Characteristics of residual symptoms following laminoplasty in diabetic patients with cervical spondylotic myelopathy: A prospective cohort study

Masaaki Machino, MD[1)]; Shiro Imagama, MD, PhD[1)]; Kei Ando, MD, PhD[1)]; Kazuyoshi Kobayashi, MD, PhD[1)]; Tetsuro Hida, MD[1)]; Kenyu Ito, MD[1)]; Mikito Tsushima, MD[1)]; Akiyuki Matsumoto, MD[1)]; Satoshi Tanaka, MD[1)]; Masayoshi Morozumi, MD[1)]; Keigo Ito, MD, PhD[2)]; Fumihiko Kato, MD, PhD[2)]; Yoshihiro Nishida, MD, PhD[1)]; Naoki Ishiguro, MD, PhD[1)]

1) Department of Orthopedic Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan
2) Department of Orthopedic Surgery, Chubu Rosai Hospital, Japan Labor Health and Welfare Organization, Nagoya, Japan

Address for correspondence and reprints:

Shiro Imagama, MD, PhD (corresponding author)

Department of Orthopaedic Surgery, Nagoya University Graduate School of Medicine

65, Tsurumai-cho, Showa-ku, Nagoya, Aichi, 466-8550, Japan

Phone: +81-51-741-2111

Fax: +81-52-744-2260

E-mail: imagama@med.nagoya-u.ac.jp

No funds were received in support of this work. No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript. The Institutional Review Board in our institution approved this study, and written informed consent was obtained from each patient before study participation or surgery. The authors declare no conflict of interest.

Presented at the 30th Annual Meeting of Cervical Spine Research Society (CSRS) -European Section, Pamplona, Spain, at June 25-27, 2014, and the 43rd Annual Meeting of CSRS, San Diego, CA, USA, at December 2-5 2015.

ABSTRACT

Study Design. A prospective cohort study

Objective. The purpose of this study was to compare cervical laminoplasty outcomes between diabetic and non-diabetic patients with cervical spondylotic myelopathy (CSM), and to characterize residual symptoms of diabetic patients.

Summary of Background Data. Diabetes is one of the most frequent comorbidities in CSM patients However, no report has elucidated residual symptoms following surgery in diabetic patients with CSM.

Methods. A total of 505 consecutive patients with CSM (331 males, 189 females; mean age, 66.6 years; range, 41–91 years; >1-year follow-up after laminoplasty) were enrolled and divided into diabetic group (n = 105) and non-diabetic group (n = 400). The Japanese Orthopaedic Association (JOA) scores and recovery rate (RR) of each function were compared between the groups. To quantitatively assess performance, the 10-s grip and release (G&R) test and the 10-s step test were evaluated.

Results. There was no significant difference in the mean RRs of upper extremity motor function between diabetic and non-diabetic patients (59.2% vs. 60.5%, respectively; *P* = 0.789). The RR of lower extremity motor function was lower in the diabetic group than in the non-diabetic group (36.1% vs. 43.4%, respectively; *P* = 0.047); the RR of upper extremity sensory function also was lower (36.8% vs. 49.6%, respectively; *P* = 0.006). However, the mean RRs of sensory functions of lower extremities were 59.7% (diabetic) and 59.2% (non-diabetic) (*P* = 0.953). There was no significant difference in the mean RRs of trunk sensory function between the groups (69.3% vs. 74.1%, respectively; *P* = 0.303). The mean RRs of urinary bladder function were 42.1% (diabetic) and 53.7% (non-diabetic) (*P* = 0.035). The preoperative mean number of the 10-s step test was lower in the diabetic group than in the non-diabetic group, and the postoperative mean number also was significantly lower in the diabetic group.

Conclusions. Gait disturbance, hand numbness and bladder dysfunction after surgery persisted more than other symptoms in the diabetic than in the non-diabetic patients.

Level of Evidence: Level Ⅱ

KEY POINTS

- Surgical outcomes of diabetic patients and non-diabetic patients with cervical spondylotic myelopathy (CSM) who underwent laminoplasty were compared.
- The residual symptoms following laminoplasty in the diabetic patients with CSM were characterised.
- Although the pre- and postoperative numbers of the 10-s grip and release (G&R) tests were lower in the diabetic group than in the non-diabetic group, the differences were not significant.
- The preoperative mean number of the 10-s step test was lower in the diabetic group than in the non-diabetic group, and the postoperative mean number also was significantly lower in the diabetic group.
- In the diabetic patients with CSM, motor function impairments of the lower extremities, sensory function impairments of the upper extremities and urinary bladder function impairments are persist more than other symptoms after surgery compared with the non-diabetic group.

