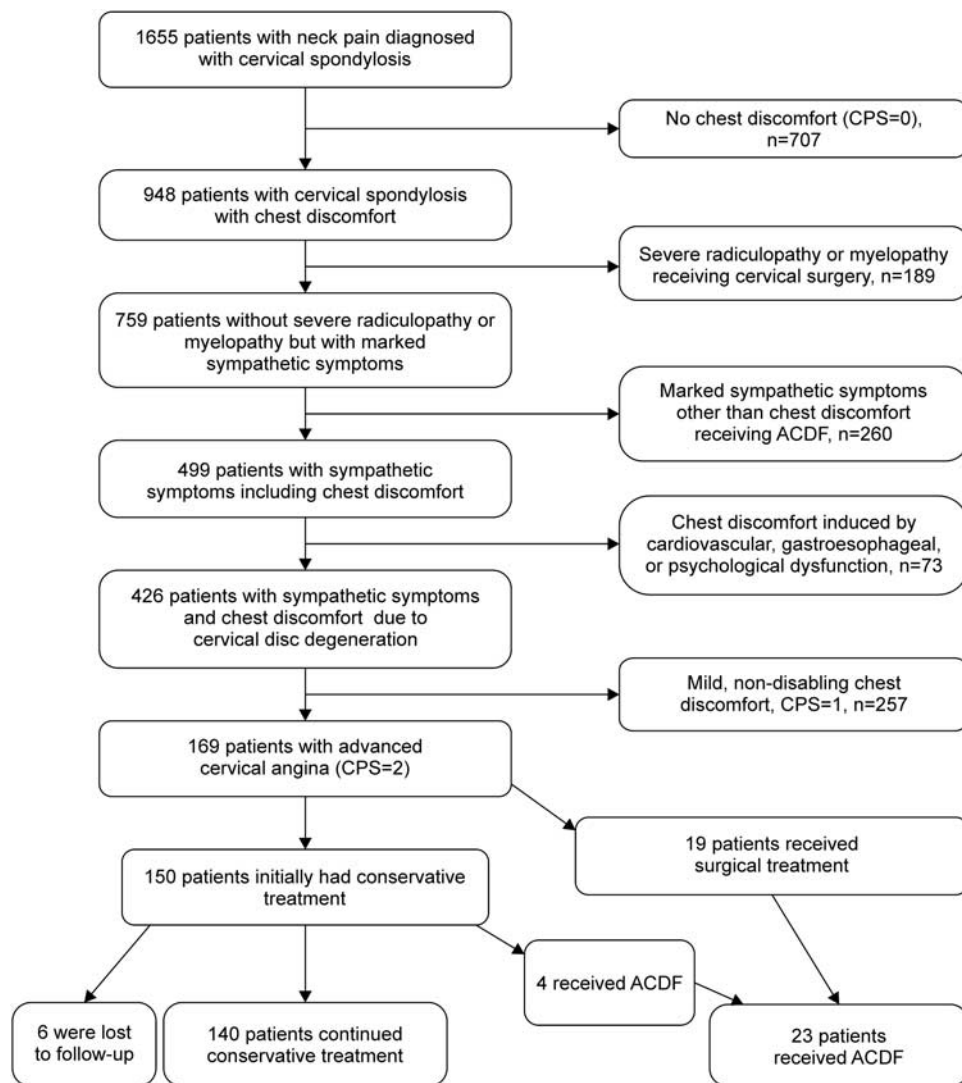
#### Surgical Treatment

A total of 23 patients with advanced angina-like symptoms (CPS  $\geq 2$ ) underwent standard ACDF through the left-sided approach under general anesthesia. The surgical indications were: (1) no improvement after at least 3 months of conservative treatment; (2) presence of 1 or more level of nerve root or cord compression on MRI; (3) no obvious abnormalities in cardiac workups; (4) presence of angina-like and other associated sympathetic symptoms in addition to various degree of radicular/myelopathic symptoms.

