The effect of multilevel anterior cervical fusion on neck motion

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Abstract

Background Anterior cervical decompression and fusion (ACDF) procedures are successful in treating multilevel cervical radiculopathy and cervical myelopathy. It was reported that this procedure would result in a loss of cervical range of motion. However, few studies have focused on the exact impact of multilevel (more than 3 levels) ACDF on cervical range of motion.

Methods 29 patients underwent a 3-level or 4-level ACDF. In all the patients, preoperative active cervical ROM measurement was performed, and postoperative measurement was performed at 1-year follow-up by a CROM device. The pre- and postoperative data were compared to each other using paired *t* tests ($\alpha = 0.05$).

Results The patients had significantly less ROM after the surgery in all planes of motion. Major reduction was observed in flexion (39.5%), left and right lateral flexion (25.7 and 25.9%), with relatively minor impact on extension (18.3%), left and right rotation (14.0 and 14.4%) observed. In the three cardinal planes, major reduction was observed in the sagittal plane (28.2%) and coronal plane (25.8%), while minor impact observed in the horizontal plane (14.1%).

Conclusions The patients of cervical spondylotic myelopathy had an obvious reduction in active cervical ROM following multilevel ACDF. However, patients might not experience great difficulties in performing daily activities with regard to the loss of neck motion after fusion.

Keywords Multilevel · Anterior cervical decompression and fusion · Cervical range of motion · Cervical spondylosis

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Introduction

Cervical spine is highly mobile, allowing for a wide visual field. While, at the same time, it functions to protect the spinal cord and contribute to overall alignment. Active range of motion (ROM) of cervical spine has been studied in healthy subjects by numerous investigators [1, 2]. Increasing age results in 30–40% decrease in cervical range of motion in all three cardinal planes, while gender and BMI do not have a substantial influence on cervical range of motion [1–5].

Cervical degenerative disorders may cause spinal cord and/or nerve root compromise. It has been shown that patients with cervical degenerative disorders have a significantly less cervical ROM than normal subjects [5–7].

Anterior cervical decompression and fusion (ACDF) has been a successful and reliable procedure for treatment of cervical degenerative disorders [8–12]. It restores cervical lordosis better and directly decompresses the spinal cord by removing the offending soft or hard discs [13]. Due to the procedure, removal of intervertebral disc and fusion at the compressive site was supposed to reduce neck motion. However, in Hilibrand's research, patients following single-level or double-level anterior cervical decompression and fusion had gained a significant increase in the passive cervical range of motion [9]. To our knowledge, few studies have focused on the exact impact of multilevel (more than 3 levels) ACDF on cervical range of motion.

The purpose of this study was to investigate the impact of multilevel ACDF on active cervical range of motion in three cardinal planes.

Materials and methods

Patient data

16 male and 13 female patients with cervical spondylotic myelopathy participated in this study. The ages varied from 40 to 56 years (mean 49 years). All the patients had a history of cervical spondylotic myelopathy varying from 5 to 20 years. The subjects included 17 patients scheduled for a 3-level ACDF and 12 patients scheduled for a 4-level ACDF. The surgical indication was cervical spondylotic myelopathy with neurological deficits. Patients with cervical spondylotic radiculopathy alone or ossification of posterior longitudinal ligament (OPLL) were excluded from this study. None of the patients had a history of spasmodic torticollis, myasthenia gravis, motor neuron disease, ankylosing spondylitis, scoliosis, cervical spine trauma or tumor.

All operations were performed by a single surgeon (Y. W.) at a single institution between 2007 and 2010. Anterior fusion was performed with interbody cage and/or titanium mesh (DePuy Spine, Johnson & Johnson, New Jersey, USA) combined with dynamic plate fixation (Slim-Loc, DePuy Spine, Johnson & Johnson, New Jersey, USA). Anterior right-sided approach was advocated for each patient. The operation time ranged from 2 to 4 h. All the patients were immobilized after surgery in cervical hard collars for 6–8 weeks. Radiographic evaluation was conducted using neutral lateral and flexion–extension lateral cervical plain radiographs before surgery and at 1-year follow-up for all the patients. The radiographs were evaluated for bony fusion at the operated segment. In all the patients, preoperative active cervical ROM measurement was performed, and postoperative measurement was performed at 1-year follow-up.

Neck pain evaluation

All patients were assessed using Visual Analog Scale (VAS) and Neck Disability Index (NDI) for neck pain before surgery and at 1-year follow-up.

