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CASE REPORT

Extraordinary positional cervical spinal cord compression in extension position as a rare cause of postoperative progressive myelopathy after cervical posterior laminoplasty detected using the extension/flexion positional CT myelography: one case after laminectomy following failure of a single-door laminoplasty/one case after double-door laminoplasty without interlaminar spacers

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Abstract
Purpose Posterior cervical laminectomies and laminoplasties are common treatments for cervical spondylotic myelopathy. However, recent studies demonstrated that positional spinal cord compression occurred after cervical laminectomies and caused postoperative progressive myelopathy. Although there were no such reports after laminoplasties, we report two cases in which symptomatic extraordinary positional spinal cord compression occurred after laminoplasties in this paper.
Methods This study included two patients who showed progressive myelopathy: one case after a laminectomy following failure of a single-door laminoplasty and one case after a double-door laminoplasty without interlaminar spacers.
Results The MRIs showed mild cord compression in the neutral position in both cases. However, the patients could not extend their necks, because it triggered severe neck pain and numbness. Therefore, the positional CT myelography (CTM) was taken in the flexion and extension positions, and it showed severe spinal cord compression only in the extension position. Posterior instrumented fusions were performed for both patients, which improved their symptoms.
Conclusions This paper demonstrates that postoperative positional spinal cord compression during neck extension caused a progressive myelopathy even after laminoplasty. When myelopathy symptoms worsen after laminoplasties, we recommend positional CTM/MRI evaluation, even though there is no apparent cord compression in the neutral MRI.

Keywords Positional spinal cord compression · Progressive myelopathy · Laminectomy · Laminoplasty · Positional CT myelography

Introduction

Cervical spondylotic myelopathy (CSM) causes quadriplegia due to spinal cord compression. The main reason for cord compression is spinal canal stenosis which is known to be affected by neck motion. Cervical flexion stretches the spinal cord and cervical extension reduces the spinal canal width, because the ligamentum flavums fold inward [1, 2]. Most primary CSM cases are considered to be affected more from an extension motion [3], except for the cases with “flexion myelopathy” [4, 5].

Although various kinds of surgical techniques are recommended to treat CSM, posterior cervical laminectomies and laminoplasties are two common treatments. However, recent studies demonstrated that positional spinal cord compression occurred after cervical laminectomy and

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Table 1 Reported cases with postoperative cervical extension myelopathy following laminectomy/laminoplasty

No.	Author	Age	gender	Pre-operative alignment	Initial operation	Period until recurrence	Treatment
1	Morimoto et al. (1998)	32	Male	Kyphosis	Laminectomy	5 years	Anterior fusion
2	Stamm et al. (2013)	58	Male	Kyphotic	Laminectomy C3–C6	10 years	Posterior fusion
3	Stamm et al. (2013)	56	Male	Kyphotic	Laminectomy C3–C6 with posterior fusion	2 years	Discussing
4	Stamm et al. (2013)	58	Male	Normal	Laminectomy C3–C7	8 years	Discussing
5	Evans et al. (2015)	90	Male	Kyphotic	Laminectomy C3–C6	Several weeks	Posterior fusion
6	Current study	87	Female	Kyphotic	Laminectomy C4–C6 (post-laminoplasty failure)	Several months	Posterior fusion
7	Current study	83	Male	Kyphotic	Double-door laminoplasty without interlaminar spacer C3–C6	Several months	Posterior fusion

caused postoperative progressive myelopathy [6–8]. The cases have similar characteristics (Table 1) in that postoperative myelopathy progressed, although no obvious spinal cord compression was observed in the neutral position magnetic resonance imaging (MRI). However, an MRI taken in the extension position showed that the spinal cord was dramatically compressed. Stamm et al. [8] speculated that the condition occurred due to the lack of the posterior osseous roof.

Suzuki et al. [9] also reported an asymptomatic case with similar positional cord compression after cervical laminectomy in an extension MRI, and they suggested that "laminoplasty benefits the patient by protecting the cervical cord from secondary injury". Certainly, there have been no reports of a similar condition after cervical laminoplasty until now.

However, we have experienced postoperative positional spinal cord compression with progressive myelopathy after cervical laminoplasty as well as following laminectomy. In this paper, we report two cases with postoperative progressive myelopathy due to positional spinal cord compression after cervical laminoplasty.

Case reports

Case 1

An 87-year-old female who showed progressive quadriplegia after laminoplasty and laminectomy.