All surgeries were performed by a single experienced spine surgeon (J.T.C.). After routine discectomy, the dura was decompressed by the resection of the PLL and adjacent osteophytes at the lesion site(s). Interbody fusion was performed with polyetheretherketone cages (Cornerstone; Medtronic) with or without plate fixation, depending on the preoperative cervical stability. All patients were asked to wear a Miami J collar (Össur Americas) for at least 3 months.

#### Outcome Measurement

History taking, physical/neurological examinations, and imaging studies were performed, and all patients were required to complete these 2 questionnaires before treatment and every 3 months after treatment. With cervical disk degeneration, the presenting symptoms could be radicular, myelopathic, sympathetic, or combined. Therefore, in addition to Japanese Orthopedic Association (JOA) score<sup>22</sup> which documents well radiculopathy and myelopathy (which were also manifested in various degree of severity in our patients of cervical angina), we adopted ANS score to better document the sympathetic symptoms in more detail throughout the follow-up, surgical or conservative. The 20-point ANS score was used to assess the intensity and frequency of cervical spine-related sympathetic symptoms, such as headache, vertigo or dizziness, angina-like symptoms, tinnitus, nausea, blurred vision, and hypomnesia. The intensity of angina-like symptoms (eg, chest pain, tightness, dyspnea, and palpitation) as described subjectively by patients (CPS) were graded as 0 (none), 1 (occasional, work normally), 2 (often, work



**FIGURE 1.** Flow chart of the study. ACDF indicates anterior cervical discectomy and fusion; CPS, chest pain score.

partially), and 3 points (frequent, unable to work). The improvement rate of the JOA score was calculated as follows:  $(\text{posttreatment score} - \text{preoperative score}) / (17 - \text{pretreatment score}) \times 100\%$ . The ANS score improvement rate was calculated as follows:  $(\text{pretreatment score} - \text{posttreatment score}) / \text{pretreatment score} \times 100\%$ .

All patients also rated their overall satisfaction based on the Odom criteria<sup>23</sup>: excellent (all pretreatment symptoms were relieved), good (minimal persistence of pretreatment symptoms), fair (definite relief of some pretreatment symptoms, other symptoms unchanged or slightly improved), and poor (symptoms and signs unchanged or exacerbated). Although subjective and general, the 4-point scale is simple, reliable, and well-validated in terms of evaluation of functional improvement in pretreatment and posttreatment symptoms, and the ability to perform daily activities.

We assessed interbody fusion status in surgical patients using plain radiographic films (anteroposterior, later-

al, and flexion-extension views) taken during postoperative visits. Any surgical complications documented in the charts were also reviewed.

### Statistical Analysis

All continuous data were examined for normal distribution and expressed as means  $\pm$  SDs. For the comparison of 2 groups (ie, ACDF and conservative treatment groups), Student independent *t* test was applied when the continuous data followed a normal distribution. Mann-Whitney *U* test was used to compare the groups when assumptions of normality were violated. Categorical variables were tested by a  $\chi^2$  test to check for significant differences between groups. To demonstrate the differences in repeated measurements between groups, generalized estimating equation (GEE) was the statistical method used in the analysis. Repeated measurements in the 2 groups at each observation interval (ie, pretreatment, 3, 6, and 9 posttreatment months, and 1, 1.5, and 2

posttreatment years) were compared by GEE. Statistical analyses were performed with IBM SPSS Statistics software 2019 (IBM Corp, Armonk, NY). A *P*-value of <0.05 was considered as statistically significant.