INTRODUCTION

Cervical spondylotic myelopathy (CSM) is one of the most prevalent and increasingly observed neurological disorders in the geriatric population.[1,2] Symptoms include sensory disturbances of extremities, clumsiness of hands, gait disturbances and urinary dysfunction. Decompression surgery is the standard treatment for this disorder. In particular, cervical laminoplasty is an established procedure for the decompression of multisegmental CSM, and numerous studies have documented satisfactory surgical results.[3,4] Surgical treatment of CSM is aimed at decompressing the spinal cord to prevent further spinal cord damage. Although some neurological function can be recovered after surgery, a degree of irreversible neurological damage is, unfortunately, unavoidable.

Diabetes mellitus is one of the most frequent comorbidities, and the number of diabetic individuals in the population is also increasing.[5] The global prevalence of diabetes among adults aged 20–79 years was estimated to be 285 million people in 2010 and is projected to increase to 439 million by 2030.[5] Therefore, surgical treatment of clinical conditions in these patients is becoming a greater concern. Diabetes is a chronic systemic disease that can affect the peripheral nervous system and microvascular system.[6] The management of CSM with diabetes has been a matter of debate; thus, it remains unclear whether and how diabetes affects the surgical outcomes for CSM.[6] To determine the best treatment for CSM, it is important to understand the differences in characteristics of preoperative impairments and postoperative residual symptoms between diabetic patients and non-diabetic patients. Previous author has reported that diabetic neuropathy and/or angiopathy influenced the outcomes of lumbar spine surgery.[7] However, to our knowledge, no report has elucidated residual symptoms following surgery in diabetic patients with CSM.

We compared outcomes of cervical laminoplasty between diabetic patients and non-diabetic patients with CSM and characterised the residual symptoms following laminoplasty in the diabetic patients.

MATERIALS AND METHODS

Study Population

Seven hundred and one consecutive patients underwent modified double door laminoplasty for CSM. Exclusion criteria included the following: (1) ossification of the posterior longitudinal ligament (OPLL); (2) history of rheumatoid arthritis, cerebral palsy or tumours; (3) spinal injuries (fractures, dislocations, spinal cord injuries, ligamentous injuries); (4) destructive spondyloarthritis caused by haemodialysis; (5) previous cervical surgery; (6) severe kyphotic deformity, spinal fusion with instrumentation; (7) thoracic spondylotic myelopathy and (8) lumbar spinal canal stenosis. Of the 701 patients, 528 with CSM were eligible for participation. Of the 528 patients, 505 who were followed up for >12 months after surgery were prospectively enrolled in this study (follow-up rate, 95.6%). The final sample comprised 311 males and 194 females (mean age, 66.6 years; range, 41–91 years).

The patients were divided into a diabetic group and a non-diabetic group. The diabetic group included patients with fasting blood glucose levels ≥126 mg/dl on preoperative screening or who were previously diagnosed with diabetes.[8] Glycated hemoglobin (HbA1c; National Glycohemoglobin Standardization Program, NGSP value) levels also were checked for the diagnosis at admission before surgery in all patients with diabetes.[9] We consulted diabetes specialists at our institution, and these patients were evaluated comprehensively based on the criteria for the diagnosis of diabetes.[9,10] All patients had palliative well-controlled blood sugar levels during the perioperative period.[10] We investigated differences in age, sex, symptom duration, body height, body weight, body mass index (BMI), cervical alignment and range of motion (ROM), increased signal intensity (ISI) on magnetic resonance T2-weighted imaging (MRT2WI),[11] prevalence of hypertension and hyperlipidaemia, use of anticoagulant or antiplatelet agents, smoking history and postoperative follow-up period between the groups.

All patients presented with symptoms of myelopathy. Magnetic resonance imaging and myelographic findings were consistent with myelopathy secondary to multisegmental cervical spondylotic stenosis. Each patient had myelopathy confirmed by physical examination, and cord compression was present only between C2/C3 and C7/T1. The Institutional Review Board in our institution approved this study, and written informed consent was obtained from each patient before study participation or surgery.

