



CLINICAL ARTICLE

The Effect of Diabetes Mellitus on the Neurological Function of Patients with Cervical Spondylotic Myelopathy

Jialin Jiang, MD¹ , Kaiqiang Sun, MD², Feng Lin, MD^{1,3}, Mincheng Lu⁴, Le Huan, MD¹, Ximing Xu, MD, MD¹, Jingchuan Sun, MD¹, Jiangang Shi, MD¹ , Yongfei Guo, MD¹

¹Department of Orthopedic Surgery, Spine Center, Changzheng Hospital, Second Military Medical University, Shanghai, ⁴Department of Orthopaedics, Nanfang Hospital, Southern Medical University, Guangzhou, ²Department of Orthopaedic Surgery, Naval Medical Center, Shanghai, Shanghai and ³Department of Orthopedic Surgery, The Affiliated Yantai Yuhuangding Hospital of Qingdao University, Qingdao, Shandong, China

Objective: To evaluate the clinical value of diabetes mellitus for diagnosis and postoperative prognosis in patients with cervical spondylotic myelopathy undergoing anterior decompression and fusion.

Methods: A total of 84 Patients (50 males and 34 females) who underwent anterior decompression and fusion were reviewed in this single-center retrospective study. The patients were divided into two groups (44 patients in the diabetes mellitus group and 40 in the non-diabetic group). Clinical manifestations were evaluated, including characteristics baseline, clinical tests, MRI information, clinical scores, and complications. The predictive effect of diabetes mellitus on clinical scores were assessed *via* the receiver operating characteristic curve. The correlation between the severity of diabetes mellitus and neurological function recovery was estimated using the Pearson correlation coefficient.

Results: Patients with diabetes mellitus exhibited a higher ratio of hyperintensity of the spinal cord ($P < 0.05$) and worse preoperative clinical scores and neurological recovery (all $P < 0.05$). Receiver operating characteristic curve results indicated that diabetes mellitus could serve as a good indicator for preoperative evaluation of the Japanese Orthopedic Association (JOA) score (area under curve [AUC] = 0.639), visual analogue score (AUC = 0.642), and Nurick score (AUC = 0.740). In addition, analysis of JOA in isolation suggested that diabetes mellitus correlated closely with the sensory function in the upper and lower limbs (both $P < 0.01$). The Receiver operating characteristic curve also demonstrated that diabetes mellitus as a clinical test had a reasonable specificity for sensory function in the upper (AUC = 0.654) and lower limbs (AUC = 0.671). Both the level of HbA1c and the duration of diabetes mellitus were negatively correlated with the recovery rate of the JOA score. There was no significant difference between the perioperative complications between the two groups ($P > 0.05$).

Conclusion: This present study revealed that the neurological impairment caused by diabetes mellitus in patients undergoing anterior decompression and fusion does not only affect postoperative functional recovery but also interferes with the preoperative clinical manifestations, especially the sensory function in the upper and lower limbs.

Key words: Cervical spondylotic myelopathy; Clinical outcomes; Diabetes mellitus; Diabetic peripheral neuropathy; Neurological recovery

Address for correspondence Jiangang Shi, MD, Department of Orthopedic Surgery, Spine Center, Changzheng Hospital, Second Military Medical University No.415 Fengyang Road, Shanghai 200003, China. Tel: (0086) 21- (0) 81885631 Fax: (0086) 21- 81885631; Email: shijiangangspine@163.com
Yongfei Guo, MD, Department of Orthopedic Surgery, Spine Center, Changzheng Hospital, Second Military Medical University No.415 Fengyang Road, Shanghai 200003, China. Tel: (0086) 21- (0)81885647 Fax: (0086) 21- 63520020; Email: guospine@163.com
Jialin Jiang, Kaiqiang Sun, Feng Lin, and Mincheng Lu contributed equally to this study and should be considered the co-first authors.
Received 16 March 2021; accepted 24 August 2022

Introduction

Cervical spondylotic myelopathy (CSM) has ranked as one of the most common cervical degenerative diseases among adults over 55 years old.^{1,2} Patients with CSM frequently exhibit severe manifestations due to its nature of insidious onset, and functional impairment in these patients can significantly reduce independence and quality of life. Thus, immediate surgical decompression has been the preferred option to decompress the spinal cord to prevent further spinal cord damage. It has been reported that many factors correlate closely with postoperative outcomes, including duration of symptoms, age, preoperative neurological status, and signal changes within the spinal cord.^{3–6} Anterior decompression and fusion (ADF) is an effective surgical method in treating CSM; it can bring about good outcomes and high fusion rates.

