Spinal Posterior Movement After Posterior Cervical Decompression Surgery: Clinical Findings and Factors Affecting Postoperative Functional Recovery

GANG XIA, MD; RONG TIAN, MD; TIANTONG XU, MD; HUIMING LI, MD; XUELI ZHANG, MD

This study investigated the posterior movement of the spinal cord after posterior decompression surgery and evaluated factors affecting postoperative functional recovery in patients with cervical spondylotic myelopathy (CSM). Thirty-two patients with CSM underwent posterior decompression from C3 to C7 through laminectomy (n = 12) and single, open-door laminoplasty (n = 20). There were no significant differences between laminectomy and laminoplasty in degree of spinal posterior movement, recovery rate, and curvature index. Japanese Orthopedic Association (JOA) scores improved from preoperative (10.63 ± 1.77; range, 7-14) to 3-months postoperative (13.57 ± 1.50; range, 11-16) (n = 32, P < .05) and from preoperative (10.24 ± 1.87; range, 7-14) to 6-months postoperative (14.16 ± 1.54; range, 12-16) (n = 21) (P < .05). C5 palsy was observed in 1 (3.1%) patient. The vertebral body-to-spinal cord distances significantly increased after operations, with the greatest posterior movement at C5 and the least posterior movement at C3 and C7. However, the difference in the degree of the spinal movement of C3 to C7 was not statistically significant (P > .05). Furthermore, no correlation was found between the magnitude of spinal posterior movement and the curvature index. In addition, the magnitude of posterior movement and age were not correlated with the postoperative JOA improvement, but the preoperative JOA scores were.

Our study shows that both laminectomy and laminoplasty can produce a similar degree of posterior movement of the spinal cord. Cervical lordosis is not associated with the posterior movement of the cord. The preoperative JOA scores, but not posterior movement of the cord and age, are important determinants for postoperative outcome.

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Figure: Pre- (A) and postoperative (B) radiographs of the cervical spine of patients who underwent laminectomy.
Cervical spondylotic myelopathy (CSM) is a common degenerative disease that affects the elderly. Narrowing of the spinal canal with age leads to compression of the spinal cord, which can cause a variety of symptoms, including pain, numbness, and weakness. Surgery is often required to widen the spinal canal to release the compression of the spinal cord, especially when the clinical symptoms are severe and progressive and when the conservative treatment, such as acupuncture, physical therapy, and various traction methods, as well as analgesic medications and neuromodulating medications, is not effective in relieving the pain and other symptoms.1-3 Posterior decompression surgery, including laminectomy and laminoplasty, has been used in clinics to allow the spinal cord to move backward to keep it clear of anterior compression.3,4

However, the mechanism of the posterior movement of the spinal cord postoperatively remains unclear. The posterior movement of spinal cord is hypothesized to result from the bowstring effect with an increased tension in the spinal cord after the posterior decompression surgery widens the spinal canal.5-7 The spinal cord (bowstring) moves backward by itself in response to the change of cervical lordosis (bow) after the posterior decompression surgery. However, the feasibility of the bowstring effect of the spinal cord has not been clearly demonstrated.

In addition, the clinical significance of posterior movement of the spinal cord after posterior decompression surgery remains controversial. Some studies have reported that the degree of posterior movement is associated with the postoperative outcome,8,9 whereas others have reported that the degree of movement is not.4 We performed laminectomy and laminoplasty on 32 patients with cervical spondylotic myelopathy to investigate the posterior movement of the spinal cord and its associated postoperative outcome.

**MATERIALS AND METHODS**

Thirty-two patients (22 men and 10 women) who underwent laminectomy (n=12) and single, open-door laminoplasty (n=20) at C3-C7 were included in this study. The average age at operation was 51 years (range, 29-73 years). All patients presented with symptoms of neural compression, and magnetic resonance imaging (MRI) findings were consistent with CSM.

This study selected patients with CSM who had progressive neurological symptoms, alterations of bladder function, and multilevel cervical involvement. Patients with spinal cord injuries due to acute traumatic injuries, ossification of the posterior longitudinal ligament, and tumors were excluded. All patients underwent plain radiographs and MRIs preoperatively and were followed-up 3 months postoperatively. The MRIs and plain radiographs for all patients were also performed at 3 months postoperatively during the follow-up.

**SURGICAL TECHNIQUE**

We performed a laminectomy or single, open-door laminoplasty. Laminoplasty was preferred by the surgeons, but laminectomy was performed in patients with severe spinal stenosis, a broken hinge during laminoplasty, or a thin and fragile lamina that is difficult to use to form a hinge.