Surgical Technique for Modified Double Door Laminoplasty

We performed double door laminoplasty according to Kurokawa’s method with some modifications.[3,12,13] The muscles attached to the C2 spinous process were preserved without detachment. Surgical exposure was limited as much as possible. The spinous processes between C3 and C7 were resected at their bases, and the laminae were cut at the centre using a high-speed drill. Bilateral gutters were created as hinges at the border between the laminae and the facets in a fashion that was slightly more medial than the original procedure, thus minimising invasion of the facets. After the laminae halves were elevated in a manner similar to a French door, the bone graft struts (16–18 mm long) created from the C6 or C7 spinous process were tied to bridge the bilateral edges of the laminae.

Postoperative Considerations

All patients, with exceptions, were allowed to sit up and walk on postoperative day 1 while wearing a Philadelphia collar. The collars were fitted to all patients but could be removed at the patient's discretion. Cervical ROM exercises were performed as soon as possible during the rehabilitation program. Ideal spinal alignment was explained to all patients.

Clinical Outcomes

Operation time and blood loss were assessed. The severity of myelopathy before and after surgery was evaluated according to a scoring system proposed by the Japanese Orthopaedic Association for cervical myelopathy (JOA score).[14,15] The assessment of postoperative JOA score was performed 1 year after surgery and at the final follow-up. The JOA score quantifies neurological impairment by evaluating motor function in the upper and lower extremities (4 points each), sensory function in the upper and lower extremities as well as in the trunk sensibility (2 points each, total 6 points) and urinary bladder function (3 points). Therefore, a perfect JOA score for cervical myelopathy is 17 points (Table 1). The recovery rate (RR) of the JOA score was calculated using the following formula originally suggested by Hirabayashi et al.[14] [RR = postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score) × 100%] (Table 1). In addition, the achieved JOA score (postoperative JOA score − preoperative JOA score) was also evaluated.[15] Each functional improvement was also expressed by RR (sub-score RRs).[16]

To quantitatively assess performance, the 10-s grip and release (G&R) test was used for upper limb function, and the 10-s step test was used for trunk and lower limb function.[17,18] In the 10-s G&R test, data were collected from the left or right side, depending on which side was weaker.

Ten-Second G&R Test

Each patient was asked to grip and release with the fingers as rapidly as possible with the forearm kept in pronation and the wrist in mild extension. The number of complete cycles of movement within 10 s was separately counted on each side.[17]

Ten-Second Step Test

Each patient was asked to take high steps by bending their knee 90° to make their thighs parallel to the floor. They were asked to take as many of these steps as they could in place without holding onto anything for balance for 10 s. If the patient seemed at risk of falling, the test was performed in proximity to a hand bar.[18,19]

Radiographic Outcomes

The lordotic angle between C2 and C7 was measured before surgery and at the final follow-up in the neutral and maximal flexion–extension lateral radiographic view using the Cobb method, with negative and positive lordotic angles indicating cervical kyphosis and lordosis, respectively.[20,21] The alignment change was also assessed: [Alignment change (degree) = (preoperative C2–7 lordotic angle) − (postoperative C2–7 lordotic angle)].[21] ROM of the cervical spine was assessed by measuring the difference in alignment at flexion and extension. Angles created by a line parallel to the inferior aspect of the C2 vertebral body and a line parallel to that of the C7 vertebral body were measured on flexion and extension lateral radiographs, and a total ROM value was obtained by summation of these angles. ROM preservation was assessed using the formula [ROM preservation (%) = (postoperative ROM)/(preoperative ROM) × 100].[21] The occurrence of ISI on MRT2WI was also evaluated.[11]

Statistical Analysis

Data were analysed using SPSS statistical software (version 18.0; SPSS, Inc., Chicago, IL, USA). All values are expressed as the mean ± standard deviation. The Mann–Whitney U test was performed to determine differences between two groups. The chi-square test was used to analyse differences between groups. $P < 0.05$ was considered statistically significant.

RESULTS

Laminoplasty was performed at the following disc levels: C3–C7 in 432 patients, C3–C6 in 37 patients (along with C7 dome-shaped fenestration), C4–C7 in 21 patients, C3–C6 in 11 patients and C3–T1 in four patients. The average operation time for laminoplasty was 76.6 min (range, 38–160 min), and the average blood loss was 51.2 ml (range, 1–500 ml). The average postoperative follow-up period was 26.5 months (range, 12–66 months). The mean disease duration was 15.4 months (range, 1–200 months). The mean preoperative JOA score was 10.6 ± 2.6 points; the mean postoperative JOA score was 13.6 ± 2.5 points 1 year after surgery and 13.8 ± 2.5 points at the final follow-up. The mean RR of the JOA score was 51.8% ± 32.0% at the final follow-up.