The CROM device

The CROM device (Performance Attainment Associates, 958 Lydia Drive, Roseville, MN 55113, USA) was applied for active cervical ROM measurement. This device has been shown to have good intra-tester and inter-tester reliability for measures of active cervical motion in the cardinal planes [14, 15]. The measurement of the six conventional motions of the cervical spine was performed (i.e., cervical flexion, extension, and left and right components of lateral flexion and rotation). The total ROM within a cardinal plane was determined by summation of the two opposite movement values in the same plane (i.e., the total ROM in the sagittal plane was a summation of the flexion and extension values).

Active cervical ROM measurement

All subjects sat in a standard metal-frame chair so that their thoracic spine maintained contact with the chair's backrest and their lumbosacral spine filled the gap between the seat and the backrest. Their feet were positioned flat on the floor, and their arms rested freely at their sides. As instructed by the tester, each subject performed three repetitions of active neck motion (warm-ups) in each direction within a designated cardinal plane to increase compliance of the neck's soft tissues. The tester instructed each subject to move the head until the ROM was stopped by muscle tightness or pain or until a substitution movement occurred. Then, subjects were instructed to sit upright and look straight ahead. This position was taken as the neutral position and was measured for each plane. An overhead transparency of a grid pattern was projected on the wall in order to mark the initial position of each subject (neutral position). The grid ensured that the same initial starting position was maintained during each trial. After each movement, the neutral position was obtained by asking the subject to replace his head until the markers of the grid confirmed the starting position.

Extension and flexion was measured by asking the patients to bend the head backward then forward as far as possible.

Lateral flexion was measured by asking the patients to touch the left and right shoulders with the ears, respectively.

Rotation was measured by asking the patients to rotate the head to the left and then to the right as far as possible.

Statistical methods

Pre- and postoperative clinical parameters were compared using the nonparametric Wilcoxon matched pairs signed-ranks test, as scores were not normally distributed. 95% binomial confidence intervals were calculated. The active cervical ROM data of the six conventional motion of the cervical spine and the total ROM data within each plane of motion were presented as mean $\pm$ SD. The mean value and the standard deviation of the preoperative data and postoperative data were calculated. The difference between the preoperative data and postoperative data was analyzed. Pre- and postoperative ROM data were compared with each other using paired *t* tests. In all instances, we considered $P < 0.05$ as significant.

Results

After surgery, neck pain improved by a VAS score of 3 (95% CI 0–4, $P < 0.0001$). An improvement in NDI score of 18 (95% CI 12.6–31.0, $P < 0.0001$) was observed.

Intervertebral fusion was documented by radiograph at 1-year follow-up for all the patients (Fig. 1). Comparison

of the pre- and postoperative active cervical ROM demonstrated that patients had significantly less ROM after the surgery in all planes of motion ($P < 0.001$) (Figs. 2, 3, 4). The mean value and the standard deviation of the preoperative, postoperative and reduced cervical ROM data are presented in Table 1 (the reduced ROM data were calculated as the preoperative ROM data subtracting the postoperative ROM data, the reduction percentage was calculated as the reduced ROM data divided by the preoperative ROM data). Major reduction was observed in flexion (39.5%), left and right lateral flexion (25.7 and 25.9%), with relatively minor impact on extension (18.3%), left and right rotation (14.0 and 14.4%) observed. In the three cardinal planes, major reduction was observed in the sagittal plane (28.2%) and coronal plane (25.8%), while minor impact observed in the horizontal plane (14.1%).

Discussion

This study demonstrated that patients of cervical spondylotic myelopathy had an obvious reduction in active cervical

Fig. 1 Photograph of active cervical ROM measurement for lateral flexion, flexion and extension

Fig. 2 Neutral lateral and flexion–extension lateral cervical plain radiographs at 1-year follow-up for one patient. Note the presence of a bony bridge across the operative segment and no movement on flexion and extension radiographs

Fig. 3 Graph indicating a decrease of cervical ROM in the six conventional motion following ACDF. Note that flexion, left and right lateral flexion was the most affected motion, while extension, left and right rotation was slightly affected

Fig. 4 Graph indicating a decrease of cervical ROM in the three cardinal planes following ACDF. Note that major limitation was observed in the sagittal plane and coronal plane, while minor impact observed in the horizontal plane

ROM following the surgery of multilevel ACDF. Okamoto et al. [16] has also reported that patients following anterior fusion (especially more than 3-level fusion) for cervical spondylotic myelopathy had restriction of neck motion in performing basic movements of daily living. This study revealed the impact of multilevel anterior fusion on neck motion. Out of the six conventional motions, flexion, left and right lateral flexion, was the most affected motion following surgery, while extension, left and right rotation was slightly affected. In the three cardinal planes, major limitation was observed in the sagittal plane and coronal plane, while minor impact was observed in the horizontal plane.