Two years before, she underwent a single-door laminoplasty at C3–C6 due to multiple spinal cord compressions in MRI with mild kyphotic alignment (Fig. 1a). Her pre-operative complaints were walking disability and hand clumsiness. Interlaminar spacers were put on C3 and C5 [10], using two autogenous bone grafts which were made by splitting the resected C6 spinous process. After the operation, she had recovered to the point that she could walk with a walker.

However, 3 months later, she had neck pain after receiving finger pressure therapy. Then, her quadriplegia worsened again. The MRI/CTM showed that the spinal cord was compressed again (Fig. 1b) due to lamina reclosure at C4–C6 (Fig. 2a, e). The grafted bone at C5 was absorbed, and the hinges at C4–C6 were unstable. Therefore, a laminectomy was performed with the removal of the remaining lamina at C4–C6. After the second operation, the spinal cord decompressed well (Fig. 1c), and the patient's quadriplegia symptoms improved again.

However, 2 years later, her numbness and difficulty in walking and hand motions gradually worsened again without any apparent reason. Although X-rays showed that the alignment had become kyphotic with spondylolisthesis at C4 and C5, there was no obvious spinal cord compression in the neutral position (Fig. 1d).

However, her symptoms were unique in that she could not extend her neck, because it triggered severe neck pain and numbness in four limbs. Moreover, the spinal cord became atrophic at C5–C6 gradually in the MRI.

Therefore, to confirm the condition of the spinal cord, a CTM was taken in neutral, flexion, and extension position. After dye injection into the cerebrospinal fluid at the lumbar spinal level, a cervical CT was taken in neutral, flexion, and extension positions. As shown in Fig. 2, no cord compression was observed in the neutral position (Fig. 2b, f), although there was a kyphotic alignment. In the flexion position, the C4 vertebral body slipped anteriorly, but the subarachnoid space remained around the spinal cord (Fig. 2c, g). However, in the extension position, the spinal cord was compressed dramatically (Fig. 2d, h).