There were 105 patients in the diabetic group and 400 patients in the non-diabetic group. There were no significant differences in age, sex, symptom duration, BMI, preoperative cervical alignment and ROM or occurrence of ISI between the groups (Table 2). Although there were significantly higher prevalences of hypertension and hyperlipidaemia and greater use of anticoagulants and/or antiplatelet agents in the diabetic group than in the non-diabetic group, there was no significant difference in smoking history (Table 2). There were no statistically significant differences in the follow-up period, operation time, blood loss, postoperative cervical alignment and ROM, alignment change and ROM preservation between the groups (Table 3). The pre- and postoperative JOA scores and RRs of JOA scores were significantly lower in the diabetic group than in the diabetic group; however, there was no significant difference in the achieved JOA scores (Table 3).

Before surgery, the mean motor function scores for the lower extremity in the diabetic and non-diabetic groups were 2.1 ± 1.1 points and 2.4 ± 1.0 points, respectively (P = 0.006) (Figure 1), and the mean sensory function scores for the lower extremity were 0.94 ± 0.89 points and 1.13 ± 0.85 points, respectively (P = 0.027). After surgery, the motor function scores for the lower extremity were 2.7 ± 1.1 points (diabetic) and 3.0 ± 1.0 points (non-diabetic) at final follow-up (P = 0.006). However, there was no significant difference in the mean sensory function scores for the lower extremity between the groups postoperatively. In the diabetic group, scores of sensory function for the upper extremities and urinary bladder function were lower than those of the non-diabetic group after surgery (P = 0.021, P = 0.044, respectively). There were no significant differences in the postoperative scores of upper extremity motor function and trunk sensory function between the groups (Figure 1).

The mean RRs of upper extremity motor function in the diabetic and non-diabetic groups were 59.2% and 60.5%, respectively (not significant) (Table 4). The RR of lower extremity motor function was significantly lower in the diabetic group than in the non-diabetic group (36.1% vs. 43.4%, respectively; P = 0.047), and the RR of upper extremity sensory function was significantly lower (36.8% vs 49.6%, respectively; P = 0.006). However, the mean RRs of sensory function of the lower extremity and trunk were 59.7% and 69.3% (diabetic) and 59.2% and 74.1% (non-diabetic), respectively. The mean RRs of urinary bladder function were 42.1% (diabetic) and 53.7% (non-diabetic) (P = 0.035) (Figure 2).

Furthermore, the preoperative mean numbers of the 10-s G&R test on the weaker side were 14.4 and 15.4 in the diabetic and non-diabetic groups, respectively, but the difference was not significant (Table 5), and there was no significant difference in the postoperative mean numbers of the 10-s G&R test (18.0 and 18.9, respectively). The preoperative mean number of the 10-s step tests was significantly lower in the diabetic group than in the non-diabetic group (10.6 and 12.3, respectively; $P < 0.001$); the postoperative results showed a similar relationship (13.8 and 15.9, respectively; $P < 0.0001$) (Figure 3).

DISCUSSION

The outcome of laminoplasty has not been fully evaluated in diabetic patients with CSM because previous retrospective studies included both OPLL and CSM. Cervical laminoplasty outcomes have been reported to be better in patients with CSM than in patients with OPLL, and it is likely that those studies contained some bias.[6,22-24] Although there have been previous reports of the influence of diabetes on surgical outcomes for cervical myelopathy, the controversy is mostly related to the impact of surgical outcomes on the cervical spine.[6,22-25] Kawaguchi et al. reported that 18 diabetic patients with CSM were more likely to have a poor recovery of sensory function in the lower extremities.[22] Kim et al. also reported that RR in 31 diabetic patients with CSM was expected to be inferior to that in non-diabetic patients.[6] They speculated that the poor recovery of neurological function resulted from diabetic polyneuropathy. These previous studies had several limitations. First, they retrospectively reviewed only patients who underwent surgery. Therefore, further prospective studies should be conducted to more clearly identify the characteristics of residual symptoms following surgery in diabetic patients with CSM. Second, those retrospective studies included both OPLL and CSM patients, which may have resulted in bias to a certain extent. Third, the sample of diabetic patients was small, which could have affected the results and led to no difference in surgical outcome between diabetic and non-diabetic patients.

