Medium-term outcomes of C3–6 laminoplasty for cervical myelopathy: a prospective study with a minimum 5-year follow-up

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Abstract C3–6 laminoplasty preserving muscle insertions into the C7 spinous process is reportedly associated with a significantly decreased frequency of postoperative axial neck pain. However, no prospective study has reported medium-term outcomes of C3–6 laminoplasty. The purpose of this study was to elucidate medium-term outcomes after C3–6 laminoplasty. Subjects comprised 31 patients with cervical myelopathy who underwent C3–6 laminoplasty preserving all bilateral muscles attached to the C2 and C7 spinous processes and were followed for ≥ 5 years. Clinical and radiological data were prospectively collected. Neurological status was assessed using Japanese Orthopaedic Association (JOA) score. Axial neck pain was graded as severe, moderate or mild. Sagittal alignment of the cervical spine and progression of ossification of the posterior longitudinal ligament (OPLL) were assessed by comparing serial lateral radiographs. Mean JOA score improved significantly from 10.6 before surgery to 14.7 at the time of maximum recovery, and slightly declined to 14.3 at final follow-up. In six patients who developed late deterioration, these conditions were unrelated to the cervical spine. As of final follow-up, only one patient (3.2%) had complained of axial neck pain persisting for 5 years.

Although progression of OPLL was found in 63.6% of patients, none had experienced neurological deterioration due to this progression. At final follow-up, sagittal alignment of the cervical spine was more lordotic than before surgery. Medium-term outcomes of C3–6 laminoplasty were satisfactory. Frequencies of persistent axial neck pain and loss of cervical lordosis after surgery remained significantly decreased for ≥ 5 years postoperatively.

Keywords Cervical myelopathy · Laminoplasty · Medium-term outcomes · Postoperative complication · Second and seventh cervical vertebrae

Introduction

Although laminoplasty has achieved widespread acceptance as a safe and effective surgical procedure for multisegmental cervical compression myelopathy, several problems remain yet to be solved: postoperative axial neck pain; loss of cervical lordosis; and segmental motor paralysis [1]. Regarding axial neck pain after cervical laminoplasty, we have previously reported a prospective study finding that C3–6 laminoplasty with preservation of muscle insertions into the C7 spinous process is associated with significantly decreased frequency of persistent postoperative axial neck pain [2, 3]. However, two major concerns remain for C3–6 laminoplasty. The first is whether C3–6 laminoplasty can maintain neurological improvements for a long time. Whether neurological deterioration can result from progression of degenerative changes or ossification of the posterior longitudinal ligament (OPLL) at C6/7 and/or lower levels must therefore be clarified. Second, whether preservation of muscle insertions into the C7 spinous process can maintain the decreased frequency of postoperative axial neck pain in

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the long term must be elucidated. Since September 2002, C3–6 open-door laminoplasty has been our standard procedure for almost all patients with cervical myelopathy. Our procedure preserves all bilateral muscles attached to the C2 and C7 spinous processes [2, 3]. To the best of our knowledge, no prospective study concerning medium-term outcomes of C3–6 laminoplasty has been reported. The purpose of this prospective study was thus to elucidate medium-term (≥ 5 years) clinical and radiological results after C3–6 laminoplasty in patients with cervical compression myelopathy.

Materials and methods

At Osaka University Hospital, all patients with chronic cervical compression myelopathy, except for those with cervical kyphosis $\geq 15^\circ$, single-level anterior lesion without narrow spinal canal, or spinal cord compression at the C6/7 and/or lower levels, have been treated using C3–6 open-door laminoplasty since September 2002. Based on these criteria, 1 patient underwent anterior spinal surgery, 5 patients underwent C3–7 laminoplasty, and 48 patients underwent our original C3–6 open-door laminoplasty with bilateral preservation of all muscles attached to the C2 and C7 spinous processes between September 2002 and December 2004. Our original procedure is a modification of unilateral-opening laminoplasty which has been fully described in previous reports [2, 4]. All patients wore a soft collar for the first 2 weeks postoperatively. Of these 48 patients, 31 patients (23 men, 8 women) have been followed for ≥ 5 years and were enrolled in this study. None of the 31 patients had a history of various disorders potentially influencing the baseline Japanese Orthopaedic Association (JOA) score [5] as follows; cerebral disorders, rheumatoid arthritis, joint disorders, and urological disorders. The remaining 17 patients were lost to follow-up. One patient died due to a reason unrelated to cervical spine surgery, seven patients moved and the residual nine patients were lost to follow-up due to unknown reasons. In the 17 patients not followed for ≥ 5 years (mean duration of follow-up, 29.8 ± 12.8 months), mean JOA score was 10.1 ± 2.3 before surgery and 13.9 ± 2.3 at the time of maximum recovery, yielding a mean recovery rate of $59.8 \pm 27.8\%$. Regarding age at surgery, preoperative JOA score, JOA score at the time of maximum recovery, and maximum recovery rate, no significant differences were seen between patients followed and not followed for ≥ 5 years. Cervical myelopathy resulted from cervical spondylotic myelopathy (CSM) in 18 patients, OPLL in 11 and cervical disc herniation with developmental spinal canal stenosis in 2. In 7 of the 11 patients with OPLL, C2 dome-like laminotomy was performed in addition to C3–6 laminoplasty. Mean age at the

