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Asymmetric atrophy of cervical multifidus muscles in patients with chronic unilateral cervical radiculopathy

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Abstract

The purpose of this study was to assess whether the asymmetry of cervical multifidus muscles occurred in radiculopathy patients, and if it did, whether it was related to the chronicity of unilateral cervical radiculopathy by assessing the cross-sectional area (CSA) of multifidus muscles using magnetic resonance imaging (MRI).

This study used a retrospective design and was conducted from January 2013 to August 2016. Seventy-seven patients (age 18–65) who had unilateral neck pain, symptom duration of 3 months to 1 year, and who were diagnosed with unilateral 6th cervical radiculopathy by electrodiagnostic testing, were included in study. The CSA of cervical multifidus muscles was measured at the midpoint between the lower margin of the upper vertebra and upper margin of the lower vertebra on axial MRI. Relative CSA (rCSA), which is the ratio of the CSA of muscles to that of the lower margin of C5 vertebra was also obtained.

At the C4-5 and C6-7 levels, CSA and rCSA of cervical multifidus muscles showed no statistically difference between the affected and unaffected sides. At the C5-6 level, multifidus muscles were significantly smaller in the affected side (at the C5-6 level, *P* value of CSA.007 and *P* value of rCSA.102).

The atrophy of multifidus muscles ipsilateral to cervical radiculopathy was observed in patients who had chronic unilateral cervical radiculopathy.

Abbreviations: ASA = abnormal spontaneous activity, CSA = cross-sectional area, DRG = dorsal root ganglion, EMG = electromyography, MRI = magnetic resonance imaging, MUAP = motor unit action potential, NCS = nerve conduction studies, PSM = cervical paraspinal muscle, rCSA = relative CSA, ROI = region of interest.

Keywords: cervical multifidus muscle, cervical radiculopathy, cross-sectional area, electrodiagnostic testing

1. Introduction

Neck pain has become a widely disabling problem, which has been reported to have a prevalence is 12.1% to 71.5%.[1] Cervical radiculopathy is defined as the inflammation or impingement of nerve root, and is due mainly to disc herniation.[2] Previously, it was reported that a decrease in the cross-sectional area (CSA) of the multifidus muscle does not recover spontaneously after pain reduction, and specialized muscle training exercises should be recommended to prevent the recurrence of back pain.[3] There are several studies that have investigated the paravertebral lumbar muscles in patients with low back pain,[3] chronic low back pain[4] and lumbosacral radiculopathy.[5] Some of these studies proposed rehabilitative exercises for these muscles;[5,6] however, there are few studies focused on cervical paraspinal muscles (PSMs).

PSMs support neck motion and provide stability to the cervical spine. Weakness in these muscles can be a cause of neck pain.[7] The multifidus muscle is located anteriorly among cervical PSMs, and forms the deepest layer of the neck extensor group. It acts to extend and laterally flex the neck, and it rotates the head and cervical spine contralaterally. Semispinalis cervicis and capitis muscles extend and laterally flex the head and neck, and this muscle assists rotation of the head when acting unilaterally. It is known that the semispinalis muscles display reduced and less defined activation in patients with neck pain.[8] All of these muscles are innervated by dorsal primary rami of the cervical root. One study that focused on cervical PSMs, showed that cervical multifidus muscles were smaller in females with chronic neck pain and whiplash syndrome compared to a group of healthy control.[9] Another study demonstrated a consistent pattern of reduced CSA in the cervical multifidus at all levels in patients with whiplash-associated disorders as compared to controls.[10] Until now, there have been few studies evaluating changes in multifidus muscles in patients with unilateral cervical radiculopathy which is diagnosed using an electrodiagnostic examination.