### RESULTS

As shown in Table 1, the average age of all the patients with advanced cervical angina symptoms was 50 years; no significant difference between the 2 groups was found (*P*=0.127). There were 117 female patients, accounting for 71% of all the patients; however, no statistically significant difference in sex distribution between the groups was noted (*P*=0.799). The history of trauma and personal underlying systemic diseases between the 2 groups was similar. The patients received stellate ganglion blocks (an average of 3.8 and 3.9 times) during treatment. The duration of symptoms before treatment was much longer in the ACDF group than in the conservative group (9.0 vs. 4.4 y, *P*<0.001). The 2 groups had a similar JOA score (13.3 vs. 11.7, *P*=0.110) and ANS score (13.0 vs. 13.3, *P*=0.928) at baseline. Other associated sympathetic symptoms were similarly distributed between the 2 groups. Moreover, the intensity of angina-like symptoms was not significantly different between the 2 groups (2.2 vs. 2.4, *P*=0.55).

GEE model demonstrated the effects of the 2 treatments in patients with cervical angina and other sympathetic symptoms at 3, 6, and 9 posttreatment months and 1, 1.5, and 2 posttreatment years. The ANS score in the ACDF group significantly improved at each observation interval compared with the conservative group. After adjusting for age, sex, symptom duration, and

trauma history, the ACDF group still showed a significant improvement in the ANS score (*P*<0.001). The final improvement in the ANS score was 39.6% in the ACDF group and 6.9% in the conservative group (*P*<0.001). The score in the ACDF group also significantly improved at 1 and 2 posttreatment years. The final improvement rate of the JOA score was 57% in the ACDF group and 8% in the conservative group (*P*<0.001).

Other associated sympathetic symptoms, including headache, dizziness, and nausea, improved significantly after ACDF, and the surgical effect was sustained for 2 years; however, the effects of ACDF on tinnitus, blurred vision, and hypomnesia were not statistically significant (Table 2).

Preoperatively, disk degeneration of various degrees on MRI with root or cord compression was present on C3/4 in 9, C4/5 in 15, C5/6 in 19, and C6/7 in 10 patients, respectively. The C5/6 segment was the most frequently involved (19/53, 35.8%). A total of 53 segments in the ACDF group were fused, including 1 level in 3 patients, 2 levels in 11 patients, 3 levels in 8 patients, and 4 levels in 1 patient.

No postoperative superficial or deep infections were found. A solid interbody fusion without cage loosening or subsidence was achieved in all patients. Three patients experienced swallowing discomfort; however, the symptoms improved at the final follow-up. No patient complained of hoarseness. As shown in Table 3, 18 patients (78.2%) reported good and excellent overall satisfaction with ACDF during the 2-year follow-up based on the Odom criteria. Only 49 patients (35%) reported good and excellent satisfaction in the conservative group.

**TABLE 1.** Comparison of the Basic Demographics of the Patients in the 2 Groups

Characteristics	Conservative Group (n = 140)	ACDF Group (n = 23)	<i>P</i>
Sex, n (%)			
Female	101 (72.1)	16 (69.5)	0.799
Age (y)	48.7 (10.9)	52.4 (9.4)	0.211
Duration of symptoms (y)	5.8 (5.0)	9.0 (6.3)	0.001
Past history of trauma, n (%)	57 (40.7)	8 (34.7)	0.590
Hypertension, n (%)	13 (9.2)	3 (13.0)	0.437
Diabetes mellitus, n (%)	9 (6.4)	2 (8.6)	0.175
Connective tissue disease, n (%)	6 (4.2)	1 (4.3)	0.448
JOA score*	13.3 (2.2)	11.7 (2.3)	0.110
ANS score*	13.0 (3.0)	13.3 (3.6)	0.928
Headache	1.8 (0.9)	1.9 (1.0)	0.394
Vertigo	1.8 (0.8)	1.9 (1.0)	0.159
Angina-like symptoms	2.2 (0.4)	2.4 (0.5)	0.055
Tinnitus	1.2 (0.7)	1.2 (0.7)	0.877
Nausea	0.8 (0.7)	0.8 (0.8)	0.943
Blurred vision	1.5 (0.6)	1.6 (0.5)	0.193
Hypomnesia	1.4 (0.6)	1.2 (0.8)	0.241
Stellate ganglion block*	3.9 (4.1)	3.8 (2.5)	0.946

Values are expressed as mean (SD) or number (%).