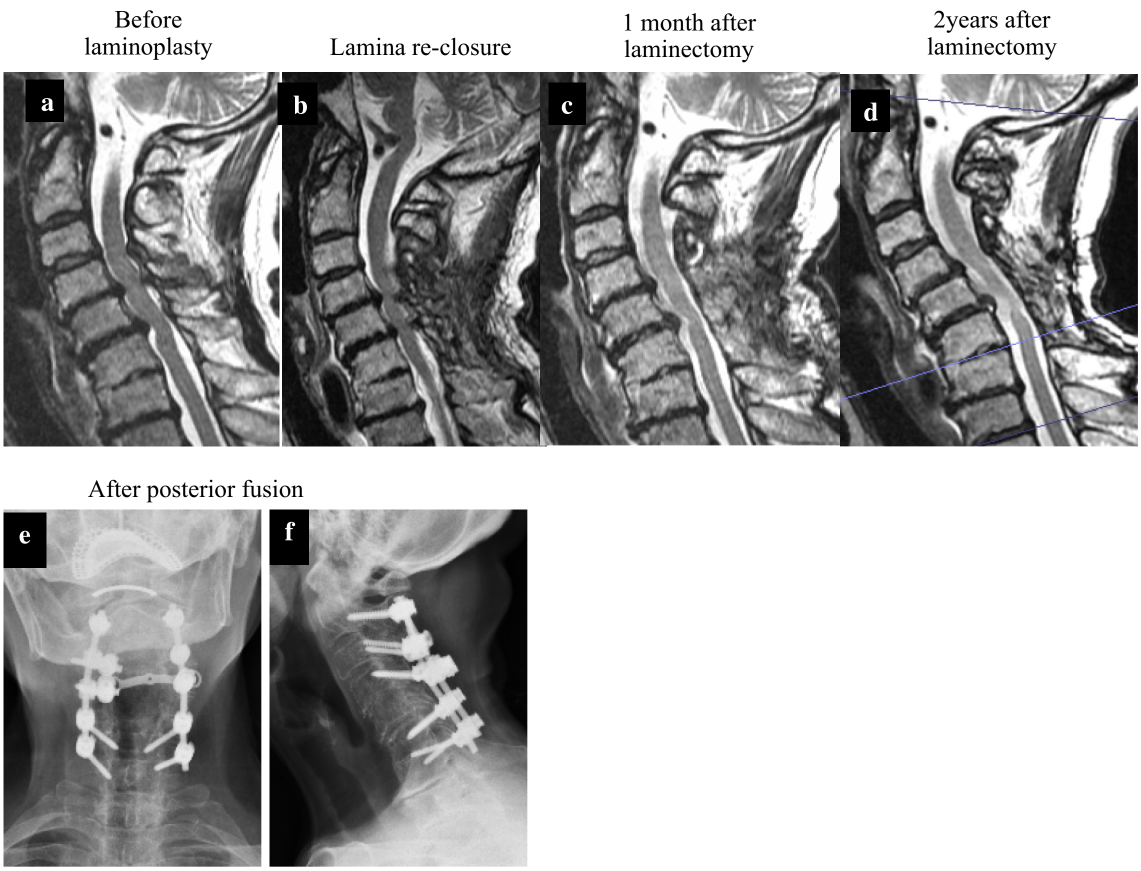

Fig. 1 MRI from Case 1. **a** MRI before the first surgery (single-door laminoplasty) revealed multilevel canal stenosis at C3–C6 with slight kyphosis. **b** MRI at 3 months after the first surgery revealed that the spinal cord was compressed again because of lamina re-closure. **c** MRI at 1 month after the second surgery (laminectomy at C4–C6) shows that the spinal cord was well decompressed. **d** MRI at 2 years after the second surgery showing kyphotic spinal alignment and an atrophic spinal cord at C5–C6 (*white arrow*). **e**, **f** Postoperative X-ray after posterior fusion surgery

The axial view (Fig. 2h) in particular showed that the spinal cord was compressed at the same level as the lateral mass.

As a result of these findings, a posterior instrumented fusion using lateral mass screws and pedicle screws was performed at C2–C6 (Fig. 1e, f). During surgery, there were severe adhesions in the epidural lesion. After revision surgery, her neck pain disappeared, and the patient was able to walk with walker.

Case 2

An 83-year-old male showed progressive quadriplegia after cervical laminoplasty.

Fifteen months previously, the patient underwent cervical laminoplasty at another institute due to hand clumsiness and walking difficulties. The pre-operative MRI (Fig. 3a) showed multilevel canal stenosis at the C3–C6 level. The surgical procedure was a double-door cervical laminoplasty at C3–C6 without interlaminar spacers. Several months following the initial laminoplasty, the patient complained of severe neck pain and progressive quadriplegia. In MRI, kyphotic alignment progressed and there is mild cord compression at C3/4 due to spondylolisthesis at C3 (Fig. 3b).

His symptoms worsened in spite of these treatments, and he visited our clinic 15 months after the initial surgery. At that time, he could not walk and could not use his hands well. His X-ray showed severe kyphosis and anterior slippage of the C3 vertebral body (Fig. 3c). Although an MRI in the neutral position shows spinal cord compression at C3/4 due to spondylolisthesis at C3, subarachnoid space remained (Fig. 3d). He also complained that he could not extend his neck as neck extension triggered severe pain which radiated through the neck and four limbs.

Therefore, CTM was taken in neutral, flexion, and extension position to confirm the pathology before operation. A neutral CTM (Fig. 4a, d) subarachnoid space remained around the spinal cord, although the opened laminas on the left side were re-closed slightly. The flexion CTM (Fig. 4b, e) showed increased anterior slippage of the C3 vertebral body but no spinal cord compression.