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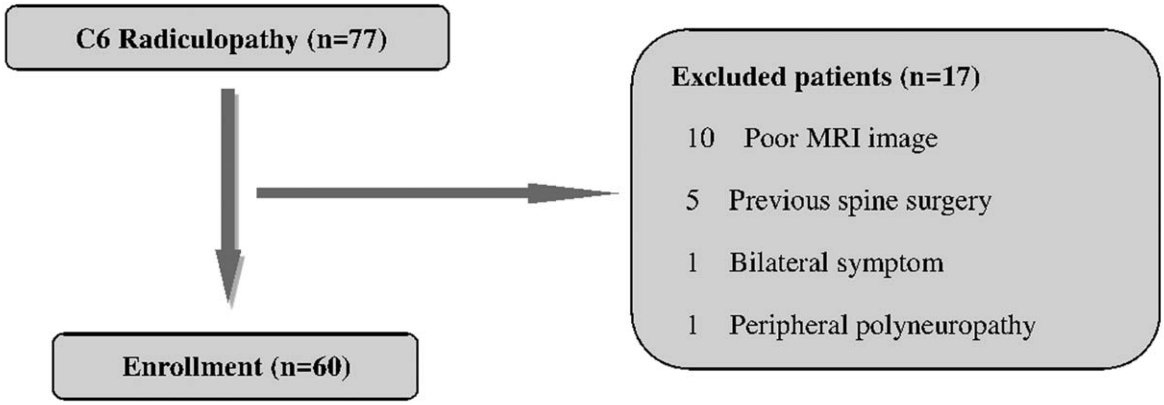

Figure 1. A flowchart of subjects.

Since the dorsal root ganglion (DRG) houses cell bodies for the sensory nerves, in pure radiculopathy sensory nerve test should have normal results. Motor nerve conduction test are also typically normal in cervical radiculopathy unless there is severe axon loss or multilevel disease.[12] To confirm radiculopathy, electrodiagnostic tests were conducted. Electrodiagnostic testing is useful for evaluating radiculopathy. It has 2 parts:

1. a needle electromyography (EMG) and;
2. nerve conduction studies (NCS).[13]

As mentioned earlier, studies of lumbar PSM on patients with lumbar radiculopathy[5] have been done before, and based on the results, exercise of the lumbar muscle was recommended for these patients. But there are few studies on cervical PSM in patients with cervical radiculopathy, making studies of cervical PSM necessary. The aim of the present study was to investigate whether asymmetry of cervical multifidus muscles occurred in patients with unilateral cervical radiculopathy by assessing the CSA of the multifidus muscle through use of magnetic resonance imaging (MRI).

2. Materials and methods

2.1. Participants

This study employed a retrospective design and was conducted from January 2013 to August 2016. Patients with clinical symptoms of unilateral cervical radiculopathy who visited the outpatient clinic of the Kyung Hee medical center from January 2013 to August 2016 were enrolled. This study was approved by the local ethics committee of Kyung Hee university hospital.

Inclusion criteria were as follows:

1. clinical symptoms of unilateral radiculopathy (symptomatic duration: 3 months – 1 year);
2. unilateral C6 radiculopathy on the electrodiagnostic test;
3. patient ages between 18 and 65; and,
4. cervical disc herniation at the C5-6 level on cervical MRI.

The electrodiagnostic criteria for unilateral cervical radiculopathy were the detection of abnormal spontaneous activity, abnormal motor unit morphology consistent with neuropathy, or neuropathic recruitment patterns in involved upper limb muscles and/or unilateral PSMs.

Exclusion criteria were as follows:

1. bilateral symptoms of upper extremities;
2. polyneuropathyl;
3. previous spinal surgery;
4. spinal fracture;
5. spinal cord injury, tumor or infection; and
6. comorbidities that impact physical activity (e.g., cerebrovascular accidents, severe heart disease).

Out of the patients, 77 exhibited clinical symptoms and electrodiagnostic findings making them eligible for the study. Seventeen patients were excluded from the study (10 due to poor MRI image; 5 because of previous spine surgery; 1 who had bilateral symptoms, and 1 patient because of peripheral polyneuropathy). Sixty subjects (36 males and 24 females) participated in this study (Fig. 1).

In this study, NCS and EMG findings diagnosed by C6 radiculopathy were as follows;

1. Normal sensory NCS.
2. Detection of abnormal spontaneous activity (ASA) or alterations in motor unit action potential (MUAP) parameters including amplitude, duration, and phase (reduced recruitment with increased duration, amplitude, and polyphasic pattern). These abnormalities should be in at least 2 muscles innervated by 2 different peripheral nerves in a C6 myotomal distribution (such as deltoid, biceps brachii, flexor carpi radialis), regardless of EMG findings of cervical PSMs.