\*Mann-Whitney *U* test.

ACDF indicates anterior cervical discectomy and fusion; ANS, autonomic nervous system; JOA, Japanese Orthopedic Association.

### DISCUSSION

Sympathetic symptoms associated with cervical spondylosis have attracted physicians' attention in the past decades. In addition to myelopathy and radiculopathy, sympathetic symptoms, such as headache, vertigo, or palpitation are not uncommon but may vary greatly in intensity and frequency among patients.<sup>24,25</sup> Barré-Liéou syndrome or cervicogenic headache is the often impression when patients complained of pain from the cervical spine to the head.<sup>26</sup> Cervical vertigo, which is also a common sympathetic symptom, is usually described as a neck-related sensation in which the patient feels that the floor or roof is spinning.<sup>27</sup> Patients with cervical angina may complain of anterior chest wall pain or retrosternal pain which are described as deep ache, sharp, or tightness in quality. The angina-like pain or discomfort may or may not be induced by cervical range of motion. Most often it is paroxysmal, but it can be continuous too. These symptoms were usually associated with other somatic symptoms, such as nuchal pain, interscapular pain, radiating pain, or numbness of upper arms. Characteristically these patients often complained of many troublesome sympathetic symptoms in addition to the less disabling radicular or myelopathic symptoms. Therefore, we asked

TABLE 2. Comparison Between Conservative Treatment Group and ACDF Group for Each Sympathetic Symptom at Each Follow-up

Symptoms	3 mo			6 mo			9 mo			1 y			1.5 y			2 y		
	Conservative	ACDF	P	Conservative	ACDF	P	Conservative	ACDF	P	Conservative	ACDF	P	Conservative	ACDF	P	Conservative	ACDF	P
ANS	10.8 (3.1)	6.0 (2.8)	0.001	11.0 (3.2)	5.9 (2.6)	0.001	11.2 (2.6)	7.1 (2.3)	0.001	11.6 (2.3)	5.7 (1.5)	0.001	11.0 (3.7)	7.6 (2.8)	0.001	12.8 (2.4)	8.2 (3.4)	0.001
Headache	1.5 (0.8)	0.7 (0.7)	0.002	1.5 (0.8)	0.6 (0.7)	0.000	1.4 (0.7)	0.7 (0.7)	0.001	1.6 (0.6)	0.6 (0.5)	0.000	1.7 (0.9)	0.8 (0.8)	0.03	1.8 (0.9)	0.9 (0.9)	0.03
Vertigo	1.3 (0.7)	0.6 (0.5)	0.001	1.3 (0.8)	0.6 (0.6)	0.001	1.4 (0.8)	0.7 (0.6)	0.001	1.5 (0.7)	0.7 (0.6)	0.001	1.4 (0.7)	0.9 (0.6)	0.001	1.8 (0.7)	1.0 (0.9)	0.001
Angina-like	1.6 (0.7)	0.8 (0.5)	0.01	1.6 (0.7)	1.0 (0.7)	0.01	1.7 (0.6)	1.0 (0.5)	0.001	2.0 (0.6)	0.9 (0.5)	0.04	1.6 (0.7)	1.1 (0.5)	0.001	2.0 (0.5)	1.1 (0.7)	0.001
Tinnitus	1.1 (0.7)	0.6 (0.8)	0.02	1.1 (0.8)	0.7 (0.8)	0.03	1.2 (0.7)	0.8 (0.7)	0.21	1.4 (0.5)	0.5 (0.5)	0.001	1.2 (0.7)	1.0 (0.9)	0.72	1.4 (0.6)	0.8 (0.8)	0.65
Nausea	0.7 (0.6)	0.2 (0.4)	0.002	0.6 (0.6)	0.1 (0.3)	0.003	0.7 (0.6)	0.2 (0.4)	0.01	1.0 (0.6)	0.4 (0.5)	0.001	0.8 (0.6)	0.2 (0.4)	0.01	0.9 (0.5)	0.4 (0.6)	0.02
Blurred vision	1.3 (0.6)	1.0 (0.7)	0.62	1.4 (0.7)	0.8 (0.6)	0.001	1.4 (0.6)	1.3 (0.4)	0.49	1.6 (0.6)	1.3 (0.4)	0.68	1.4 (0.6)	1.2 (0.7)	0.36	1.5 (0.6)	1.4 (0.6)	0.03
Hypomnesia	1.3 (0.7)	0.7 (0.7)	0.02	1.3 (0.6)	0.5 (0.6)	0.04	1.4 (0.5)	1.0 (0.6)	0.45	1.4 (0.5)	1.0 (0.5)	0.82	1.4 (0.6)	1.4 (0.5)	0.01	1.6 (0.4)	1.2 (0.8)	0.35
JOA				13.3 (2.3)	14.7 (1.5)	0.001				13.8 (2.2)	15.1 (1.5)	0.001						