time of surgery was 64.2 years (range 36–87 years). Mean duration of follow-up was 64.8 months (range 60–75 months). The protocol was approved by the institutional review boards of the hospital and fully informed consent was obtained from all participants.

All patients underwent follow-up examinations at every 3 months for the first 1 year after surgery and thereafter at every 1 year. Clinical and radiological data were collected prospectively. Neurological assessment was performed by one of the authors (H.S., N.H., Y.M., and M.I.) and radiological assessment was performed by the first author (H.S.). Neurological results were assessed using JOA score and recovery rate [6]. In patients who showed decreased JOA score during postoperative follow-up, causes of deterioration were investigated.

Axial neck pain was defined as nuchal and/or scapular pain. Pain intensity was graded as severe (painkillers or local injection needed regularly), moderate (physiotherapy or compress needed regularly) or mild (no treatment needed), in accordance with a previous report [4]. Severe or moderate pain that was newly developed or became aggravated after surgery was considered to constitute postoperative axial neck pain.

Maximal flexion, neutral and maximal extension were examined on lateral radiographs of the cervical spine taken before surgery and at regular intervals thereafter. Sagittal alignment of the cervical spine was measured as the C2–7 angle formed by two lines drawn parallel to the posterior margin of the vertebral body on a radiograph in the neutral position. Kyphosis and lordosis were defined as C2–7 angle $\leq -10^\circ$ and $\geq 10^\circ$, respectively. All other spines were classified as straight. C2–7 range of motion (ROM) of the cervical spine was calculated by subtracting maximal flexion C2–7 angle from maximal extension C2–7 angle. Progression of OPLL was assessed by comparing serial lateral radiographs. Progression of ossification was defined as an increase of ≥ 2 mm in longitudinal extent and/or sagittal thickness [7].

The unpaired *t* test, paired *t* test, Mann–Whitney *U* test, Friedman test, Wilcoxon signed-rank test or Fisher's exact probability test were applied for statistical analysis using JMP version 5.0.1 software (SAS Institute, Cary, NC), as appropriate. Values of $p < 0.05$ were considered to indicate statistical significance.

Results

Neurological results

Mean JOA score improved significantly from 10.6 before surgery to 14.7 at the time of maximum recovery (at 1 year after surgery), giving a mean recovery rate of 68.9%. None

of the 31 patients showed worsening after surgery. At final follow-up, mean score declined slightly to 14.3 (average recovery rate 62.6%) (Table 1; Fig. 1).

In 6 of the 31 patients followed for ≥ 5 years, JOA score at final follow-up decreased by ≥ 1 from the score at maximum recovery. In these six patients, these conditions were unrelated to the cervical spine. Causes of late deterioration were as follows: lumbar spinal canal stenosis in two patients; femoral neck fracture in one; carpal tunnel syndrome in one; stress urinary incontinence in one; and hepatocellular carcinoma and benign prostate hypertrophy in one (Table 2). Excluding these 6 patients who displayed late deterioration, mean JOA score in the remaining 25 patients was 15.1 (average recovery rate 72.2%) at the time of maximum recovery and 15.0 (average recovery rate 70.0%) at final follow-up. Differences in JOA score and recovery rate between these 2 time points were not significant (Table 3).

Axial neck pain

In 10 of the 12 patients who had complained of mild to severe axial neck pain before surgery, pain was alleviated after surgery. Conversely, the remaining two patients suffered from aggravated axial neck pain and one patient developed new axial pain after surgery. In these three patients (9.7%), axial neck pain had persisted for 1 year

postoperatively. At final follow-up, however, only one patient (3.2%) complained postoperative axial neck pain persisting for 5 years.

Radiological results

Mean C2–7 angle increased significantly from $16.8 \pm 14.6^\circ$ before surgery to $21.1 \pm 14.2^\circ$ at final follow-up ($p < 0.01$). According to our classifications, no patients developed postoperative kyphosis. Mean C2–7 ROM decreased significantly from $32.6 \pm 14.1^\circ$ before surgery to $27.4 \pm 10.1^\circ$ at final follow-up ($p < 0.05$).