2.2. Measures and procedures

All patients underwent cervical spine MRI 4 weeks before or after diagnosis of unilateral C6 radiculopathy. Axial T2-weighted images of MRI between the lower margin of C4 and upper margin of C5 vertebrae (C4-5 level), between the lower margin of C5 and upper margin of C6 vertebrae (C5-6 level), and between the lower margin of C6 and upper margin of C7 vertebrae (C6-7 level) were captured. The CSA of both sides of cervical multifidus muscles and lower margin of C5 vertebra were measured by drawing outlines of them with the region of interest (ROI) described in the PiView program (Infinitt, Seoul, Korea). Afterwards, the relative CSA (rCSA), which is the ratio of CSA of muscles to that of the lower margin of C5 vertebra, was

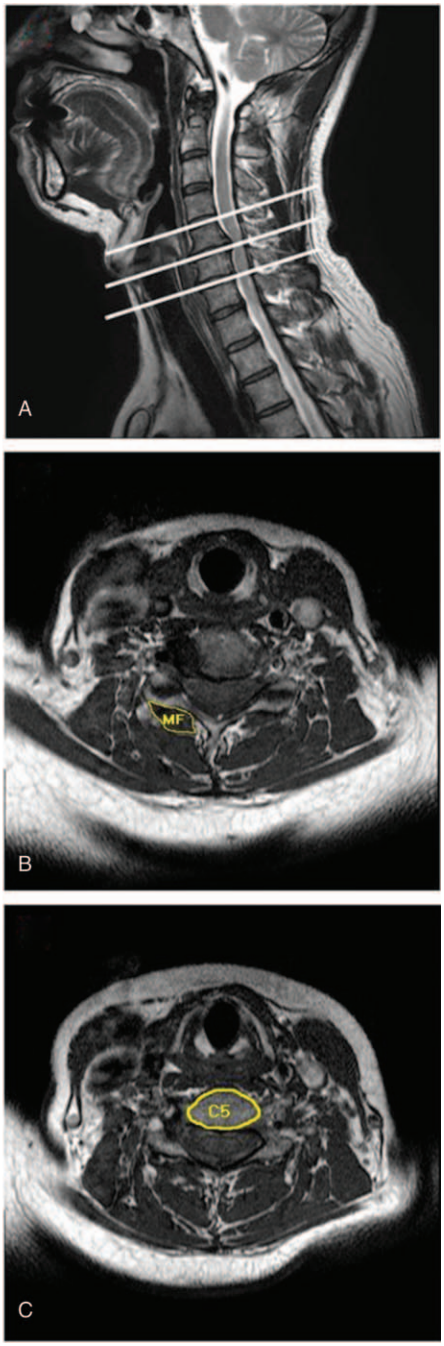

Figure 2. The cross-sectional area of the paraspinal muscles and 5th and 6th Cervical Vertebrae in a Patient with Unilateral Radiculopathy. (A) Sagittal T2-weighted image shows axial plane at the middle between lower margin of 5th cervical and upper margin of 6th cervical vertebrae. (B) Cross sectional area measurement of the cervical multifidus muscles (MF: Multifidus muscle). (C) Cross sectional area measurement of the lower margin of 5th cervical vertebrae.

calculated and used to compensate for the influence of individual body shape, body weight and height on the CSA of cervical multifidus muscles (Fig. 2).

All CSA measurements were performed independently twice by the same person to minimize potential for error in constructing the polygons around the margins of the muscles, and the average values were analyzed. Clinical and electrodiagnostic findings of all cases were blinded to the study investigators.

Table 1

Demographic characteristics of the patients.

	Patients (n = 60)	Range
Sex (male/female)	36/24	
Age (years)	48.4 ± 10.95	23–65
Height (cm)	165.5 ± 8.23	145–180
Weight (kg)	67.2 ± 12.3	53–80
Body mass index (kg/m^2)	24.9 ± 2.9	20.3–29.3
Visual analogue scale of pain	5.3 ± 1.33	2–8
Smoking (N)	13	

2.3. Statistical analysis

Statistical analysis was performed using SPSS for Windows, version 20.0 (Armonk, NY: IBM Corp.). A paired *t* test was used to compare the CSA and rCSA between affected and unaffected sides at each level; the Shapiro-Wilk test was conducted to confirm normal distribution of each group. Statistical significance was defined as *P* value of less than .05. All values were presented as mean ± standard deviation.