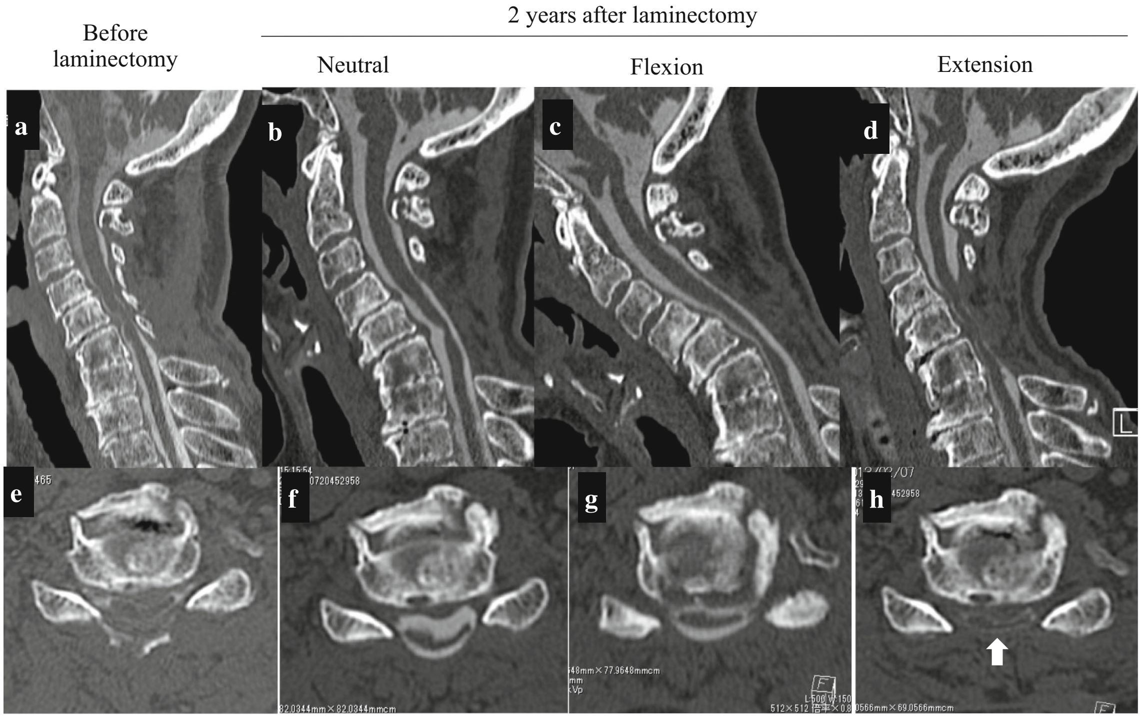

Fig. 2 CTM from Case 1. **a** Sagittal and **e** axial images from a neutral CTM before the second surgery (laminectomy) reveal that the spinal cord was severely compressed by lamina re-closure. **b**–**d**, **f**–**h** Positional CTM at 2 years after laminectomy. **b** Sagittal and **f** axial images from a neutral CTM did not show spinal cord compression, although the spinal cord became atrophic at C5–C6. **c** Sagittal and **g** axial images from a flexion CTM show that the spinal cord shifted towards the anterior, but sufficient subarachnoid space remained in front of the spinal cord. **d** Sagittal and **h** axial views of an extension CTM revealed a dramatic increase in spinal cord compression by the soft tissues located at the dorsal side of the spinal cord. The axial image especially shows that the spinal cord was compressed to the height of the remaining lateral mass (*arrow*)

However, the extension CTM showed a dramatic increase in spinal cord compression by the soft tissues located on the dorsal side of spinal cord (Fig. 4c, f).

According to these findings, a posterior instrumented fusion was performed at C2–C6 using lateral mass screws (Fig. 3e, f). During surgery, there were severe adhesions in the epidural lesion. After revision surgery, his neck pain disappeared, and the patient was able to walk with walker.

Discussion

This paper demonstrates that postoperative positional spinal cord compression caused a progressive myelopathy after laminoplasty: one case after a laminectomy following failure of single-door laminoplasty and one case after a double-door laminoplasty without interlaminar spacers. Although three authors [6–8] previously reported five cases of a similar pathology following cervical laminectomies [11], there were no reports of positional spinal cord compression occurring after laminoplasties.

Table 1 demonstrates the characteristics of two current cases and the previously reported five cases. Most patients had pre-operative kyphotic alignment (six cases). These findings are consistent with the previous reports that kyphotic alignment patients showed poor surgical outcomes after laminectomies/laminoplasties, although it is not clear whether positional cord compression occurs in those cases with poor outcomes, or not.

Stamm et al. [8] described the condition of post-laminectomy positional cord compression as “because the osseous roof of the posterior portion of the spine has been resected, soft tissues may compress the exposed cord”. The current case 1 demonstrated that cervical lateral masses are not large enough to protect the spinal cord from posterior soft-tissue compression after cervical laminectomies. Therefore, the spinal cord was compressed equal to the exact height of the lateral masses in the extension position, as shown in Figs. 2h and 5b. There are anatomical differences between the cervical spine and the thoraco-lumbar spine: the lateral masses in the thoraco-lumbar spine are large enough to protect the spinal cord even after a laminectomy, as shown in Fig. 5c and d.

Suzuki et al. speculated that a cervical laminoplasty may have an advantage over a laminectomy, because the opened lamina protects the spinal cord [9], and certainly, there were no reports of postoperative positional cord compression after laminoplasties. However, caution is necessary,