Progression of OPLL after surgery was found in 7 (63.6%) of the 11 patients. This progression occurred in the longitudinal axis in six patients and sagittal thickness increased in two. None of the seven patients, however, had experienced neurological deterioration due to progression of OPLL by final follow-up.

Discussion

Maintenance of neurological recovery after C3–6 laminoplasty

Several surgery-associated problems after cervical laminoplasty have yet to be solved, including axial neck pain, undesirable postoperative radiological changes such as deterioration of sagittal alignment and segmental motor paralysis [1]. To prevent these problems, some surgeons have recently applied less-invasive selective laminoplasty, reducing the damage to cervical posterior elements such as paraspinal muscles, nuchal ligaments and facet joints [8–12]. Takeuchi and Shono [9] found no difference in JOA score between a C3–6 laminoplasty group and a C3–7 group both before surgery and at 2-year follow-up. Compared with C3–7 laminoplasty, selective laminoplasty has been reported to provide equal short-term (2 or 2.5 years) neurological recovery [8, 10, 11]. However, only one report has described long-term outcomes after C3–6 laminoplasty [12]. Higashino et al. [12] in their study with a mean

Table 1 Neurological outcomes

	Before surgery	Maximum recovery	Final follow-up
JOA score (points)	10.6 ± 2.6	$14.7 \pm 2.1^*$	$14.3 \pm 2.4^{***}$
Recovery rate (%)		68.9 ± 24.7	$62.6 \pm 27.9^{***}$

Mean $\pm$ standard deviation

JOA Japanese Orthopaedic Association

* Significantly higher than before surgery (Wilcoxon signed-rank test with Bonferroni correction, $p < 0.01$)

** Significantly lower than at the time of maximum recovery (Wilcoxon signed-rank test with Bonferroni correction, $p < 0.01$)

*** Significantly lower than at the time of maximum recovery (Wilcoxon signed-rank test, $p < 0.01$)

Fig. 1 Changes in mean JOA score over time. Bars indicate standard deviations. Mean JOA score reached its maximum at 1 year after surgery and this maximum mean score was maintained at 2 years postoperative. Thereafter, mean score had slightly decreased by final follow-up

Table 2 Causes of late deterioration

Causes	No. of patients
Lumbar spinal canal stenosis	2
Femoral neck fracture	1
Carpal tunnel syndrome	1
Stress urinary incontinence	1
Hepatocellular carcinoma and benign prostate hypertrophy	1

Table 3 Neurological outcomes excluding the six patients with late deterioration

	Before surgery	Maximum recovery	Final follow-up
JOA score (points)	11.1 ± 2.7	15.1 ± 1.9*	15.0 ± 2.0* [§]
Recovery rate (%)		72.2 ± 24.6	70.0 ± 25.8 ^{§§}

Mean ± standard deviation

JOA Japanese Orthopaedic Association

* Significantly higher than before surgery (Wilcoxon signed-rank test with Bonferroni correction, $p < 0.01$)[§] Not significantly lower than at the time of maximum recovery (Wilcoxon signed-rank test with Bonferroni correction, $p > 0.05$)^{§§} Not significantly lower than at the time of maximum recovery (Wilcoxon signed-rank test, $p > 0.05$)

follow-up of 9.6 years (minimum 5 years), reported that none of their 42 patients showed late neurological deterioration due to cervical spine lesions after C3–6 laminoplasty. However, unfortunately, their candidates only had CSM and their study design was retrospective. Thus, to the best of our knowledge, this represents the first prospective study to examine medium-term (≥ 5 years) outcomes after C3–6 laminoplasty for cervical compression myelopathy.

In the present study, mean recovery rate for JOA score was 68.9% at the time of maximum recovery, with only a slight decline to 62.6% at final follow-up. Although JOA score at final follow-up was decreased by ≥ 1 from the score at maximum recovery in 6 of 31 patients, none of them developed late deterioration due to cervical spine lesions. These six patients were associated with comorbidities such as degenerative changes in the lumbar spine, benign prostate hypertrophy as well as general complications. It is the limited specificity of the JOA score that this scoring system is influenced by these age-related changes. A novel outcome measurement tool is needed to deduct age-related influence and assess the true surgical effect on myelopathic symptoms. After excluding these six patients with late deterioration, mean recovery rate was 72.2% at the time of maximum recovery and 70.0% at final follow-up. The difference between these 2 time points was not significant. Kawaguchi et al. [13] reported that mean recovery rate for JOA score was 61.6% at the 5-year follow-up after conventional C3–7