In the present study, upper extremity motor function, particularly finger movement, and sensory function of the trunk and lower extremities of diabetic patients showed relatively good improvement postoperatively; however, lower extremity motor function, upper extremity sensory function and bladder function improved less than did those in the non-diabetic patients. In particular, gait disturbances, hand numbness and bladder dysfunction often persisted. The hyperglycaemia might have affected the peripheral nervous system and microvascular system in our patients, which probably influenced the outcomes.[26] In addition, the JOA score in the diabetic patients might have been influenced by additional impairments in peripheral nerves or other diabetic complications.[27] Kobayakawa et al. suggested that hyperglycaemia pathologically negatively affects neurological recovery after central nervous system injury.[28]

If our findings are replicated, disruptions to upper extremity sensory function may be particularly worrisome to potential surgical candidates. Gait abnormalities and bowel and/or bladder dysfunction are very bothersome symptoms in patients with CSM. Gait disturbances can result from involvement of long spinal cord tracts. Similarly, bowel and bladder symptoms, including incontinence, develop because of long tract involvement.[29]

The JOA score is the most comprehensive of the traditional and available measures for quantifying the degree of impairment secondary to myelopathy.[25] However, the JOA scoring system is subjective and may influence results. Furthermore, the evaluation uses discrete variables, so small differences in the patient's conditions cannot be detected.[30,31]

Thus, the JOA score alone is insufficient for effectively quantifying outcomes. Therefore, we used the 10-s G&R and 10-s step tests to quantitatively measure symptom severity.[18,19] Although the pre- and postoperative numbers of the 10-s G&R tests were lower in the diabetic group than in the non-diabetic group, the differences were not significant. These quantitative measurements supported the pre- and postoperative JOA scores for upper extremity motor function. The preoperative mean number of the 10-s step test was lower in the diabetic group than in the non-diabetic group, and the postoperative mean number also was significantly lower in the diabetic group. These results also support the outcomes based on pre- and postoperative JOA motor function scores of lower extremities.

A possible limitation of our study was the relatively brief follow-up period. In addition, scores of motor function for the lower extremities of the diabetic patients were lower than those of the non-diabetic patients preoperatively. Therefore, it should be noted that the diabetic patients are originally inferior in the motor function for the lower extremities before surgery. Moreover, patient-based objective outcomes, such as quality of life determined using the Short-Form Health Survey 36 and subjective satisfaction as well as axial back pain using the visual analogue scale, were not assessed. However, the 10-s G&R and 10-s step tests were included as quantitative performance tests. Quantitative physical tests could be confidential objective assessment methods for CSM. When these tests are combined with clinical tests, such as the JOA score, even more, objective and quantitative evaluation of CSM is possible. No electrophysiological study was performed to evaluate the existence of diabetic polyneuropathy. Therefore, preoperative and postoperative neurological status may be ascribed to polyneuropathy and CSM in diabetic patients. Further electrophysiological studies are needed. However, this study evaluated the largest number of patients who had undergone the same single procedure. The patients were prospectively followed up with a high follow-up rate.

CONCLUSION

Gait disturbance, hand numbness and bladder dysfunction persisted more than did other symptoms after surgery in the diabetic patients than in the non-diabetic patients. These findings provide baseline data that may allow clinicians to accurately assess preoperative impairment and postoperative outcomes in diabetic patients with CSM.

REFERENCES

1. Batzdorf U. *The Adult Spine: Principles and Practice*. New York: Raven Press, Ltd., 1991:1207–17.
2. Machino M, Yukawa Y, Ito K, et al. Dynamic changes in dural sac and spinal cord cross-sectional area in patients with cervical spondylotic myelopathy: cervical spine. *Spine* 2011;36:399–403.
3. Seichi A, Takeshita K, Ohishi I, et al. Long-term results of double-door laminoplasty for cervical stenotic myelopathy. *Spine* 2001;26:479–87.
4. Chiba K, Ogawa Y, Ishii K, et al. Long-term results of expansive open-door laminoplasty for cervical myelopathy: average 14-year follow-up study. *Spine* 2011;31:2998–3005.
5. Shaw JE, Sicree RA, Zimmet PZ. Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Res Clin Pract* 2010;87:4–14.
6. Kim HJ, Moon SH, Kim HS, et al. Diabetes and smoking as prognostic factors after cervical laminoplasty. *J Bone Joint Surg Br* 2008;90-B:1468–72.
7. Browne JA, Cook C, Pietrobon R, et al. Diabetes and early postoperative outcomes following lumbar fusion. *Spine* 2007;32:2214–9.
8. Qaseem A, Vijan S, Snow V, et al. Glycemic control and type 2 diabetes mellitus: the optimal hemoglobin A1c targets. A guidance statement from the American College of Physicians. *Ann Intern Med* 2007;147(6):417–22.
9. The American Diabetes Association. Standards of medical care in diabetes—2010. *Diabetes Care* 2010;33(1):S11–61.

