Changes in the cross-sectional area of deep posterior extensor muscles of the cervical spine after anterior decompression and fusion: 10-year follow-up study using MRI

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Abstract

Purpose To evaluate changes in the transverse area of deep posterior muscles of the cervical spine 10 years after anterior cervical decompression and fusion (ACDF), in comparison with healthy volunteers.

Methods Thirty-one patients (22 males, 9 females, mean age at follow-up 59.3 years, mean follow-up 12.1 years) who had undergone preoperative MRI and non-instrumented ACDF within levels C3-4 to C5-6 were enrolled. 32 asymptomatic volunteers (17 males, 15 females; mean age, 54.7 years; mean follow-up, 11.7 years) who underwent MRI between 1993 and 1996 served as controls. Follow-up MRI was performed on both patients and control subjects,

and the cross-sectional areas of deep posterior muscles were measured digitally at levels C3-4, 4-5, and 5-6.

Results The mean total cross-sectional area in the ACDF and control groups was $4,693.6 \pm 1,140.9$ and $4,825.8 \pm 1,048.2 \text{ mm}^2$ in the first MR study ($P = 0.63$), and $4,616.7 \pm 1,086.0$ and $5,036.7 \pm 1,105.6 \text{ mm}^2$ at follow-up ($P = 0.13$). The total cross-sectional area in the ACDF group slightly decreased, while that in the control group increased (-77.1 ± 889.7 vs. $210.9 \pm 622.0 \text{ mm}^2$, $P = 0.14$). The mean change in the cross-sectional area had no significant correlation with clinical symptoms, including neck pain or JOA score.

Conclusions ACDF patients did not show a marked decrease in the cross-sectional area of the deep posterior cervical muscles, but as compared with control subjects there was a slight decrease. A decrease in the cross-sectional area of these muscles after ACDF may not result in the axial symptoms as seen in patients treated by posterior surgery.

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Introduction

The deep posterior extensor muscles of the cervical spine (posterior muscles) are important anatomical structures that maintain cervical alignment and neck extension. Posterior surgeries for cervical spinal disorders have been reported to cause atrophy and damage in these muscles, leading to neck pain either with or without malalignment of the cervical spine [1, 7, 13, 14].

Anterior decompression and fusion (ACDF) is a standard surgical method for various cervical spinal disorders.

ACDF is considered advantageous over posterior procedures in that it does not violate posterior structures of the cervical spine, thereby preventing the development of postoperative axial pain [14]. However, ACDF may potentially affect the posterior muscles due to a loss of motion at fused segments. Although there have been several cross-sectional studies on posterior muscles in healthy subjects [2], patients undergoing posterior surgery [12, 13], and those suffering from whiplash injury [3], no study to date has examined the long-term changes in posterior muscles after ACDF.

Therefore, the present study's objective was to evaluate the change in the cross-sectional area of posterior muscles 10 years after ACDF in comparison with the change in healthy volunteers, using MRI.

Materials and methods

Before beginning this study, we obtained approval from the institutional review boards of the participating institutions. As previously reported [9], 110 patients underwent pre-operative MRI and one- or two-level non-instrumented ACDF for disc hernia or spondylosis at the participating hospitals between 1990 and 1997. Of these patients, 68 agreed to participate in the follow-up study. The inclusion criteria for the present study were as follows: (1) patients who underwent ACDF at levels including C3-4, 4-5, and 5-6; (2) patients whose initial and follow-up MRIs were performed with a 1.5-Tesla superconducting machine; (3) those with T2-weighted axial images from both initial and follow-up scans of sufficient quality to allow quantitative measurements; and (4) patients who did not undergo revision surgery before the follow-up MRI. Thus, 31 patients (22 males, 9 females, mean age at follow-up study 59.3 years, mean follow-up 12.1 years) were included for the final analyses. 17 patients and 14 patients underwent one- or two-level fusion, respectively. The fusion level was C3-4 in two, C4-5 in seven, C5-6 in eight, C4-6 in four, C5-7 in nine, C3-4 and C5-6 in one. In the 1990s, the usual postoperative course was for patients to stay in bed with their head held between hard pillows for 1 week, after which they were allowed to stand and walk using a plastic cervical brace, which was used for 3 months.

In the previous study, which was conducted between 1993 and 1996, MRIs were also performed on 497 asymptomatic healthy volunteers who had no history of cervical trauma or surgery [5, 8, 10, 11]. In the follow-up study 10 years later, 223 of these volunteers participated. Of these, 32 volunteers who were 35 years or older, and who fulfilled the second and third inclusion criteria for the ACDF group, were included as controls in this study (17 males, 15 females; mean age at follow-up 54.7 years; mean

Table 1 Demographics of subjects

	ACDF	Control
No.	31	32
Age at follow-up (years)	59.3	54.7
Male/female	22:9	17:15
Interval (years)	12.1	11.7

follow-up; 11.7 years) (Table 1). The cut-off line for age was determined to match the control group with the ACDF group.

The male-to-female ratio and the mean age were slightly higher in the ACDF group than in the control group, but the differences were not statistically significant. The follow-up period did not differ between the two groups.