or C3–T1 open-door laminoplasty for CSM and OPLL. Given these results, our C3–6 laminoplasty maintained satisfactory medium-term neurological recovery. Long-term (≥ 10 years) follow-up studies of conventional laminoplasty, however, have shown that mean preoperative JOA score had increased by 3 years after surgery, which was then maintained for 5 years postoperatively, but mean JOA score had gradually decreased by 10 years after surgery or later [13–15]. Further long-term follow-up is thus needed to verify the reliability of C3–6 laminoplasty. Conversely, in patients with CSM, the spinal cord is reportedly seldom affected at the C6/7 level [16, 17]. Although progression of OPLL after laminoplasty has been observed in around 70% of patients, similar to the present results [7, 18, 19], Hori et al. [20] reported that progression in OPLL thickness was most frequent at C2, followed by C3 and C4, and that progression in the longitudinal axis was also frequent towards the cranial segments. Since we performed C2 dome-like laminotomy in addition to C3–6 laminoplasty preserving all bilateral muscles attached to the C2 and C7 spinous processes in patients with OPLL at the C2 level, none of the patients experienced neurological deterioration due to progression of OPLL by final follow-up. These results suggest that the risk of neurological deterioration due to progression of degenerative changes or OPLL at C6/7 and/or lower levels after C3–6 laminoplasty might be reduced.

Maintenance of reduced axial neck pain

Regarding axial neck pain after cervical laminoplasty, we have previously reported that C3–6 laminoplasty with preservation of muscle insertions into the C7 spinous process is associated with significantly decreased frequency of persistent postoperative axial neck pain [2, 3]. An anatomical study confirmed that C3–6 laminoplasty in which the C7 spinous process is preserved can reduce invasion of the nuchal muscles including the trapezius, rhomboideus minor and major, splenius capitis and cervicis [21]. Although the exact pathogenesis of postoperative axial neck pain remains unclear, we speculate that postoperative persistent axial neck pain might result from injury to these shoulder suspensory muscles following surgical exposure of the C7 spinous processes. Some surgeons have recently reported results supporting our speculation [9]. However, follow-up periods in previous studies examining axial pain after C3–6 laminoplasty were only 1 or 2 years [2, 3, 9], so whether preservation of muscle insertions into the C7 spinous process can maintain decreased frequency of postoperative axial neck pain in the long-term remains unclear. In the present study, axial neck pain persisted for 1 year postoperatively in three patients (9.7%), and only one patient (3.2%) complained of postoperative axial neck pain persisting for 5 years by final follow-up. On the contrary, we

have reported incidence of axial pain after our original C3–7 laminoplasty using the same pain grading system as that used in this prospective study, although axial pain was prospectively examined only for the first 1 year postoperative [3]. All patients in this C3–7 group also wore a soft collar for the first 2 weeks postoperatively. The only difference between our C3–7 laminoplasty and C3–6 procedure was that the C7 lamina was exposed and opened in the C3–7 procedure. Thus, the C3–7 group in our previous report and the C3–6 group in the present study are sufficiently comparable. In 10 (30%) of the 33 patients who underwent our C3–7 laminoplasty, severe or moderate axial pain was noted for the first 1 year postoperative [3]. The difference in incidence of axial pain between the C3–7 group and the C3–6 group was significant (10/33 vs. 3/31, $p < 0.05$). These results indicate that C3–6 laminoplasty preserving the muscle insertions into the C7 spinous process significantly lowers the incidence of axial neck pain 1 year after surgery and the incidence of persistent axial pain was further decreased by 5 years postoperatively.

Sagittal cervical alignment after surgery

Loss of C2–7 angle reaches 6.2–11.7° after conventional (non-muscle insertion sparing) C3–7 laminoplasty [13, 22, 23]. These changes have been assumed to mostly result from detachment of muscle insertions into the C2 spinous process. Biomechanical analysis demonstrated that the semispinalis cervicis and C2 lamina act as the main dynamic stabilizers of the cervical spine and that removal of the semispinalis attachment to the C2 spinous process results in a loss of cervical lordosis [24]. Laminectomy from C1 or C2 to the subaxial cervical spine has also been shown to often lead to kyphotic deformity [25]. Some surgeons have recently reported that preservation of muscle insertions into the C2 spinous process reduces the loss of lordosis after surgery compared to conventional laminoplasty [26–28]. In the present study, all bilateral muscles attached to the C2 spinous processes were preserved in all patients, and mean C2–7 angle increased significantly from 16.8° before surgery to 21.1° at final follow-up. According to our classifications, no patient developed postoperative kyphosis. Taken all together, preservation of muscle insertions to the C2 spinous process plays the most important role in maintaining cervical lordosis after laminoplasty.

In conclusion, medium-term clinical outcomes of C3–6 laminoplasty with preservation of all bilateral muscles attached to the C2 and C7 spinous processes were satisfactory. In six patients who developed late deterioration, these conditions were unrelated to the cervical spine. Frequencies of persistent axial neck pain and loss of sagittal cervical lordosis after surgery remained significantly decreased for ≥ 5 years postoperatively.

IRB of the institute approved this study.

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