The patient was placed in a prone position on an operating table. A midline approach was made to expose the spinous process. For laminectomies, lateral gutters were created at the medial margin of bilateral intervertebral joints, and the C3-C7 lamina were then taken out by removing the outer cortex, cancellous bone, and inner cortex. The posterior wall of the spinal canal was completely removed by this surgery (Figure 1A, B). For single, open-door laminoplasty, lateral gutters were created at the medial margin of the bilateral intervertebral joints. The gutter on the lateral margin of the lamina was completed first.
on the open side to remove the outer cortex, cancellous bone, and inner cortex. On the hinge side, the inner cortex and part of the cancellous bone remained. The lamina door was opened by carefully moving the lamina on the open side laterally toward the hinge side. The lamina was fixed to the surrounding ligament and muscle, and bones trimmed from spinous processes were grafted into the hinges to secure the expansion of the spinal canal (Figure 1C, D).

During the posterior decompression surgery, the enlargement and expansion of the spinal cord was observed after the lamina was removed for laminectomy (Figure 2A) and after the lamina door was opened for laminoplasty (Figure 2B).

**Evaluation**

For each patient, neurologic functions were evaluated pre- and postoperatively according to the Japanese Orthopedic Association (JOA). The recovery rate was calculated according to the equation: recovery rate = (postoperative score - preoperative score)/(17 - preoperative score)×100%. The patients were categorized into 2 groups according to the recovery rate: an excellent group with recovery rate ≥33% and a fair group with recovery rate ≤33%

The MRI study was produced by a 1.5-T MRI device (Philips, Best, The Netherlands). T1-weighted images were captured by the spin-echo method in which the echo time (TE) was 12 ms, and the repetition time (TR) was 500 ms. T2-weighted images were captured by the fast spin echo sequence method in which the TE was 112 ms and the TR was 4500 ms. In the sagittal plane, the field of view was 28 cm, and the slice thickness was set at 3 mm with a spacing of 0.5 mm.

To estimate the magnitude of posterior movement of the spinal cord, the distance from the posterior surface of the vertebral body to the anterior surface of the spinal cord (vertebral body-to-spinal cord distance) was measured using T1-weighted sagittal MRIs (Figure 3). The degree of postoperative posterior movement of the spinal cord was calculated by the difference between the pre- and postoperative vertebral body-to-spinal cord distances. To quantify postoperative cervical lordosis, a cervical curvature index was calculated using postoperative MRI (Figure 4) according to the equation: curvature index = 100×(a1 + a2 + a3 + a4)/A.
Statistical Analysis
The values were presented as means and standard deviations. Student’s t test and analysis of variance (ANOVA) were used for comparison of the difference in the means. A paired t test was used to assess the statistical significance between pre- and postoperative JOA scores. Pearson correlation analysis was applied to assess the relationship between the magnitude of the posterior movement and the curvature index. A P value < .05 was considered statistically significant. Analyses were performed using SPSS version 17.0 software (SPSS, Inc, Chicago, Illinois).

RESULTS
C3-C7 laminectomy was performed in 12 patients, and C3-C7 single, open-door laminoplasty was performed in 20 patients. No significant differences were observed between laminectomy and laminoplasty in preoperative JOA scores, recovery rate, curvature index, and the degree of posterior movement of the spinal cord (Table 1). Therefore, we grouped all 32 patients to analyze the pre- and postoperative differences.

In the 32 patients followed-up at 3-months postoperatively, the JOA scores improved from 10.63 ± 1.77 (range, 7-14) preoperatively to 13.57 ± 1.50 (range, 11-16) postoperatively (P < .05). The improving rate of JOA scores ranged from 33.33% to 80.00% (average, 50.93%). Only 21 patients were followed-up at 6-months postoperatively, and the JOA scores for these patients improved from 10.24 ± 1.87 (range, 7-14) preoperatively to 14.16 ± 1.54 (range, 12-16) postoperatively (P < .05). The improvement rate of JOA scores ranged from 42.86% to 85.71% (average, 60.58%). The JOA scores at 6 months postoperatively significantly improved compared with those at 3 months postoperatively (P < .05), indicating a better functional recovery at 6 months postoperatively.

