

Importance of preserving the C7 spinous process and attached nuchal ligament in French-door laminoplasty to reduce postoperative axial symptoms

Tatsuto Takeuchi · Yasuhiro Shono

Received: 20 January 2006 / Revised: 14 February 2007 / Accepted: 26 February 2007 / Published online: 27 March 2007
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Abstract A comparative clinical trial was conducted to clarify the importance of preserving the C7 spinous process and attached nuchal ligament for the reduction of the axial symptoms after French-door laminoplasty in cervical spondylotic myelopathy patients. Forty-one cervical spondylotic myelopathy patients were enrolled. French-door laminoplasty from C3 to C7 in 22 patients (group 1), and from C3 to C6 in 19 patients (group 2) was performed. The whole structure of the C7 spinous process and the attached nuchal ligament were preserved in group 2. The pre- and post-operative evaluation regarding severity of clinical symptoms was assessed using the Japanese Orthopaedic Association (JOA) score. Pre-operative and subjective outcome regarding axial symptoms were also assessed using a visual analog pain scale questionnaire (VAS: 10–0, where a higher score indicates greater pain) at 1- and 2-year follow-up. Non-parametric testing (Mann–Whitney's *U* test) was used to establish differences between the two groups for categorical data ($P < 0.05$). There was no significant difference between the two groups in pre- and post-operative JOA score. The mean VAS was 5.6 ± 1.4 in group 1, 5.4 ± 1.7 in group 2 pre-operatively, and 6.4 ± 1.7 in

group 1 and 2.4 ± 1.9 in group 2 at 1-year follow-up. The mean VAS score at 2-year follow-up exhibited 6.2 ± 1.9 in Group 1, 2.3 ± 1.8 in group 2. There was no significant difference in VAS between the two groups before surgery ($P = 0.506$), but significant differences were noticed at 1-year and 2-year follow-up ($P < 0.05$), indicating the presence of significantly fewer post-operative axial symptoms in group 2. Laminoplasty of the entire C7 structure is not necessary to obtain satisfactory recovery based on JOA score. Preservation of the C7 spinous process and the attached nuchal ligamentous structures is important to reduce post-laminoplasty axial symptoms.

Keywords Axial symptoms · Laminoplasty · Nuchal ligament · Spinous process

Introduction

Laminoplasty has been widely used in the treatment of cervical spondylotic myelopathy (CSM). Various surgical procedures for laminoplasty have been reported, mainly for discussion of surgical techniques focused on osteoplastic procedures [2, 3, 6, 14–16, 19, 20], and most of them include the C7 level within a decompression range. The mean recovery rate of clinical symptoms regarding motor, sensory and bladder functions based on JOA score after laminoplasty in CSM patients have been reported ranging from 44.9 to 69.2% [1, 5, 6, 9, 12, 13, 17, 21, 24, 25]. Although an excellent recovery of the clinical symptoms is obtained after laminoplasty, patients often suffer from post-operative neck and shoulder pains, which are referred to as axial symptoms. There is not a strict definition of axial symptoms, which has been expressed as stiff neck [9], neck

No funds were received in support of this study. No benefits in any form have been or will be received from a commercial party related directly to the subject of this manuscript. The manuscript submitted does not contain information about medical device(s)/drug(s).

T. Takeuchi · Y. Shono
Department of Orthopaedic Surgery,
Kushiro Rosai Hospital, Hokkaido, Japan

T. Takeuchi (✉)
Department of Orthopaedic Surgery,
Shin-Nittetsu Muroran General Hospital,
1-45 Chiribetsu, Muroran, Hokkaido 050-0076, Japan
e-mail: july4th@mui.biglobe.ne.jp

pain [11], shoulder pain [11], or neck and shoulder pain [8, 9, 11]. However, in practice, such axial symptoms pose substantial problems for patients and lead to disability in daily life [9]. In this study, persistent pain distributed in the area of posterior neck and shoulder angle is considered as axial symptoms. Nuchal muscle atrophy is occasionally observed at follow-up in the patients which C7 spinous process was resected in laminoplasty. Absence of the C7 spinous process and the attached nuchal ligament may be related to axial symptoms, but this remains unclear, despite several studies of the biomechanical, histological and anatomical consequences of nuchal ligament detachment. Is it always necessary to decompress at the C7 level in cervical laminoplasty? The aim of this study was to evaluate the efficacy of preserving the C7 spinous process for reduction of axial symptoms after surgery.