Data are expressed as mean (SD).  
ACDF indicates anterior cervical discectomy and fusion; ANS, autonomic nervous system; JOA, Japanese Orthopedic Association.

TABLE 3. Posttreatment Subjective Satisfaction by Odom Criteria

Group	Excellent, n (%)	Good, n (%)	Fair, n (%)	Poor, n (%)
Conservative	3 (2.1)	46 (32.9)	67 (47.9)	24 (17.1)
ACDF	5 (21.7)	13 (56.5)	4 (17.4)	1 (4.3)

ACDF indicates anterior cervical discectomy and fusion.

the patients to record their complaints on the JOA and ANS questionnaires to encompass all possible symptoms.

Some authors suggested that cervical angina causes noncardiogenic chest pain originating from disorders of the cervical spine.<sup>4,6,8,10,12,28,29</sup> Some patients with cervical angina responded well to nonsurgical methods, including medication administration, collar immobilization, and physical therapy such as cervical traction.<sup>15,30,31</sup> However, some patients still required surgery for symptom relief, especially for those whose conservative treatments failed and those with persisting severe symptoms.<sup>4,5,30</sup> With microdiscectomy, Sussman et al<sup>4</sup> in 1976 successfully treated a 50-year-old patient with cervical angina, which was related to C5/6 foraminal stenosis. In 1985, Brodsky<sup>5</sup> reported an excellent surgical outcome in 68 patients with cervical angina (78.2%) who had anterior discectomy and fusion. A retrospective study<sup>17</sup> in 2011 with a mean follow-up of 15.6 months investigated the clinical effectiveness of ACDF to treat cervical sympathetic symptoms. We conducted this study because the definitive treatment for patients with cervical angina remains controversial and no comparative study that evaluates the outcomes of conservative versus surgical treatments in such patients has been performed. Our study demonstrated and compared the clinical improvements in angina-like as well as sympathetic symptoms before and after the 2 treatments at different observation intervals for 2 years. Results showed that not only the angina-like symptoms were alleviated significantly by surgery but also the JOA and ANS scores improved significantly postoperatively.

Diagnosis of chest discomfort due to cervical spine lesions requires a high index of suspicion, comprehensive history taking, thorough physical examination, positive findings of cervical spondylosis on MRIs, and the absence of any significant pathologic changes in cardiac enzymes, EKGs, or computed tomography/angiography.<sup>4,32</sup> Nevertheless, consensus regarding its diagnostic criteria is lacking.<sup>12,33</sup> In 2015, Sussman et al<sup>4</sup> recommended some common characteristics for diagnosing cervical angina by history and physical examination. Patients may complain of subjective upper extremity weakness or sensory changes, with concomitant occipital headaches or neck pain. Chest symptoms could be induced by cervical motion or upper extremity movement. Patients may recall their history of cervical injury or recent manual labor. Moreover, chest pain is likely noncardiogenic when the duration of persisting chest pain is > 30 minutes or < 5 seconds. During physical examinations, the patients should be observed for restricted cervical motion or paraspinal tenderness, positive Spurling

test, and radicular symptoms associated with a specific dermatome. Lastly, radiologic evidence of degenerative changes in the cervical spine and negative cardiac workup should also be investigated.