Diabetes mellitus (DM) is one of the most age-related chronic systemic diseases. The high global prevalence of diabetes among adults aged 20–79 has imposed numerous economic burdens on society.⁷ The possibility of DM should be considered in the differential diagnosis of many neurologic conditions, because peripheral nerves, autonomic nerves, cranial nerves, spinal cord and brain are all frequently involved in DM. DM has recently aroused wide public attention in CSM patients coexisting with DM due to DM damaging the peripheral nervous and microvascular systems. Previous studies have suggested that DM can affect a patient's overall recovery rate and sensory/motor function on the lower extremities, and enhance the incidence of perioperative complications.^{8–10} However, those reports above have focused on the effects of DM on surgical outcomes. The impact of DM on preoperative clinical presentations in individuals with CSM coexisting DM has not been thoroughly evaluated. In addition, no studies have been conducted on the correlation between HbA1c level and postoperative neurological recovery of patients undergoing ADF, and few studies on the effects of DM on CSM patients have focused on patients undergoing ADF. However, the postoperative outcome of ADF is more direct and effective, which can partially reduce the influence caused by the surgical effect when comparing the neurological function recovery differences.

Therefore, this present study was designed to investigate: (i) the correlation between DM and patients' preoperative manifestations; (ii) the impact of DM on surgical outcomes in CSM patients undergoing ADF; and (iii) the correlation between the severity of DM and neurological function recovery of the patients undergoing ADF.

Methods and Materials

This study is a single-center retrospective study. The subjects were selected from CSM patients who underwent ADF in our institution from May 2017 to February 2019, and the grouping method was whether they had DM or not. The two groups were mainly divided into the DM and non-DM groups. The results were primarily to compare differences in neurological function recovery.

Ethical Considerations

The independent ethics committee (IEC) of Shanghai Changzheng Hospital approved the study protocol (Approval No.2017SL030). The IEC agreed that this study would not raise patients' risk or cause any extra harm to patients. The IEC further agreed that the investigation is in accordance with the Declaration of Helsinki and that the study will be conducted without ethics problems.

Inclusion and Exclusion Criteria

Patients were enrolled if they satisfied the following criteria: (i) with CSM and underwent ADF; (ii) without obvious response to conservative more than 3 months; (iii) had complete medical records including patients' baseline characteristics, physical examination, clinical evaluations, and imaging information; and (iv) had MRI suggesting evident compression of neural elements.

The exclusion criteria were as follows: (i) with a previous history of spine surgery due to trauma, infection, or tumor; (ii) clinical symptoms resulting from thoracic or lumbar degenerative disease; (iii) clinical symptoms inconsistent with radiological results; (iv) combined with neurological diseases such as Parkinson and Alzheimer dementia; and (v) with congenital or degenerative spinal deformity.

Evaluation of the Severity of DM

The amount of HbA1c produced is closely related to the level of blood glucose, and HbA1c is much more stable than blood glucose, so the measurement of HbA1c can reflect the average level of blood glucose in a period of 8–12 weeks before this blood draw and is an excellent indicator to reflect the quality of blood glucose control over a long period. We recorded the time of diagnosis of DM and the last preoperative measurement of HbA1c (usually on the final morning before the operation day) to assess the DM group's severity.

Preoperative Clinical Manifestations

The clinical tests for myelopathy were carried out within 2 h after admission and performed blindly and independently by two spine surgeons. In addition, the two examiners were blinded to mutual results, the patients' imaging information, and the patients' initial diagnosis. The final diagnosis was determined by the consensus of the two clinicians. All patients underwent preoperative radiological examination of the cervical spine.