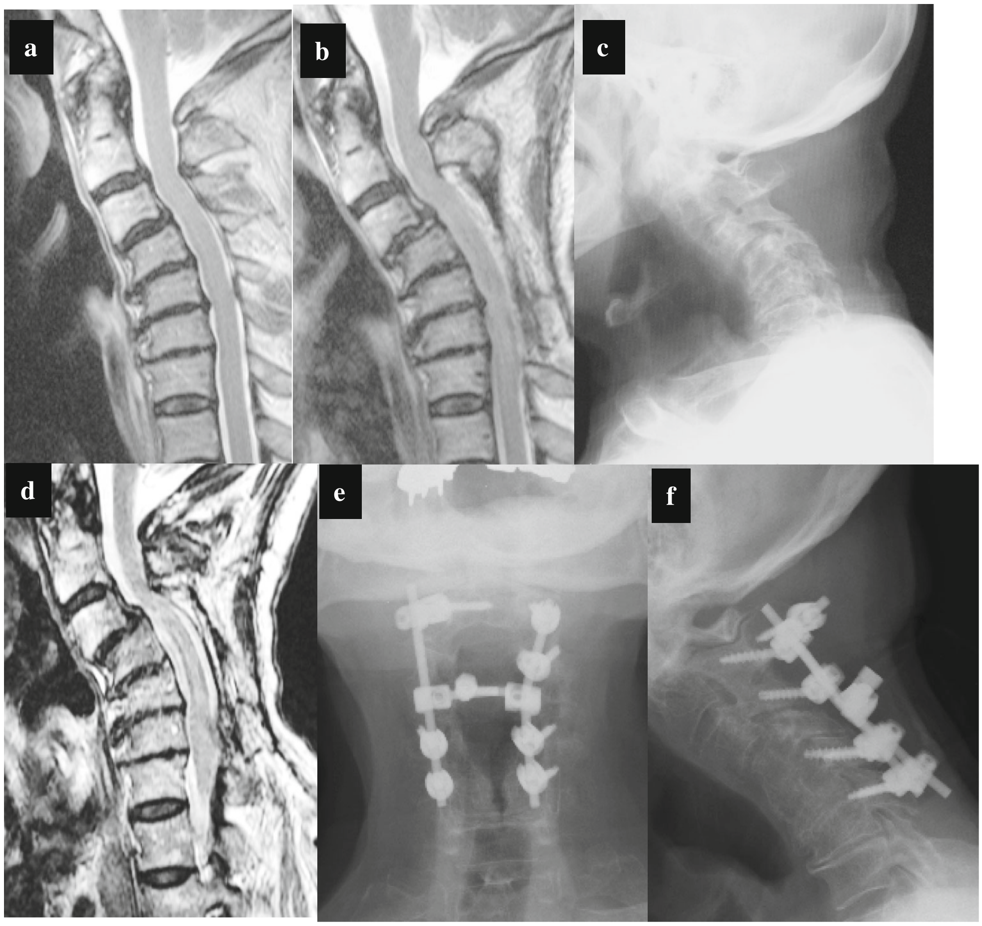

Fig. 3 MRI from Case 2. **a** MRI before the initial operation reveals multilevel canal stenosis at C3–C6. **b** Postoperative follow-up MRI shows kyphotic deformity and anterior slippage of the C3 vertebral body, but no obvious spinal cord compression in the neutral position MRI. **c** Lateral X-ray before the second operation shows severe kyphotic change and C3 anterior slippage. **d** Sagittal MRI before the second operation shows no obvious spinal cord compression. **e**, **f** Postoperative X-ray after posterior fusion surgery

because not all laminoplasty techniques maintain the posterior osseous barrier. Various laminoplasty techniques have been reported [10, 12–14], and representative procedures are shown in Fig. 5e–h. The most important difference is the single [10, 13] vs. double [12, 14] door techniques. The second most important difference is with [10, 12] or without [13, 14] interlaminar spacers.

Among the four major types of laminoplasties, as shown in Fig. 5, a double-door laminoplasty without interlaminar spacers does not have a posterior barrier (Fig. 5), which is one of the most traditional methods of laminoplasty and is widely used [11, 14]. In case 2, progressive myelopathy and kyphotic change progressed after a double-door laminoplasty without interlaminar spacers. Although satisfactory surgical outcomes have been reported after this procedure [15], caution is necessary for the occurrence of positional spinal cord compression.

In case 1, a single-door laminoplasty with interlaminar spacers was performed first, but lamina re-closure occurred. Even in cases with interlaminar spacers, there is a risk of lamina re-closure in cases with kyphotic alignment [16], and we would like to emphasize the importance of hinge union in the laminoplasty technique.

Before surgery in both the current cases, cases 1 and 2 showed progression of kyphosis and anterior vertebral slippage even in the neutral position. Although there was no severe cord compression in the neutral MRI, those findings could have been enough for a surgical decision. Moreover, we performed a positional evaluation in extension/flexion positions for those patients, because they complained of unique symptoms in which they could not extend their neck, although their spondylolisthesis progressed in the flexion position.