10. Machino M, Yukawa Y, Ito K, et al. Risk factors for poor outcome of cervical laminoplasty for cervical spondylotic myelopathy in patients with diabetes. *J Bone Joint Surg Am* 2014;96(24):2049–55.
11. Yukawa Y, Kato F, Yoshihara H, et al. MR T2 image classification in cervical compression myelopathy: predictor of surgical outcomes. *Spine* 2007;32:1675–8; discussion 9.
12. Yukawa Y, Kato F, Ito K, et al. Laminoplasty and skip laminectomy for cervical compressive myelopathy. *Spine* 2007;32:1980–5.
13. Machino M, Yukawa Y, Hida T, et al. Modified double-door laminoplasty in managing multilevel cervical spondylotic myelopathy: surgical outcome in 520 patients and technique description. *J Spinal Disord Tech* 2013;26:135–40.
14. Hirabayashi K, Miyagawa K, Satomi K, et al. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. *Spine* 1981;6:354–64.
15. Machino M, Yukawa Y, Hida T, et al. Can elderly patients recover adequately after laminoplasty?: a comparative study of 520 patients with cervical spondylotic myelopathy. *Spine* 2012;37:667–71.
16. Machino M, Yukawa Y, Hida T, et al. Persistent physical symptoms after laminoplasty: analysis of postoperative residual symptoms in 520 patients with cervical spondylotic myelopathy.*Spine* 2012;37(11):932–6.
17. Ono K, Ebara S, Fuji T, et al. Myelopathy hand. New clinical signs of cervical cord damage. *J Bone Joint Surg Br* 1987;69:215–9.
18. Yukawa Y, Kato F, Ito K, et al. ”Ten Second Step Test.,” as a new quantifiable parameter of cervical myelopathy. *Spine* 2009;34:82–6.

19. Yukawa Y, Nakashima H, Ito K, et al. Quantifiable tests for cervical myelopathy; 10-s grip and release test and 10-s step test: standard values and aging variation from 1230 healthy volunteers. *J Orthop Sci* 2013;18(4):509–13.

20. Imagama S, Matsuyama Y, Yukawa Y, et al. C5 palsy after cervical laminoplasty: a multicentre study. *J Bone Joint Surg Br* 2010;92(3):393–400.

21. Machino M, Yukawa Y, Hida T, et al. Cervical alignment and range of motion after laminoplasty: Radiographic data from over 500 cases with cervical spondylotic myelopathy and a review of the literature. *Spine* 2012;37:E1243–50.

22. Kawaguchi Y, Matsui H, Ishihara H, et al. Surgical outcome of cervical expansive laminoplasty in patients with diabetes mellitus. *Spine* 2000;25:551–5.

23. Dokai T, Nagashima H, Nanjo Y, et al. Surgical outcomes and prognostic factors of cervical spondylotic myelopathy in diabetic patients. *Arch Orthop Trauma Surg* 2012;132:577–82.

24. Arnold PM, Fehlings MG, Kopjar B, et al. Mild diabetes is not a contraindication for surgical decompression in cervical spondylotic myelopathy: results of the AOSpine North America multicenter prospective study (CSM). *Spine J* 2014;14(1):65–72.

25. Machino M, Yukawa Y, Ito K, et al. Impact of diabetes on the outcomes of cervical laminoplasty: a prospective cohort study of more than 500 patients with cervical spondylotic myelopathy. *Spine* 2014;39(3):220–7.

26. Tarsy D, Freeman R. The nervous system and diabetes. In: Kahn CR, Weir GC (eds) Joslin's diabetes mellitus, 13th edn. Lea and Febiger, Philadelphia, 1994;794–816.