3. Results

Included subjects were 36 men and 24 women with a mean age of 53.5 ± 13.5 years (range, 23–65 years). The baseline demographic and clinical characteristics of the patients are presented in Table 1.

There was a difference of CSA of cervical muscles between the affected side and the unaffected side. At the C4-5 level, the CSA of cervical multifidus muscles showed no statistically significant difference between the affected and unaffected side (affected side 81.47 ± 26.15 mm^2 and the unaffected side 83.56 ± 23.70 mm^2, respectively) ($P = .172$). Also, there was no statistically significant difference in the affected and unaffected side at the C6-7 level (affected side 92.50 ± 26.64 mm^2 and the unaffected side 95.10 ± 27.12 mm^2, respectively) ($P = .166$). A statistically significant difference of CSA between the affected side and the unaffected side was observed in multifidus muscles at the C5-6 level (CSA of multifidus: 81.32 ± 23.31 mm^2 in the affected side and 86.43 ± 26.87 mm^2 in the unaffected side) ($P < .05$) (Table 2). The rCSA of these muscles also showed a statistically significant difference

Table 2

Cross-sectional area of the cervical multifidus muscles in the patients.

Variable	Affected side	Unaffected side	*P* value*
Multifidus (mm^2) at the C4-5 level†	81.47 ± 26.15	83.56 ± 23.70	.172
Multifidus (mm^2) at the C5-6 level†	81.32 ± 23.31	86.43 ± 26.87	.007
Multifidus (mm^2) at the C6-7 level†	92.50 ± 26.64	95.10 ± 27.12	.166

Paired *t* test.
Values are presented as mean ± standard deviation.
* $P < .05$; Significantly different between 2 sides.
† Cervical spine level.

Table 3

Relative Cross-sectional area of the cervical multifidus muscles in the patients.

Variable	Affected side	Unaffected side	*P* value*
Multifidus (mm^2) at the C4-5 level†	0.26±0.10	0.27±0.09	.102
Multifidus (mm^2) at the C5-6 level†	0.27±0.10	0.28±0.10	.013
Multifidus (mm^2) at the C6-7 level†	0.30±0.12	0.31±0.11	.241

Paired *t* test.
Values are presented as mean±standard deviation.
* $P<.05$; Significantly different between 2 sides.
† Cervical spine level.

at the C5-6 level (rCSA of multifidus: 0.27±0.10 in the affected side and 0.28±0.10 in the unaffected side, respectively) ($P<.05$) (Table 3). There was no significant difference of rCSA between both sides at the C4-5 level (rCSA of multifidus: 0.26±0.10 in the affected side and 0.27±0.09 in the unaffected side, respectively) ($P=.102$) (Table 3). Similar results were shown in the rCSA of the multifidus muscle at the C6-7 level (rCSA of multifidus: 0.30±0.12 in the affected side and 0.31±0.11 in the unaffected side, respectively) ($P=.241$). There were no significant differences in CSAs that were independently measured twice ($P>.05$).

4. Discussion

In electrodiagnostic evaluation, following any lesion that results in deprivation of the muscle fiber's nerve supply, the first abnormality noted is an alteration in the resting membrane potential to a less negative value that approaches within several millivolts of the threshold value. The resting membrane potential then begins to ossilate.[14] The combination of the above 2 factors results in the generation of spontaneous single muscle fiber discharges that continue until the muscle fiber is either reinnervated or completely atrophied. These single muscle fiber denervation discharges (positive sharp waves and fibrillation potentials) are the hallmark of abnormal potentials in radiculopathies.[29]

After denervation, reinnervation begins to occur, with the development of alteration in MUAP morphology. The MUAP changes expected secondary to collateral sprouting is based upon the addition of more muscle fibers to individual motor units. Thus, the spared motor units each participating in collateral reinnervation of denervated fibers eventually contain a greater number of muscle fibers. Each newly formed collateral sprout requires some time to be fully myelinated. As a result, impulse conduction through the collateral sprout is at first tenuous and may fail. Also, poorly myelinated fibers demonstrate rather slow conduction velocities initially. These characteristic anatomic changes have direct consequences with respect to MUAP morphology in a patient with radiculopathies (reduced recruitment with increased duration, amplitude, and polyphasic pattern). If these electrodiagnostic findings are present in C6 myotomal distribution with normal sensory NCS, it can be diagnosed as C6 radiculopathy regardless of the EMG findings of cervical PSMs.[30]