To evaluate positional pathology, there are two methods: a positional MRI taken in the flexion and extension positions [6–9] and a positional CTM taken in the flexion and extension positions [5, 17–21]. Those methods are also reported as dynamic MRI/CTM or kinematic MRI/CTM. Both methods have advantages and disadvantages. A positional CTM has the advantage of requiring less

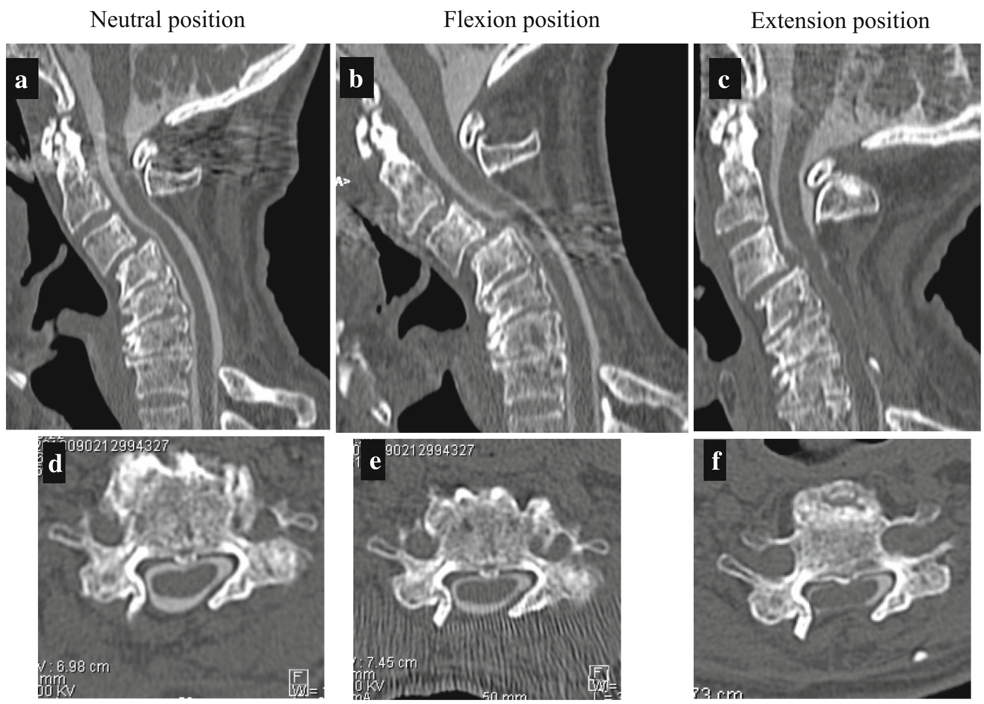

Fig. 4 Positional CTM from Case 2. **a** Sagittal and **d** axial images from a neutral CTM did not show spinal cord compression, although the opened laminas on the left side were re-closed slightly. **b** Sagittal and **e** axial images from a flexion CTM show increased anterior slippage of the C3 vertebral body but no spinal cord compression. **c** Sagittal and **f** axial images from an extension CTM show a dramatic increase in spinal cord compression by the soft tissues located on the dorsal side of spinal cord