27. Nakanishi K, Tanaka N, Kamei N, et al. Electrophysiological assessments of the motor pathway in diabetic patients with compressive cervical myelopathy. J *Neurosurg Spine* 2015;23(6):707–14.

28. Kobayakawa K, Kumamaru H, Saiwai H, et al. Acute hyperglycemia impairs functional improvement after spinal cord injury in mice and humans. *Sci Transl Med* 2014;6(256):256ra137.

29. Small JM, Dillin WH, Watkins RG. Clinical syndromes in cervical myelopathy. In: Herkowitz H, Garfin SR, Balderson RA, et al, editors. *The Spine*. 4th ed. Philadelphia: W.B. Saunders Co; 1999:465–74.

30. Suzuki A, Misawa H, Simogata M, et al. Recovery process following cervical laminoplasty in patients with cervical compression myelopathy: Prospective cohort study. *Spine* 2009;34:2874–9.

31. Nikaido T, Kikuchi S, Yabuki S, et al. Surgical treatment assessment using the Japanese Orthopedic Association cervical myelopathy evaluation questionnaire in patients with cervical myelopathy: A new outcome measure for cervical myelopathy. *Spine* 2009;34:2568–72.

Table 1.

Evaluation of cervical myelopathy using the scoring system proposed by the Japanese Orthopaedic Association (JOA) score and recovery rate of the JOA score.

JOA score

I. Motor function of the upper extremity
  0. Impossible to eat with chopsticks or spoon
  1. Possible to eat with spoon, but not with chopsticks
  2. Possible to eat with chopsticks, but inadequate
  3. Possible to eat with chopsticks, awkward
  4. Normal

II. Motor function of the lower extremity
  0. Impossible to walk
  1. Needs cane or aid on flat ground
  2. Needs cane or aid only on stairs
  3. Possible to walk without cane or aid but slowly
  4. Normal

III. Sensory function
  A. Upper extremity
    0. Apparent sensory loss
    1. Minimal sensory loss
    2. Normal
  B. Lower extremity (same as A)
  C. Trunk (same as A)

IV. Bladder function
  0. Complete retention
  1. Severe disturbance (sense of retention, dribbling, incomplete continence)
  2. Mild disturbance (urinary frequency, urinary hesitancy)
  3. Normal

■ Recovery rate of the JOA score (Hirabayashi method)

Recovery rate (%) = [Postoperative score − Preoperative score]/[Full score (17) − Preoperative score] × 100

■Achieved JOA score

Achieved score (points) = Postoperative score − Preoperative score

Table 2.
Patient demographics, summary details and comorbidities for the diabetic and non-diabetic groups

	Diabetes	Non-Diabetes	*P* value
Number of patients	105	400	
Age (years)	68.2 ± 8.2	66.2 ± 10.6	0.542
Sex (Males/Female)	65/40	246/154	0.940
Duration of symptom (months)	17.8 ± 26.0	14.7 ± 23.4	0.269
Body height (cm)	158.6 ± 8.9	159.2 ± 9.4	0.733
Body weight (kg)	60.5 ± 11.4	59.3 ± 10.6	0.332
BMI (kg/m^2)	23.9 ± 3.4	23.3 ± 3.2	0.145
Preoperative C2–7 lordotic angle (degrees)	11.5 ± 7.5	11.0 ± 9.9	0.590
Preoperative ROM (degrees)	38.5 ± 8.9	38.8 ± 10.4	0.778
Occurrence of ISI on MRT2WI	74/105 (70.5%)	263/400 (65.8%)	0.425
Hypertension	73/105 (69.5%)	156/400 (39.0%)	<0.0001*
Hyperlipidemia	32/105 (30.5%)	26/400 (6.5%)	<0.0001*
Use of Anticoagulant/Antiplatelet agent	55/105 (52.4%)	61/400 (15.3%)	<0.0001*
Smoking history	33/105 (31.4%)	101/400 (25.3%)	0.202

Values given are mean ± SD unless otherwise specified.
BMI: body mass index
ROM: range of motion

ISI: increased signal intensity
MRT2WI: magnetic resonance T2-weighted imaging
SD: standard deviation
*: statistically significant

Table 3.
Patient clinical and radiographic outcomes in the diabetic and non-diabetic groups