The true incidence and prevalence of cervical angina remain unknown and vary among previous studies. Brodsky<sup>5</sup> noted that more than half of his patients who were surgically treated for cervical angina experienced autonomic symptoms (headache, vertigo, dyspnea, tinnitus, or blurred vision) in addition to radicular or myelopathic symptoms. Ozgur and Marshall<sup>32</sup> reported that 36 of 241 patients who underwent C6/7 ACDF presented with atypical chest pain or subscapular pain. Nakajima et al<sup>3</sup> retrospectively reviewed 706 patients who underwent cervical spine surgery for myeloradiculopathy and found that only 10 patients were considered to have cervical angina. In another retrospective study, Sussman et al<sup>4</sup> found 6 patients with cervical angina among 44 patients (13.6%) presenting with atypical chest pain. In our study, the prevalence of cervical angina was ~10% (163/1655) in patients of cervical spondylosis with neck pain and associated symptoms.

Additional functional evaluation is recommended when a discordance between symptoms and imaging studies exists.<sup>4</sup> In Brodsky series,<sup>5</sup> the negative rate of cardiac catheterization and EKG was 80% (44/55) and 79% (69/87), respectively, which were conducted to rule out organic heart disease for patients with angina symptoms. In our study, all patients with cervical angina showed negative cardiac workup, including EKGs, cardiac enzymes, cardiac angiography, or treadmill stress tests. However, as heart disease may coexist, several authors<sup>7,8,10,12</sup> have recommended cardiac workup to exclude organic heart problems, especially for patients with left-sided chest pain that radiates to the shoulder. Besides patient history, physical examinations, and cardiac workups, a 20-point ANS score was used to evaluate sympathetic symptoms related to the degenerative cervical spine and to assess treatment outcomes.<sup>16,17</sup> The ANS questionnaire comprises 7 major sympathetic symptoms, including headache, vertigo, tinnitus, blurred vision, chest pain/palpitation, nausea and vomiting, and hypomnesia, and the other associated atypical symptoms. Sympathetic symptoms are defined as mild (<6 points), moderate (7–14 points), and severe (> 15 points). The ANS score is widely accepted by previous published clinical papers.

The pathomechanism of cervical angina is still unclear; nevertheless, some possible mechanisms were proposed in clinical observational studies that were conducted to explain the association between lesions and symptoms. Moore et al<sup>21</sup> used stellate ganglion blockades to treat refractory cervical angina and obtained good results. They suggested that temporary angina relief was due to the blocking of the transmission of sympathetic afferent nerves. Ozgur and Marshall<sup>32</sup> investigated patients with a C6/7 disk degenerative disease; the patients presented predominantly subscapular/chest pain. Most of these patients with cervical angina improved after ACDF, and the result was sustained for 6 months. Moreover, the authors also suggested their symptoms could be associated with

the C7 nerve root, which was compressed by a herniated disk. Hong and Kawaguchi<sup>17</sup> demonstrated that patients with cervical spondylosis with sympathetic symptoms could be successfully treated with ACDF. They speculated that sympathetic nervous system irritation induces symptoms, such as chest pain, nausea, or gastrointestinal symptoms. In 2016, Li et al<sup>16</sup> showed a good mid-term outcome of ACDF and PLL resection for cervical sympathetic symptoms. The authors suggested that PLL may play an important role in the presentation of sympathetic symptoms. From the viewpoint of neuroanatomy, the anterior chest wall is innervated by the cervical roots from C4 and C8, which contribute to the sensory and motor innervation of the chest wall. The pattern of referred pain may be similar to that in lumbar disk herniation.<sup>33,34</sup> Through the gray ramus communicans, the sympathetic fibers joined the sinuvertebral nerves that arise from the ventral ramus of the spinal nerves and contribute to the sympathetic innervation of intervertebral disks and PLL.<sup>35</sup> Coppes et al<sup>36</sup> demonstrated the distribution of post-ganglionic sympathetic fibers in the PLL by immunoreactive staining. Yamada et al<sup>37</sup> found that sympathetic fibers are distributed on the vascular wall, dura, and PLL and accompanied by nociceptive sensory fibers in the cervical spine. They also showed that the sympathetic plexus is reduced after the removal of the cervical sympathetic ganglion in the upper cervical PLL. However, whether symptom alleviation results from the decompression of dura, nerve roots, or sympathetic ganglion or the removal of irritating nerve endings on PLL during ACDF remains unclear.