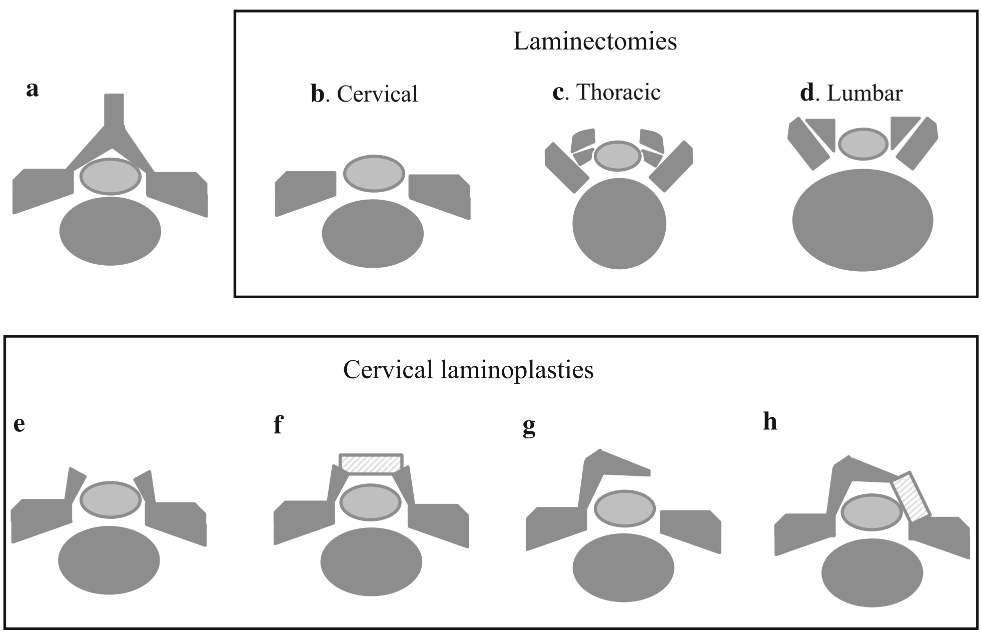

Fig. 5 Various posterior decompression techniques. **a** Normal cervical spine. Laminectomies: **b** cervical laminectomy, **c** thoracic laminectomy, and **d** lumbar laminectomy. Lateral masses are not large enough to protect the dura from posterior soft-tissue compression after the laminectomy in the cervical spine, although the lateral masses are large enough in the thoracic and lumbar spine. Representative techniques of cervical laminoplasties: **e** double-door technique without interlaminar spacers (Iwasaki method) [14]; **f** double-door technique with interlaminar spacers (Kurokawa method) [12]; **g** single-door technique without interlaminar spacers (Hirabayashi method) [13]; and **h** single-door technique with interlaminar spacers (Ito–Tsuji method) [10]. Most laminoplasties maintain the posterior barriers, but there are no posterior barriers in **e**

examination time, compared with a positional MRI. In cases with severe cord compression in the neck extension position, there is a potential risk of worsening the neurological condition after an extension MRI/CTM, but a CTM has fewer risk because of the less examination time. Moreover, the current patients could not extend their necks for a long time because of the severe neck pain and numbness. Therefore, we used a positional CTM in our study. In contrast, a positional MRI has the advantage that there is no radiation affect which is very important especially in younger patients. Moreover, it does not require the use of a dye injection which may cause the risk of dye allergies, infections, and CSF leakage. Therefore, we recommend the positional MRI as the first choice in patients with less severe symptoms.

Although we cannot clarify whether extension or flexion motions have a bigger role in causing neurological deficits in the current cases, our results demonstrate that the spinal cord was compressed more severely in the extension position than in the flexion position. Moreover, the symptoms worsened in the extension position more than in the flexion position. Therefore, we speculate that extension motion has a bigger role in causing progressive myelopathy. In the previous reports with post-laminectomy positional cord compression [6–8], the authors also concluded that the extension position caused progressive myelopathy, according to their findings.

However, because it is impossible to clarify whether only the extension motion causes the worsening of neurological conditions, while the vertebral body slipped in the flexion position at the same time, we performed a posterior instrumented fusion to treat both extension and flexion conditions. The results after fusion surgery were favorable in the current cases.

To prevent postoperative positional cord compression following laminectomies/laminoplasties, primary fusion surgery including both anterior and posterior fusion is considered to be the ideal primary surgery for CSM with kyphotic alignment. However, caution is necessary, because Stamm et al. [8] reported that positional cord compression by soft tissues occurred even after laminectomy with fusion. They concluded that laminectomy procedures have the risk of positional cord compression because of the lack of a posterior barrier even with posterior fusion. Further investigation will be necessary.

There is a limitation in this paper in that we evaluated only two cases with progressive cervical myelopathy caused by the positional cord compression after cervical laminoplasty. Therefore, it is unclear whether postoperative positional cord compression is more common or not in patients who show poor recovery after laminectomies/laminoplasties. Further study will be necessary and we recommend performing positional MRI/CTMs when patients show progressive myelopathy after laminectomies/laminoplasties, even though a neutral MRI does not show severe spinal cord compression.

Conclusion

Two cases of progressive myelopathy after laminoplasty were reported: one case after a laminectomy following the failure of the single-door laminoplasty and one case after a double-door laminoplasty without interlaminar spacers. These cases showed that postoperative positional spinal cord compression caused the progressive myelopathy. In cases with poor surgical outcomes after posterior decompression surgery, it is essential to evaluate positional spinal cord compression using a positional CTM/MRI, even though there is no apparent cord compression in the neutral position.

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Compliance with ethical standards

Conflict of interest None of the authors has any potential conflict of interest.