Materials and methods

From April 2001 to May 2003, fifty-nine patients (44 males, 15 females) with cervical myelopathy underwent French-door laminoplasty in our hospitals. Excluding three patients who died of unrelated causes, a total of 56 patients (41 males, 15 females) were enrolled. Cervical myelopathy was caused by spondylosis in 41 patients, ossification of the posterior longitudinal ligament in 12 patients, ossification of the ligamentum flavum in 1 patient and trauma in 2 patients. In this study, these 41 CSM patients were evaluated to standardize comorbidity. The minimum post-operative follow-up period was 25.9 months. Patients were classified into two groups. Group 1 included 22 patients (13 males, 9 females) who underwent French-door laminoplasty without preservation of the C7 spinous process; therefore the region from C3 to C7 was posteriorly decompressed. The average age at the time of surgery in group 1 was 63.9 years old (range: 34–80 years old). They received operation between April 2001 and April 2002. Group 2 included 19 patients (15 males, 4 females) who underwent the same laminoplasty from C3 to C6; therefore the whole structure of the C7 spinous process and the attached nuchal ligament were preserved. In 10 patients of group 2, upper-half laminotomy of C7 was additionally performed. Spinal cord was compressed in the middle cervical spine in all patients before surgery. The mean age at the time of surgery in group 2 was 69.7 years old (range: 35–85 years). Patients in group 2 received operation after April 2002. There was no significant difference in age, JOA and VAS score and anteroposterior spinal canal diameter between the two groups preoperatively (Table 1). Patients in both groups received surgery within 12 months from the onset. All patients were allowed to ambulate the day after the operation, using no external supports.

Isometric neck and shoulder muscle exercises were started within a few days after surgery, and the patients were encouraged to continue the isometric muscle exercise after discharge. Patients were requested to visit our outpatient clinic at least once a year for the post-operative evaluations including JOA and VAS score. Final evaluation was accomplished at 2-year follow-up in this study.

Surgical procedure

The patient was placed in a prone position on the surgical table. A median incision was made, and the nuchal ligament was split along its midline. Ordinary midsagittal splitting laminoplasty from C3 to C7 was conducted in group 1. The same procedure ranging from C3 to C6 was performed in group 2 preserving the spinous process of C7 and the attached nuchal ligament. In both groups, the spinous processes in the range of decompression were resected. After the decompression from C3 through C6 in group 2, when the space between dural tube and the ventral aspect of C7 lamina was judged tight by surgeons using a micro probe, upper-half laminotomy of C7 was additionally performed to loosen the space. Although laminoplasty was performed in patients of group 2, the C7 spinous process was completely preserved. No bone grafting was performed in both groups. After a suction tube was positioned in the epidural space, bilateral paraspinal muscles and the divided nuchal ligaments were securely sutured.

JOA score

The severity of clinical symptoms was assessed using the JOA score (Table 2), both pre-operatively and at final follow-up. The recovery rate proposed by Hirabayashi et al. [7] was calculated according to the following formula: recovery rate (%) = $([\text{post-operative JOA score} - \text{pre-operative JOA score}] / [17 - \text{pre-operative JOA score}]) \times 100$. Pre-operative and the latest JOA

Table 1 Summary of cases

	Group 1	Group 2	P
Number of cases	22 (M 13, F 9)	19 (M 15, F 4)	
Age (years)	63.9 (34–80)	69.7 (35–85)	0.054
A–P canal diameter (mm)	14.0 ± 0.2	13.9 ± 0.2	0.830
Pre-operative JOA score	8.6 ± 1.7	8.3 ± 2.1	0.362
Pre-operative VAS score	5.6 ± 1.4	5.4 ± 1.7	0.506

All the subjects in both groups were cervical spondylotic myelopathy patients. Group 1: C7 spinous process was resected. Group 2: C7 spinous process was preserved. Data for age are shown as mean and the range is given in parentheses. Mean anteroposterior (A–P) spinal canal diameters from C3 to C7 are also shown. Patients received our interview at least once a year after discharge

Table 2 Scoring system (17-2) for cervical myelopathy proposed by the Japanese Orthopaedic Association (JOA score)

Category
<i>Motor function</i>
Fingers
0 = Unable to feed oneself with any tableware including chopsticks, a spoon or fork, and/or unable to fasten buttons of any size
1 = Can manage to feed oneself with a spoon and/or a fork but not with chopsticks
2 = Either chopstick-feeding or writing is possible but not practical, and/or large buttons can be fastened
3 = Either chopstick-feeding or writing is clumsy but practical, and/or cuff buttons can be fastened
4 = Normal
Shoulder and elbow
Evaluated by MMT score of the deltoid or biceps muscles, which is weaker
-2 = MMT 2 or below
-1 = MMT 3
-0.5 = MMT 4
0 = MMT 5
Lower extremity
0 = Unable to stand up and walk by any means
0.5 = Able to stand up but unable to walk
1 = Unable to walk without a cane or other support on a level
1.5 = Able to walk without a support but with a clumsy gait
2 = Walks independently on a level but needs support on stairs
2.5 = Walks independently when going upstairs, but needs support when going downstairs
3 = Capable of fast walking but clumsy
4 = Normal
<i>Sensory function</i>
Upper extremity
0 = Complete loss of touch and pain sensation
0.5 = 50% or below of normal sensation and/or severe pain or numbness
1 = Over 60% of normal sensation and/or moderate pain or numbness
1.5 = Subjective numbness of a slight degree without any objective sensory deficit
2 = Normal
Trunk
0 = Complete loss of touch and pain sensation
0.5 = 50% or below of normal sensation and/or severe pain or numbness
1 = Over 60% of normal sensation and/or moderate pain or numbness
1.5 = Subjective numbness of a slight degree without any objective sensory deficit
2 = Normal
Lower extremity
0 = Complete loss of touch and pain sensation