C5 palsy was observed in 1 (3.1%) of 32 patients. The C5 palsy developed first on the open side at 2 weeks after single, open-door laminoplasty and was present on the hinge side at 4 weeks postoperatively. The posterior movement of spinal cord at C3-C7 is listed in Table 2. The C5 palsy did not heal with time and conservative treatment. The patient was treated with anterior C5 corpectomy surgery 3.5 months after laminoplasty and recovered at 6 months postoperatively.

The average postoperative posterior movement of the cervical spinal cord was 1.6 ± 1.0 mm (range, 0.3-4.9 mm). We measured the distance from the posterior surface of the vertebral body to the anterior surface of the spinal cord at C3-C7 (Table 3). A significant increase occurred in the postoperative posterior movement of the spinal cord at each level (P < .001), with the greatest posterior movement at C5 and the least posterior movement at C3-C7. However, the difference in the degree of the spinal movement at C3-C7 was not statistically significant between each spinal level (ANOVA, P > .05).

The frequency of occurrence of maximum posterior movement was 37.5% (12 patients) at C5, 25% at C4 and C6, 12.5% at C3, and 0% at C7 (Table 4). The postoperative curvature index was 15.15 ± 10.91, with a range of −4.23 to 47.25. No correlation was observed between the magnitude of posterior movement and the curvature index (r = 0.2396, P > .05).

We further evaluated the potential effects of posterior movement of the cord after laminectomy and laminoplasty on postoperative outcomes. We divided our patients into 2 groups based on the recovery rate: an excellent group including patients at the top 33% of recovery rate, and a fair group including patients at the bottom 33% of recovery rate. The recovery rate is often used to evaluate the postoperative outcome in many studies.10-12

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### Table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preoperative JOA Scores</th>
<th>Recovery Rate</th>
<th>Curvature Index</th>
<th>Posterior Movement, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laminectomy</td>
<td>10.42 ± 1.38</td>
<td>45.18% ± 12.34%</td>
<td>13.18 ± 6.90</td>
<td>1.55 ± 1.37</td>
</tr>
<tr>
<td>Laminoplasty</td>
<td>10.75 ± 2.00</td>
<td>54.39% ± 14.25%</td>
<td>16.33 ± 12.76</td>
<td>1.58 ± 0.79</td>
</tr>
</tbody>
</table>

Abbreviations: JOA, Japanese Orthopedic Association; SD, standard deviation. *P* > .05, laminectomy vs laminoplasty using Student’s t test.

### Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preoperative, mm</th>
<th>Postoperative, mm</th>
<th>Posterior Movement, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3</td>
<td>3.0</td>
<td>4.8</td>
<td>1.8</td>
</tr>
<tr>
<td>C4</td>
<td>3.4</td>
<td>6.8</td>
<td>3.4</td>
</tr>
<tr>
<td>C5</td>
<td>3.3</td>
<td>7.6</td>
<td>4.3</td>
</tr>
<tr>
<td>C6</td>
<td>5.4</td>
<td>8.4</td>
<td>3.3</td>
</tr>
<tr>
<td>C7</td>
<td>4.3</td>
<td>5.4</td>
<td>1.1</td>
</tr>
</tbody>
</table>

a Calculated by the difference between the preoperative and postoperative vertebral body-to-spinal cord distances.
We found no correlation between the degree of posterior movement and the recovery rate at both 3 months and 6 months postoperatively (Tables 5, 6), suggesting that the degree of posterior movement is not a good indicator for postoperative function recovery. In addition, the improvement rate of JOA scores of patients with maximum posterior movement at C5 (n=12; range, 33.3%-75%; average, 52.36%) is not significantly different from that of patients with maximum posterior movement at C3 (n=4; range, 33.3%-60%; average, 48.73%) (P>.05), suggesting that the spinal cord level of posterior movement is also not associated with postoperative function recovery.

Although younger patients tended to recover more quickly than elderly patients, we did not find a significant correlation between age and postoperative JOA score improvement (P>.05) at 3 and 6 months postoperatively (Tables 5, 6). However, we identified a significant correlation between the preoperative JOA score and postoperative JOA score improvement (P<.05) at both 3 and 6 months postoperatively, suggesting that preoperative JOA scores are associated with postoperative prognosis.

**DISCUSSION**

Clinically, posterior decompression surgery, such as laminectomy and laminoplasty, has been used to treat CSM patients and can result in satisfactory outcomes.\(^2,13-16\) Posterior movement of the cervical spinal cord after posterior decompression surgery is one of the most important factors for achieving satisfactory decompression and is the major mechanism of the posterior decompression surgery to release the anterior compression in patients with CSM.\(^3,4\)

Our study confirms the posterior spinal cord movement in 32 patients who underwent laminectomy and laminoplasty. Unlike laminectomy to remove the posterior structure of the spinal canal, laminoplasty widens and reconstructs the posterior spinal canal structure possibly restricting the posterior spinal cord movement. However, we identified a similar degree of posterior movement of spinal cord in patients treated with laminectomy and laminoplasty, suggesting that laminoplasty provides enough space for the spinal cord and does not restrict the posterior movement of the spinal cord.