Patients with cervical degenerative disease, including cervical spondylotic myelopathy and/or radiculopathy, have a significantly less cervical ROM than normal subjects (Table 2). In an earlier cadaveric study, Lysell et al. found that degenerative changes had no effect on segmental motion. However, this was contradicted by a passive cervical ROM study, Dvorák et al. [7] demonstrated that patients in the degenerative group and radicular group had significantly less cervical ROM than normal subjects. The same result was reported in an active cervical ROM study by Dvir et al. [6], who showed a reduction in overall cervical ROM in patients with degenerative changes. In this study, before surgery, patients had a lower active cervical range of motion compared with the normal cervical ROM for healthy subjects in the previous studies [1, 2, 4, 17] (Table 2). Cervical spondylosis would adversely affect facet joint and intervertebral disc mobility and limit their overall ROM. Pain is another factor that could account for the decreased ROM.

Two possible factors may contribute to the impact on the postoperative cervical ROM, namely pain and loss of

Table 1 The mean value and the standard deviation of the preoperative, postoperative and reduced cervical ROM data

	Flexion	Extension	Flexion–extension	Left flexion	Right flexion	Lateral flexion	Left rotation	Right rotation	Total rotation
Preoperation	49.1 ± 6.6	56.4 ± 10.7	105.5 ± 12.8	41.7 ± 8.1	40.6 ± 7.4	82.3 ± 13.8	64.8 ± 8.5	64.1 ± 8.8	128.8 ± 14.3
Postoperation	29.6 ± 8.8	46.1 ± 7.7	75.8 ± 13.5	31.0 ± 6.9	30.1 ± 7.2	61.1 ± 13.5	55.7 ± 6.5	54.9 ± 5.2	110.6 ± 10.9
Reduction	19.4 ± 8.3	10.3 ± 7.3	29.7 ± 10.8	10.7 ± 6.5	10.5 ± 9.3	21.2 ± 13.9	9.1 ± 9.33	9.2 ± 6.9	18.2 ± 12.3
Reduction (%)	39.5	18.3	28.2	25.7	25.9	25.8	14.0	14.4	14.1

Table 2 The active cervical ROM data of normal subjects from other studies and patients from this study

Authors	The mean value of active cervical ROM data		
	Sagittal plane	Coronal plane	Horizontal plane
Alund and Larsson	140.0	91.0	156.0
Bennett et al.	148.0	75.0	151.0
Leighton	127.0	98.0	159.0
Defibaugh	137.0	95.0	164.0
Wu			
Preoperative	105.5	82.3	128.8
Wu			
Postoperative	75.8	61.1	110.6

^a Some data were quoted from the paper by Youdas et al. [2]

segmental motion at fusion sites. Pain might be a limiting factor affecting the ROM before surgery. In this study, surgical decompression and fusion relieved the pain; this may allow patients to gain significant ROM after surgery. Hilibrand et al. has indicated that patients following single-level or double-level anterior cervical fusion had gained a significant increase in the cervical range of motion. However, the opposite factor was that fusion eliminated the mobile segment of the cervical spine, which resulted in a loss of cervical ROM in these segments. This may play a major role in cervical ROM following multilevel anterior cervical fusion. Although compensatory motion always developed at the adjacent level [8, 18–20], the compensation may not be enough for the loss of motion of 3 or 4 segments.

Patients might not experience great difficulties in performing daily activities with regard to the loss of neck motion after fusion. In Okamoto's research, a questionnaire including 11 basic movements for daily living was evaluated for active cervical ROM [16]. Flexion–extension and rotation of the cervical spine are important for functional activity. After major decrease in flexion, restriction of movements in flexion can be compensated for by movements of the eyes, at the upper cervical spine, at the thoracolumbar spine, or at the hips and knees [9]. Bennett's research provided a baseline of normal motion of the neck

required for activities of daily living [21]. Of the 13 daily functional tasks performed, tying shoes (flexion–extension 66.7°), backing up a car (rotation 67.6°), washing hair in the shower (flexion–extension 42.9°), and crossing the street (rotation head left 31.7° and rotation head right 54.3°) required the greatest active range of motion of the cervical spine [8]. According to these results, patients after multilevel ACDF might not have difficulties in the tasks, such as reading, tying shoes, washing hair in the shower and crossing the street, but might have difficulties in the task of backing up a car (Table 1).

This study demonstrated that patients of cervical spondylotic myelopathy had an obvious reduction in active cervical ROM following multilevel ACDF. Major reduction was observed in flexion and lateral flexion, less impact on extension and rotation was detected. Patients might not experience great difficulties in performing daily activities, except for backing up a car, with regard to the loss of neck motion after fusion.

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Conflict of interest None.

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