As for selection of level of surgery and levels of fusion, it is still a matter of debate and controversy. Unlike the radicular or myelopathic symptoms in the typical presentation of cervical spondylosis, there are no specific pathologic or radiologic abnormalities that can be responsible for angina-like or other sympathetic symptoms. Therefore, sometimes it is hard to decide and choose the level of fusion. However, we selected the level of surgery and segments to fuse in our patients with cervical angina by (1) level of root or cord compression on MRI; (2) clinical symptoms and signs of radicular, myelopathic, and/or sympathetic dysfunction; (3) in some cases, more levels were fused to avoid ending a construct adjacent to a level of instability as shown on flexion-extension views; (4) in some cases, we tended to include more levels to reduce chances of reoperation for additional levels due to incomplete relief of chest discomfort.

The decision on whether or when surgical or non-surgical treatment should be performed in patients with cervical angina remains controversial. Numerous authors suggested that patients undergo surgery when their symptoms do not improve after at least 3 months of conservative treatments.<sup>16–18</sup> In our study, the symptoms of the majority of the patients in the conservative treatment group were relieved by medication, physical therapy, collar immobilization, or repeated stellate ganglion block. Overall, 23 patients (14%) required surgical decompression and fusion for relief of symptoms. In 2016, a prospective study conducted by Li et al<sup>16</sup> showed a

satisfactory mid-term surgical outcome in patients with cervical sympathetic symptoms. The postoperative JOA and ANS score improvement rates were 56% and 69%, respectively, in a 5-year follow-up. Our study retrospectively followed 163 patients with cervical angina associated with cervical spondylosis; they were treated with 2 different treatments. We found that patients who had surgery were more satisfied with the improvement of their neurological deficits and also with the alleviation of sympathetic symptoms in a 2-year follow-up. To our knowledge, this is the first comparative study on ACDF and conservative treatment in patients with cervical angina. Our result was encouraging, and we recommend that patients with persistent or recurrent cervical angina may undergo ACDF after conservative treatment for at least 3 months.

This study has some limitations. First, this was a retrospective study and thus potential selection bias exists. To avoid this, we followed the criteria of diagnosing cervical angina by history taking and physical examination, which were recommended by Sussman et al.<sup>4</sup> Cardiac workup, such as electrocardiogram, arterial catheterization, and cardiac enzymes, and radiographic studies with plain film and MRIs of the cervical spine were performed in all patients before a diagnosis was made. Thus, the baseline characteristics between the 2 groups were similar, except for the symptom duration; second, the sample size of this study was small; hence, the conclusion should be carefully interpreted; and third, the diagnostic methods to classify cervical angina are still not definite; thus, misclassification was possible even though we ruled out other possible diagnoses.

In summary, our study showed that surgical patients were more satisfied than those who received nonsurgical treatment. ACDF resulted in a significant alleviation of angina-like symptoms and other associated sympathetic symptoms. The surgical effects were also more consistent and more sustained for both angina-like symptoms and overall sympathetic symptoms. With the evidence of symptom relief after surgical resection of PLLs, we recommend that a further study on the distribution of sympathetic fibers in human PLL and its association with cervical angina be conducted. Moreover, further research should focus on investigating the molecular and cellular mechanisms of such an intriguing phenomenon.

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