Written consent was obtained from all participants after explaining the details of the present study. The participants also filled out questionnaires on their clinical symptoms related to the cervical spine.

MRI protocols

The previous study used a fast spin-echo technique on a 1.5-Tesla superconducting imager (Signa, General Electronic, WI, USA) with phased array coils. The pulse sequence was as follows: T1-weighted sagittal images [repetition time (TR)/echo time (TE), 520/12; echo train length, 4; thickness of slice, 5 mm; field of view (FOV), 24 cm; matrix size, 256 × 192; number of excitation (NEX), 4 times], T2-weighted sagittal images (TR/TE, 5,000/102; echo train length, 16; remaining items were the same as for the T1-weighted sagittal images), and T2-weighted axial images (FOV, 16 cm; remaining items were the same as for the T2-weighted sagittal images). In the present study, images were also taken by a fast spin-echo technique using a 1.5-T superconducting imager (Signa Excite HD 1.5 T, General Electronic WI) with the following imaging parameters: T1-weighted sagittal images (TR/TE, 380/8.2; echo train length, 2; thickness of slice, 4 mm; FOV, 24 cm; matrix size, 256 × 192; NEX, 3 times), T2-weighted sagittal images (TR/TE, 5,000/100; echo train length, 16; NEX, 3 times; remaining items were the same as for the T1-weighted sagittal images), and T2-weighted axial images (TR/TE, 5,000/102; thickness of slice, 5 mm; FOV, 16 cm; remaining items were the same as for the T2-weighted sagittal images). The axial images were taken on planes parallel to each intervertebral disc.

Measurements

The MR images of the previous and present studies were stored as DICOM formatted data. The cross-sectional areas of the multifidus, semispinalis cervicale, semispinalis

capitis, and splenius capitis at the intervertebral levels C3/4, C4/5, and C5/6 were digitally measured on T2-weighted axial images using Image J 1.42, a Java-based version of the public domain NIH Image software. The measurement was conducted by manually tracing defined regions of interest within the fascial border of each muscle bilaterally, as previously described [11]. This was repeated twice and the results were averaged. The intraobserver and interobserver reliabilities of the measurement were confirmed to be acceptable in the previous study [11]. Interval changes in the cross-sectional area were evaluated and compared between the two groups using paired and unpaired *t* tests.

Results

The mean cross-sectional area of posterior muscles in the ACDF group was $1,474.6 \pm 431.0 \text{ mm}^2$ at C3-4, $1,663.1 \pm 431.8$ at C4-5, $1,556.0 \pm 436.8$ at C5-6, and $4,693.6 \pm 1,140.9$ in total before surgery, and $1,514.7 \pm 396.5 \text{ mm}^2$, $1,622.2 \pm 532.3$, $1,484.4 \pm 316.4$, and $4,616.7 \pm 1,086.0$ at follow-up, respectively (Table 2). There was a slight decrease in the total cross-sectional area at follow-up (mean, $77.1 \pm 889.7 \text{ mm}^2$), although it was not statistically significant ($P = 0.63$). Although the cross-sectional area was significantly larger in males (preop., $5,188.5 \pm 937.1$; follow-up, $5,024.5 \pm 1,003.5 \text{ mm}^2$; $P < 0.001$) than in females (preop., $3,484.0 \pm 506.7$; follow-up, $3,620.0 \pm 452.5 \text{ mm}^2$; $P < 0.001$) in both studies, the change over time was not significantly different between genders (decrease by 164.3 ± 886.6 vs. increase by $136.0 \pm 912.6 \text{ mm}^2$, $P = 0.4$).

The mean change in the cross-sectional area at fusion levels and non-fusion levels was $68.0 \pm 339.0 \text{ mm}^2$ (decrease) and 362.1 ± 1.4 (increase) ($P = 0.139$), respectively; it was $132.1 \pm 834.7 \text{ mm}^2$ (increase) in patients with single-level fusion and 331.2 ± 917.8 (decrease) in those with two-level fusion ($P = 0.152$).

There was no significant association between changes in the cross-sectional area and clinical symptoms, including neck pain, shoulder stiffness, or arm pain/numbness (Table 3); nor was there a significant correlation between changes in the cross-sectional area and JOA score at the follow-up examination (14.6 ± 2.8 points) (Pearson's correlation coefficient: 0.08, $P = 0.67$).

In the control group, the mean cross-sectional area of posterior muscles was $1,504.0 \pm 344.3 \text{ mm}^2$ at C3-4, $1,640.9 \pm 391.8$ at C4-5, $1,681.0 \pm 376.9$ at C5-6, and $4,825.8 \pm 1,048.2$ in total in the first MR study, and $1,619.5 \pm 388.6$, $1,707.0 \pm 406.9$, $1,710.3 \pm 369.7$, $5,036.7 \pm 1,105.6$ at the follow-up, respectively.