	Diabetes	Non-Diabetes	*P* value
Follow-up period (months)	25.7 ± 14.2	25.1 ± 12.5	0.959
Surgery time (minutes)	75.3 ± 19.7	76.9 ± 23.2	0.946
Blood loss (ml)	47.3 ± 40.5	52.3 ± 53.0	0.782
Preope JOA score (points)	10.1 ± 2.7	10.8 ± 2.5	0.039*
Postope JOA score 1 year (points)	13.0 ± 2.8	13.8 ± 2.4	0.019*
Postope JOA score final f/u (points)	13.1 ± 2.9	13.9 ± 2.4	0.011*
Achieved JOA score (points)	3.1 ± 2.3	3.2 ± 2.0	0.343
Recovery rate (%)	47.3 ± 30.7	53.6 ± 29.4	0.047*
Postoperative C2–7 lordotic angle (degrees)	14.0 ± 8.4	14.9 ± 11.3	0.312
Postoperative ROM (degrees)	33.5 ± 9.0	34.3 ± 9.7	0.437
Alignment change (degrees)	2.5 ± 6.5 lordotic	3.9 ± 6.7 lordotic	0.072
ROM preservation (%)	89.1 ± 23.6	92.4 ± 33.9	0.248

Values given are mean ± SD unless otherwise specified.
JOA score: Japanese Orthopaedic Association score for cervical myelopathy
ROM: range of motion
Alignment change (degree): (preoperative C2–7 lordotic angle) − (postoperative C2–7 lordotic angle)
ROM preservation (%) = (postoperative ROM)/(preoperative ROM) × 100
SD: standard deviation
*: statistically significant

Table 4.
Recovery rate of the Japanese Orthopaedic Association (JOA) score for each function in the diabetic and non-diabetic groups

	Diabetes	**Non-Diabetes**	***P* value**
Motor function of the Upper extremity (%)	59.2 ± 44.3	60.5 ± 44.0	0.789
Motor function of the Lower extremity (%)	36.1 ± 38.5	43.4 ± 39.3	0.047*
Sensory function of the Upper extremity (%)	36.8 ± 39.3	49.6 ± 43.3	0.006*
Sensory function of the Lower extremity (%)	59.7 ± 42.9	59.2 ± 45.5	0.953
Sensory function of the Trunk (%)	69.3 ± 44.7	74.1 ± 38.0	0.303
Bladder function (%)	42.1 ± 42.8	53.7 ± 48.8	0.035*

Values given are mean ± SD unless otherwise specified.
SD: standard deviation
*: statistically significant

Table 5.
Preoperative and postoperative quantifiable tests in the diabetic and non-diabetic groups (10-s G&R test and 10-s step test)

	Diabetes	**Non-Diabetes**	***P* value**
Preoperative 10-s G&R test (right)	14.4 ± 4.9	15.4 ± 4.9	0.077
Preoperative 10-s G&R test (left)	14.8 ± 4.9	15.7 ± 4.9	0.095
Preoperative 10-s step test	10.6 ± 4.8	12.3 ± 4.7	<0.001*
Postoperative 10-s G&R test (right)	18.0 ± 4.8	18.9 ± 4.6	0.101
Postoperative 10-s G&R test (left)	18.3 ± 4.7	19.1 ± 4.7	0.174
Postoperative 10-s step test	13.8 ± 4.5	15.9 ± 3.9	<0.0001*

Values given are mean ± SD unless otherwise specified.
10-s G&R test indicates the 10-s grip and release test
SD: standard deviation
*: statistically significant

FIGURE LEGENDS

Figure 1

The Japanese Orthopaedic Association scores for each function between the diabetic and non-diabetic groups

Scores of motor function of lower extremities, sensory function of upper extremities and urinary bladder function were lower than those of other symptoms after surgery in the diabetic group than in the non-diabetic group.

Figure 2

Comparison of the recovery rates of the Japanese Orthopaedic Association scores for each function between the diabetic and non-diabetic groups

The recovery rates for motor function of lower extremities, sensory function of upper extremities and urinary bladder function were significantly lower in the diabetic group than in the non-diabetic group.

Figure 3

Comparisons of the preoperative and postoperative quantifiable 10-s grip and release (G&R) and 10-s step test results between the diabetic and non-diabetic groups

Although the pre- and postoperative numbers of the 10-s G&R tests were lower in the diabetic group than in the non-diabetic groups, the difference was not significant. The pre- and postoperative numbers of the 10-s step test were significantly lower in the diabetic group than in the non-diabetic group.