Table 2 continued

Category
0.5 = 50% or below of normal sensation and/or severe pain or numbness
1 = Over 60% of normal sensation and/or moderate pain or numbness
1.5 = Subjective numbness of a slight degree without any objective sensory deficit
2 = Normal
<i>Bladder function</i>
0 = Urinary retention and/or incontinence
1 = Sense of retention and/or dribbling and/or thin stream and/or incomplete continence
2 = Urinary retardation and/or pollakiuria
3 = Normal
Total for normal patient 17
Total (Recovery Rate %)

When selection is uncertain between two items, the one with the lower score should be adopted. When neurological disturbance is different between left side and right side, the side of lower score should be evaluated

score at 2-year follow-up and recovery rate were evaluated whether there was a significant difference between the two groups.

Terminology

Persisting nuchal pain distributed over the posterior neck and shoulder pain in the area of suspensory muscles were defined as axial symptoms. In this study, a term of axial symptom is distinguished from clinical symptoms including motor, sensory and bladder function based on JOA score.


Visual analog axial pain scale (VAS)

Preoperative neck and shoulder pain and subjective outcome regarding axial symptoms were assessed using a VAS questionnaire, on a scale from ten points (extremely severe pain) to 1 point (almost no pain) at discharge and at 1- and 2-year follow-up (Fig. 1). Zero point denoted no pain. Face mark system was used at the same time to assist patients understand. Pre- and post-operative VAS scores were evaluated whether there was a significant difference between the two groups.

Statistics

Non-parametric two-independent-samples testing, Mann–Whitney's *U*-test, was used to test the difference between

Fig. 1 Visual analog pain scale questionnaire. Patients were asked to indicate how much pain they had in their neck and shoulders; pre-operatively, at the time of discharge, at 1- and 2-year follow-up

					
	Little	Slight	Moderate	Major	Severe
	1 2	3 4	5 6	7 8	9 10
Neck and shoulder pain	0 = No pain Which number on the scale best fits the extent of your neck and shoulder pain?				

the two groups. *P* values less than 0.05 were considered significant.

Results

JOA score

No deterioration of clinical symptoms based on JOA score was observed after surgery. The mean JOA score in group 1 was 8.6 pre-operatively and 14.0 at the time of 2-year follow-up; an improvement rate of 65.0%. In group 2, the mean JOA score was 8.3 pre-operatively and 14.2 at final follow-up; an improvement rate of 65.2%. There was no significant difference in JOA score between the two groups before surgery and at follow-up. Recovery rate was not also significantly different between group 1 and 2 (Table 3).

VAS

All the patients replied to the VAS questionnaire before surgery, at the time of discharge. After discharge, patients were requested to visit our outpatient clinic at least annually, and they replied to the VAS questionnaire. The mean pre-operative VAS was 5.6 ± 1.4 in group 1 and 5.4 ± 1.7 in group 2. The mean VAS was 6.6 ± 2.3 in group 1 and 5.4 ± 2.0 in group 2 at discharge. The mean VAS at 1-year follow-up was 6.4 ± 1.7 in group 1 and 2.4 ± 1.9 in group 2. Similarly, the mean VAS at 2-year follow-up was 6.2 ± 1.9 in group 1 and 2.3 ± 1.8 in group 2. Although no significant difference in neck and shoulder pain was

observed between the two groups before surgery and at the time of discharge, there were significant differences at 1- and 2-year follow-up with patients in group 2 showed significantly less post-operative axial pain (Table 4).

Discussion

Axial symptoms expressed as neck and shoulder pain are often observed following cervical laminoplasty. Neck pain indicates a pain distributed over the posterior neck, while shoulder pain occurs over the shoulder angle [9]. However, it is difficult to strictly distinguish the pain between posterior neck and shoulder angle. In this study, persistent pain distributed in the area of posterior neck and shoulder angle was considered as axial symptoms.