Therefore, we believe that laminoplasty is the preferred posterior decompression method of treatment for CSM because it has been reported to work well in the majority of patients and has a low risk of adverse effects such as instability.\(^1,13,15,17\) which often develops in laminectomy.\(^18-20\) In addition, Kaminsky et al\(^2\) compared 2 similar groups of CSM patients treated with laminectomy or laminoplasty and found a similar improvement rate between the 2 groups, with fewer late complications in laminoplasty group.

Laminectomy is still commonly performed in China and Japan. Although a trend in cervical spinal surgery has moved to replace laminectomy with laminoplasty, laminectomy is still useful as an alternative in our hospital when the laminoplasty fails due to a broken hinge during an operation or when a thin or fragile lamina that is not easily formed into a hinge is present. In addition, laminectomy is preferred to perform on patients with severe spinal stenosis, which causes a severe compression on the spinal cord or nerve root.

If the patients show no signs of spinal instability preoperatively, we prefer to perform laminectomy without fusion to prevent the potential risks associated with fusion, such as the injury of the spinal cord and nerve root and improper fusion of the bone, as well as the risks of bleeding and infection associated with the site on the body from which the bone for grafting is taken.
It is hypothesized that the posterior movement of the spinal cord is caused by a so-called bowstring effect, which suggests that the spinal cord moves backward and elongates by itself after posterior decompression surgery, acting like the bowstring after removal of the external force.5,7

The bowstring effect is largely based on the assumption that the physiological cervical lordosis (bow) determines the degree of posterior movement of the spinal cord (bowstring). With the bow spreading (the cervical lordosis changing), the bowstring (spinal cord) is gradually tensed to move backward.7

Our finding that the posterior movement of the spinal cord is the greatest at C5 and is least at C3 and C7 agrees with the bowstring effect, which hypothesizes that the greatest movement in the middle of the cervical spine is due to the lordosis of the spinal cord.6 According to the bowstring effect, the cervical spinal cord moves greatest at the point of maximum concavity, when the spinal cord spreads under tension.6

However, our study shows that the magnitude of posterior movement is not correlated with cervical curvature index, suggesting that cervical lordosis is not necessary for the posterior movement. In addition, the degree of posterior movement between C3-C7 was not significantly different. The maximum posterior movement occurs only 37.5% at C5. These facts are not consistent with the bowstring effect. Therefore, the bowstring effect alone is not enough to explain the posterior movement of the cord.

If the spinal cord does not move backward like a bowstring, other stressors have to force it to move backward. One possibility is that the spinal cord is dragged backward by the denticulate ligament. It is well documented that posterior decompression surgery will lead to enlargement of the spinal cord (Figure 2),6,21-23 which may stretch the dural sac and cause the backward shift of the spinal cord through the denticulate ligament. However, the exact mechanism of how the posterior movement occurs after posterior decompression remains to be determined.

Although plain radiography is good enough to determine cervical lordosis, MRI was selected in this study to investigate the correlation between the magnitude of posterior movement and cervical lordosis. Magnetic resonance imaging has an advantage over upright plain radiography because it can show clear images on both the spinal cord and the vertebrate body, which are critical for measurement of spinal posterior movement. If upright radiography images are used for measuring cervical lordosis, the different patient posture between radiography images (upright position) and MRI (supine position) may affect spinal cord position,24 leading to measurement errors. Therefore, the same MRI image used for measuring both spinal posterior movement and cervical lordosis is best suitable for our purpose of studying the relationship between spinal posterior movement and cervical lordosis.