The mean total cross-sectional area did not differ between ACDF and control groups in the first ($P = 0.63$)

Table 2 Cross-sectional area of posterior extensor muscles in ACDF group

	Preop.				Postop.			
	Multifidus	Semispinalis cervicale	Semispinalis capitis	Splenius capitis	Total	Multifidus	Semispinalis cervicale	Semispinalis capitis
C3-4	225.0 $\pm$ 67.0	214.9 $\pm$ 65.3	586.7 $\pm$ 233.3	448.0 $\pm$ 138.6	1,474.6 $\pm$ 431.0	208.9 $\pm$ 71.3	191.2 $\pm$ 74.3	605.3 $\pm$ 221.4
C4-5	321.5 $\pm$ 126.1	326.7 $\pm$ 108.3	537.4 $\pm$ 154.2	477.5 $\pm$ 159.7	1,663.1 $\pm$ 431.8	312.0 $\pm$ 203.6	296.7 $\pm$ 177.0	543.8 $\pm$ 145.3
C5-6	294.2 $\pm$ 87.3	318.4 $\pm$ 66.3	470.7 $\pm$ 190.3	472.7 $\pm$ 156.4	1,556.0 $\pm$ 436.8	264.8 $\pm$ 88.6	306.6 $\pm$ 78.5	457.0 $\pm$ 140.3
Total	840.6 $\pm$ 228.5	860.0 $\pm$ 178.7	1,597.7 $\pm$ 502.5	1,398.2 $\pm$ 419.3	4,693.6 $\pm$ 1,140.9	785.6 $\pm$ 310.0	794.7 $\pm$ 269.8	1,606.0 $\pm$ 450.2
Total								

The cross-sectional area is shown as mm^2

Table 3 Clinical symptoms and time-interval changes in total cross-sectional area of posterior extensor muscles

	Neck pain		Shoulder stiffness		Arm pain/numbness	
	+	–	+	–	+	–
No. of patients	8	23	17	14	15	16
Changes in cross-sectional area	-210.8 ± 736.7	-30.6 ± 947.6 ($P = 0.63$)	-281.9 ± 706.0	$171.5 \pm 1,044.8$ ($P = 0.16$)	-354.1 ± 700.1	182.5 ± 988.4 ($P = 0.09$)

or follow-up ($P = 0.13$) MR study. The decrease in total cross-sectional area in the ACDF group (decrease by 77.1 ± 889.7) versus the increase in the control group (increase by 210.9 ± 622.0), represented no statistically significant difference ($P = 0.14$).

Discussion

The present study demonstrated that the cross-sectional area of posterior muscles in ACDF patients was almost maintained, even at the 10-year follow-up point (Fig. 1). This is in remarkable contrast to previously reported results of posterior procedures, which showed a decrease of up to 60% in posterior muscles after surgery [12, 13]. Although neck pain was observed in 25.8% of the ACDF patients at follow-up, no significant association was observed between neck pain and changes in the cross-sectional area of the posterior muscles over time. Thus, the present study supports the advantage of ACDF in preserving the posterior muscles, thereby making postoperative axial pain less likely.

It is reported that body muscle mass tends to decrease with aging [2, 4, 6]. Therefore, changes in the cross-sectional area of posterior muscles in ACDF patients at long-term follow-up may have been influenced by the aging process, and should be compared with the changes in healthy controls to adjust for this influence. In the present study, the decrease in cross-sectional area in ACDF patients represented a slight difference from control subjects, whose cross-sectional area slightly increased. This decrease may be partly attributable to mobility loss in the cervical spine from fusion; the decrease tended to be greater at fusion than at non-fusion levels, and greater in patients with two-level fusion than in those with single-level fusion, although these findings were not statistically significant.

Janssen et al. [6] measured skeletal muscle mass using whole-body MRI in 468 healthy adults, and found that men had significantly more skeletal muscle mass than women and that significant muscle mass reduction was not observed until the end of the fifth decade. The results of Janssen's study were quite similar to those of the present study. The amount of decrease or increase in the cross-sectional area of the posterior muscles was very small in both ACDF patients and controls, possibly because the

Fig. 1 A 35-year-old male underwent ACDF at C5-6 for cervical disc herniation. **a** MRI from the previous study. The cross-sectional area of posterior extensor muscles was $1,605.8 \text{ mm}^2$ at C5-6. **b** MRI at follow-up. The cross-sectional area of posterior extensor muscles increased slightly to $1,752.2 \text{ mm}^2$ at C5-6

mean age at the follow-up MR study, fifties in both groups, was before a significant reduction of muscle mass would be expected, according to Janssen's observations.

This study has several limitations. First, the sample size was not large. Second, although superconductive MRI machines were used in both studies, there were differences in the MR machines and in the pulse sequences used

between the two studies, which might have influenced the measurement results. However, this condition was true for both groups, so their comparison is reasonable.

In conclusion, ACDF patients did not show a marked decrease in the cross-sectional area of posterior muscles, but it was slightly different from that of control subjects, who showed an increase. However, this decrease in the cross-sectional area of posterior muscles after ACDF did not result in development of the axial symptoms seen in patients treated by posterior surgery.

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Conflict of interest None.

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