Alterations in the physical characteristics of cervical muscles indicate changes in the behavior and function of the patients with cervical pain.[15] Fear of painful movement leads to a decrease in related movement. Consequently, avoidance of motion leads to muscle disuse and atrophy, which can lead to more pain.[16] Structural changes of the deep extensors muscles, such as CSA asymmetrical atrophy, constitutional change, and delayed activation patterns have been reported in patients with neck pain when compared to healthy controls.[15] Fortin et al reported that a significant increase in the asymmetry of CSA of multifidus muscles was present at the level below spinal cord compression in the patients with cervical myelopathy.[17]

There are several theories that have been proposed to explain the atrophy of paraspinal muscles in lumbar radiculopathy. In some studies, it has been suggested that muscles denervation is the reason for asymmetric atrophy of the lumbar multifidus in patients with unilateral radiculopathy.[5,18,19] In other studies, disuse is proposed as the main reason for reflex inhibition and atrophy of lumbar multifidus following disc injuries.[20–22] These theories could explain the unilateral reduction of CSA of cervical multifidus muscles in patients with unilateral radiculopathy. This study included those who were diagnosed with cervical radiculopathy via electromyography and MRI. Electromyography showed denervation in the muscle of the lesion side, which may be attributed to dysfunction of the cervical nerve root. It can be assumed that muscle atrophy of patients with cervical radiculopathy results from the same cause as denervation resulting from asymmetric atrophy of lumbar multifidus in patients with lumbar radiculopathy. Alternatively, neural drive to the multifidus could be reduced by an inhibitory process (reflex inhibition), involving afferent discharge from the mechanoreceptors in the disc. The activity of extensor muscles is reduced in response to mechanical stimuli, such as pinching the joint capsulea.[23–25] Reduced activity due to inhibition is likely to result in disuse-related muscle changes. However, multifidus muscle fascicles also pass further inferiorly. Localization to a single vertebral level suggests that atrophy may specifically involve the deeper fibers of the muscle. Michele et al. reported that asymmetry of multifidus is most apparent from the muscle measurement at the disc level below the affected disc, and to a lesser degree at the level of herniation, because of the unisegmental innervation of multifidus.[19] Because we include C5-6 radiculopathy patients, C4 level multifidus may not seem to be affected by denervation of a nerve root. As the cervical multifidus is one of the neck stabilizer muscles,[26] loss of its CSA and rCSA might decrease muscle function.[11] Reduction in the stability of the neck due to atrophy of the longus colli muscle could make the cervical region susceptible to more injuries. Therefore, functional and strengthening exercises for cervical PSMs might prevent further dysfunction.[27] It is also unclear whether atrophy of the multifidus muscles in patients with cervical radiculopathy is a consequence or cause. Nonetheless, these study findings indicate that after reduction of cervical radicular pain, a rehabilitation program aiming at strengthening neck flexor muscles might be required. Further studies in this field would be helpful for promoting knowledge regarding the role of this muscle in the nonsurgical management of cervical radicular pain.

This study had some limitations. First, the study sample size was small. Second, medical treatment and daily activity were not assessed. Medical treatment may lead to pain relief, which may also affect the structure of cervical muscles. Third, we only used a gross measurement technique and did not allow for any computation of muscle degeneration by an increased amount of fatty deposits within the muscle. Fourth this study was implemented at a single institution, and there is a strong rationale for it to be multicenter-based study. Finally, the muscle composition of the unilateral radiculopathy patients was unknown. Change in the composition of muscle, such as fatty atrophy, should be included in the future studies.

5. Conclusion

In conclusion, the study findings suggest that atrophy of the multifidus muscles ipsilateral to the cervical radiculopathy was observed in patients who suffered from unilateral radiculopathy. Therefore, rehabilitation exercises should be recommended for patients with PSMs dysfunction.

Author contributions

Conceptualization: Yong Kim, Jinmann chon.
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