References

1. Breig A, Turnbull I, Hassler O (1966) Effects of mechanical stresses on the spinal cord in cervical spondylosis. A study on fresh cadaver material. J Neurosurg 25:45–56. doi:10.3171/jns.1966.25.1.0045
2. Panjabi M, White A (1988) Biomechanics of nonacute cervical spinal cord trauma. Spine (Phila Pa 1976) 13:838–842
3. Penning L, van der Zwaag P (1966) Biomechanical aspects of spondylotic myelopathy. Acta Radiol Diagn (Stockh) 5:1090–1103
4. Hirayama K, Tsubaki T, Toyokura Y, Okinaka S (1963) Juvenile muscular atrophy of unilateral upper extremity. Neurology 13:373–380
5. Fujimoto Y, Oka S, Tanaka N et al (2002) Pathophysiology and treatment for cervical flexion myelopathy. Eur Spine J 11:276–285. doi:10.1007/s005860100344
6. Morimoto T, Ohtsuka H, Sakaki T, Kawaguchi M (1998) Post-laminectomy cervical spinal cord compression demonstrated by dynamic magnetic resonance imaging. Case report. J Neurosurg 88:155–157. doi:10.3171/jns.1998.88.1.0155
7. Evans LT, Lollis SS (2015) Dynamic compression of the spinal cord by paraspinal muscles following cervical laminectomy: diagnosis using flexion-extension MRI. Case Rep Radiol 2015:275623. doi:10.1155/2015/275623
8. Stamm S, McClellan JW, Knierim A et al (2014) Dynamic MRI reveals soft-tissue compression causing progressive myelopathy in postlaminectomy patients: a report of three cases. JBJS Case Connect 3:e17. doi:10.2106/JBJS.CC.L.00174
9. Suzuki F, Nakajima M, Matsuda M (1999) Cervical cord compression caused by a pillow in a postlaminectomy patient

undergoing magnetic resonance imaging. Case report. J Neurosurg 90:145–147

10. Itoh T, Tsuji H (1985) Technical improvements and results of laminoplasty for compressive myelopathy in the cervical spine. Spine (Phila Pa 1976) 10:729–736
11. Suda K, Abumi K, Ito M et al (2003) Local kyphosis reduces surgical outcomes of expansive open-door laminoplasty for cervical spondylotic myelopathy. Spine (Phila Pa 1976) 28:1258–1262. doi:10.1097/01.BRS.0000065487.82469.D9
12. Kurokawa T, Tsuyama N, Tanaka H et al (1982) Double-door laminoplasty. Bessatsu Seikeigeka 2:234–240
13. Hirabayashi K, Watanabe K, Wakano K et al (1983) Expansive open-door laminoplasty for cervical spinal stenotic myelopathy. Spine (Phila Pa 1976) 8:693–699
14. Iwasaki H (1987) Expansive laminoplasty. Bessatsu Seikeigeka Seikeigeka 2:228–233
15. Shigematsu H, Ueda Y, Takeshima T et al (2010) Degenerative spondylolisthesis does not influence surgical results of laminoplasty in elderly cervical spondylotic myelopathy patients. Eur Spine J 19:720–725. doi:10.1007/s00586-010-1338-5
16. Matsumoto M, Watanabe K, Hosogane N et al (2012) Impact of lamina closure on long-term outcomes of open-door laminoplasty in patients with cervical myelopathy: minimum 5-year follow-up study. Spine (Phila Pa 1976) 37:1288–1291. doi:10.1097/BRS.0b013e3182498434
17. Fujibayashi S, Neo M, Nakamura T (2007) Flexion myelopathy of the thoracic spine. Case report. J Neurosurg Spine 6:68–72. doi:10.3171/spi.2007.6.1.13
18. Ito K, Yukawa Y, Machino M, Kato F (2013) Spinal cord cross-sectional area during flexion and extension in the patients with cervical ossification of posterior longitudinal ligament. Eur Spine J 22:2564–2568. doi:10.1007/s00586-013-2982-3
19. Yoshii T, Yamada T, Hirai T et al (2014) Dynamic changes in spinal cord compression by cervical ossification of the posterior longitudinal ligament evaluated by kinematic computed tomography myelography. Spine (Phila Pa 1976) 39:113–119. doi:10.1097/BRS.0000000000000086
20. Kobayashi S, Matsuyama Y, Shinomiya K et al (2014) A new alarm point of transcranial electrical stimulation motor evoked potentials for intraoperative spinal cord monitoring: a prospective multicenter study from the Spinal Cord Monitoring Working Group of the Japanese Society for Spine Surgery and Related. J Neurosurg Spine 20:102–107. doi:10.3171/2013.10.SPINE12944
21. Fujiwara Y, Izumi B, Fujiwara M et al (2016) C2 spondylotic radiculopathy: the nerve root impingement mechanism investigated by para-sagittal CT/MRI, dynamic rotational CT, intraoperative microscopic findings, and treated by microscopic posterior foraminotomy. Eur Spine J. doi:10.1007/s00586-016-4710-2