The incidence of C5 palsy after cervical spinal surgery ranges from 0% to 23%.7,25,26 Sasai et al25 reported that none of their 74 patients experienced C5 palsy after laminoplasty. The incidence of C5 palsy in our study (3.1%) is in the lower range of the reported incidence. The large variation in the incidence of C5 palsy remains unknown, possibly because many

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Excellent Recovery Groupa (n=10)</th>
<th>Fair Recovery Groupa (n=10)</th>
<th>Pp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior movement, mm</td>
<td>1.56±0.96</td>
<td>2.04±1.41</td>
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<tr>
<td>Age, y</td>
<td>46.4±10.4</td>
<td>56.2±11.6</td>
<td>&gt;.05</td>
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<tr>
<td>Preoperative JOA score</td>
<td>11.9±1.37</td>
<td>9.9±1.20</td>
<td>&lt;.05</td>
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</tbody>
</table>

Abbreviations: JOA, Japanese Orthopedic Association; SD, standard deviation.
*Top 33% (n=10), with recovery rate 60%.
*Bottom 33% (n=10), with recovery rate 40%.
*Student’s t test, excellent recovery vs fair recovery.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Excellent Recovery Groupb (n=7)</th>
<th>Fair Recovery Groupb (n=7)</th>
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<tbody>
<tr>
<td>Posterior movement, mm</td>
<td>1.44±0.88</td>
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<tr>
<td>Preoperative JOA score</td>
<td>9.0±1.15</td>
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<td>&lt;.05</td>
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Abbreviations: JOA, Japanese Orthopedic Association; SD, standard deviation.
*Top 33% (n=7), with recovery rate 75%.
*Bottom 33% (n=7), with recovery rate 50%.
*Student’s t test, excellent recovery vs fair recovery.

<table>
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<tr>
<th>Parameter</th>
<th>Excellent Recovery Groupc (n=10)</th>
<th>Fair Recovery Groupc (n=10)</th>
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<tbody>
<tr>
<td>Posterior movement, mm</td>
<td>1.41±0.12</td>
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<tr>
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<tr>
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*Student’s t test, excellent recovery vs fair recovery.
factors contribute to the etiology of C5 palsy, such as C5 nerve injury during operation\textsuperscript{27} and tethering of the nerve by spinal posterior movement.\textsuperscript{7,9,28}

Some studies reported that tethering of the nerve root might cause the development of C5 palsy as a result of posterior movement of the spinal cord after posterior decompression.\textsuperscript{7,9,28} Yamashita et al\textsuperscript{28} reported that patients with C5 palsy had significantly greater posterior movements of the cord than those without C5 palsy. The extent of posterior movement was greatest at the C5 level, with an average movement of 5 mm at the C4 or C5 level. In agreement with their study, our study showed that the posterior movement in the patient with C5 palsy was 4.3 mm, which is greater than the average (1.9 mm).

However, Sodeyama et al\textsuperscript{9} reported that no correlation existed between the incidence of C5 palsy and the degree of posterior movement of the cord. The difference among these studies is likely due to an insufficient number of cases with C5 palsy (1 case in our study, 3 cases reported by Yamashita et al,\textsuperscript{28} and 4 cases reported by Sodeyama et al\textsuperscript{9}).

Although posterior decompression surgery has been reported to produce satisfactory postoperative outcomes,\textsuperscript{2,13,15} some controversies regarding the prognostic factors still exist. It is well documented that postoperative outcomes are affected by various factors, such as age, preoperative JOA scores, symptom duration, transverse area of the spinal cord at maximum compression, and signal change on MRI scan.\textsuperscript{10,12,28,31} However, few studies have reported the correlation between the postoperative outcomes and the degree of posterior movement of the spinal cord after laminectomy and laminoplasty. In the current study, we found no correlation between the degree of posterior movement and the recovery rate, suggesting that the degree of posterior movement is not a good indicator for postoperative function recovery. In contrast, patients with good preoperative JOA scores recovered more quickly, suggesting that preoperative JOA scores are associated with postoperative prognosis.

Despite its sound results, this study has some limitations. The spinal posterior movement was only measured at 3 months postoperatively. An MRI taken earlier than 3 months postoperatively may lead to erroneous outcome due to postoperative swelling. However, we are not sure whether the degree of posterior movement will change over a longer period of time, such as 6 months or 1 year. A study of the posterior movement of the spinal cord with time is worth further investigation. We also observed the enlargement of the spinal cord postoperatively. The spinal cord enlargement may stretch the dural sac, causing the backward shift of the spinal cord through denticulate ligament. However, we did not make any attempt to study the change in the morphology in detail. Therefore, the correlation between the enlargement and posterior movement is a potential area for future study.

**Conclusion**

The degree of posterior movement of spinal cord is similar between laminoplasty and laminectomy and is not correlated with cervical lordosis. The outcomes of posterior decompression surgery are not correlated with the degree of spinal posterior movement. Preoperative JOA scores are an important determinant for postoperative outcomes.

**References**