Laminoplasty has been widely used for the treatment of cervical myelopathy, and this procedure provides satisfactory neurological recovery [1, 5, 6, 9, 12, 13, 17, 21, 24, 25]. However, even an excellent neurological recovery is obtained after laminoplasty, patients often suffer from axial symptoms. Several authors have briefly discussed axial symptoms with regard to laminoplasty [2, 11, 17, 18, 21]. These studies suggest that persistent axial pain is one of the main complaints that disturb activities of daily living following laminoplasty, even though neurological improvement is achieved post-operatively. Low back pain is one of the most important interests associated with lumbar spine surgery; nevertheless, merely one quantitative study analyzing axial symptoms after laminoplasty has been reported [9]. However, there has been no study that explains the

Table 3 Pre-operative and post-operative JOA scores

	Pre-operative	2-year follow-up	Recovery rate (%)
Group 1	8.6 ± 1.7	14.0 ± 1.9	65.0 ± 19.5
Group 2	8.3 ± 2.1	14.2 ± 1.6	65.2 ± 23.0
<i>P</i>	0.362	0.798	0.866

Mean \pm standard deviation. Recovery rate was calculated by JOA scores at pre-operative and 2-year follow-up

Table 4 Visual analog axial pain scale (VAS)

	Pre-operative	Discharge	1-year	2-year
Group 1	5.6 ± 1.4	6.6 ± 2.3	6.4 ± 1.7	6.2 ± 1.9
Group 2	5.4 ± 1.7	5.4 ± 2.0	2.4 ± 1.9	2.3 ± 1.8
<i>P</i>	0.506	0.158	<0.05	<0.05

Mean \pm standard deviation

mechanics of axial pain. How can we prevent axial symptoms after laminoplasty?

Cervical laminoplasty is a well-established surgical procedure for treatment of myelopathy. There are several kinds of laminoplasty, including French-door type, expansive open-door type [6, 17], osteoplastic type [20], Kurokawa type [2, 15, 16], and hardware-assisted type laminoplasty [4, 19, 22]. The mean recovery rate of clinical symptoms based on JOA score of 44.9–69.2% have been reported after laminoplasty in CSM patients [1, 5, 6, 9, 12, 13, 17, 21, 24, 25]. In most of these reports, C7 level was usually included within the decompression range without any reasons. In our study, posterior decompression at C7 level resecting spinous process was done in group 1, on the other hand, C7 spinous process and attached nuchal ligament was preserved in group 2. The average recovery rate based on JOA score showed 65.0% in group 1, 65.2% in group 2, and there was no significant difference in recovery rate between the two groups. Our results were similar to those reported in previous studies [1, 9, 12, 17, 25]. Therefore, it is suggested that laminoplasty of the entire C7 structure is not necessary to obtain satisfactory recovery.

A VAS questionnaire showed that there was a significant difference in the subjective outcome with regard to axial symptoms at final follow-up. Significantly less post-operative axial pain was observed in group 2 (patients with surgery preserving the C7 spinous process and attached nuchal ligament). Hosono et al. [9] have reported that axial symptoms after laminoplasty occurred with an incidence of 60% in their CSM patients, and Kawaguchi et al. [12] showed significant neck pain and stiffness in 68% of their patients. Other authors have reported an incidence of axial symptoms after laminoplasty [9, 11, 17, 18, 21], but no study has investigated the effects of C7 spinous process preservation in axial symptoms after laminoplasty. Brief, easy-to-use and common outcome measures may be required to evaluate the axial symptoms [23]. According to Johnson et al., even nuchal ligament detachment from the C7 spinous process may affect contraction of the nuchal muscles [10]. We consider that nuchal ligament is a strong ligamentous structure that functions like a tightly-stretched cable between the two struts of a suspension bridge. It supports the tension of the nuchal musculature, and assist in head position and control as a proprioceptive ligament [3]. Therefore, tension of the nuchal ligament is important and its attachment to the C7 spinous process should be preserved to decrease post-laminoplasty axial symptoms. Our study showed that axial symptoms observed at final follow-up were significantly reduced in group 2 when compared to group 1 (patients with surgery resecting the C7 spinous process). That is, surgeon should preserve the C7 spinous process to prevent axial symptoms after French-door laminoplasty.

Conclusion

The goal of this study is to report an important point to decrease axial symptoms after laminoplasty. We have compared the two groups (C7 spinous process resection group and preserved group) to find differences in recovery rate and in VAS. Recovery rate, that is, improvement in the severity of clinical symptoms based on JOA score after cervical laminoplasty did not differ between the two groups, while axial symptoms observed at 1- and 2-year follow-up by VAS were significantly less in the C7 spinous process preserved group than in the C7 spinous process resecting group. As a result, preserving the C7 spinous process and attached nuchal ligament is important to prevent axial symptoms.

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