Evaluation of the Clinical Outcomes and Perioperative Complications

Visual analogue scale (VAS) score was used to evaluate patients' pain index. Neurological function was assessed by the Japanese Orthopedic Association (JOA) score, Nurick score, before surgery and at the follow-up. The recovery rate of JOA was calculated as follows: The recovery rate of JOA = (final JOA score – preoperative JOA score / 17 – preoperative JOA score) × 100%. In addition, the preoperative

and follow-up JOA score was further evaluated intergroup in isolation. Perioperative complications were recorded.

Statistical Analysis

Data were analyzed using SPSS (Version 20.0; IBM Corp., Armonk, NY, USA). The data were expressed as the mean \pm standard deviation. Independent-sample *t*-test was used to compare the difference in demographic profile and clinical outcomes (JOA, VAS, and Nurick score) between the two groups. The chi-square test or Fisher's exact test was used in the comparisons of the gender, vertebral surgery segment, preoperative symptoms sign (neck pain, radiating pain of upper extremities, myelopathy symptoms, hyperintensity of the spinal cord, and clinical test items), and perioperative complications between the two groups. The sensitivity and specificity of DM predicting clinical scores were evaluated via the receiver operating characteristic (ROC) curve. The correlation between the recovery rate of neurological function and HbA1C/Duration time of DM was estimated using the Pearson correlation coefficient (*r*). Values less than 0.05 ($P < 0.05$) were considered statistically significant.

Results

Characteristic Baseline

Table 1 showed the demographic characteristics of patients. There were 44 patients (28 males and 16 females) in the DM group and 40 (22 males and 18 females) in the non-DM group. The mean age of patients was 56.81 ± 11.01 years in the DM group and 55.93 ± 10.86 years in the non-DM group. The mean follow-up period was 12.39 ± 4.18 months in the DM group and 12.15 ± 6.65 months in the non-DM group. No difference was observed between the two groups regarding gender, age, and follow-up period.

Clinical Evaluation

Regarding the patient's preoperative symptoms, patients in the DM group showed a relatively high incidence of radiation pain and numbness in the upper extremity (both $P < 0.05$). Patients in the DM group also exhibited a higher

ratio of hyperintensity in the spinal cord, knee-jerk reflex, and ankle clonus preoperatively ($P < 0.05$). With regards to outcomes of preoperative clinical scores, patients in the DM group showed higher Nurick ($P < 0.05$) and VAS scores ($P < 0.001$) and lower JOA score ($P < 0.05$) than patients in the non-DM group (Table 2).

Table 3 showed perioperative information and postoperative clinical scores at the final follow-up. Although postoperative clinical scores of patients in both groups improved to some extent, JOA ($P < 0.01$), Nurick ($P < 0.05$), and VAS ($P < 0.001$) of patients in the DM group were worse than those in the non-DM group. The recovery rate of the JOA score in the DM group was also lower than in the non-DM group ($P < 0.05$).

The JOA Score in Isolation

To investigate the specific effect of DM on patients' preoperative dysfunction, we further analyzed JOA items in isolation (Table 4). The results showed that the preoperative sensory function score of the upper and lower extremities was significantly worse in patients with DM than in non-DM patients (both $P < 0.01$). The postoperative sensory function score of the upper ($P < 0.001$) and lower ($P < 0.05$) extremities/ in the DM group was lower than that in the non-DM group. At the same time, the postoperative trunk sensory function of patients in the DM group was also worse than that of the non-DM group ($P < 0.05$) (Table 4).

Comparison of Clinical Characteristics Based on the Recovery Rate

We further divided the patients into two groups according to the recovery rate of JOA score (group less than 75% and group more than 75%). As shown in Table 5, a large proportion of patients with a recovery rate of less than 75% have DM ($P < 0.05$). Furthermore, for preoperative JOA and Nurick scores, patients with a recovery rate of more than 75% had significantly better clinical scores (all P s < 0.05). Moreover, although there was only a significant difference in sensory function in the lower extremity, all the isolated items of the JOA score were worse in the patients with a recovery

TABLE 1 General characteristics

	DM(+)	DM(-)	Statistic	P value
Gender, no.				
Male	28	22	$\chi^2 = 0.641$	0.421
Female	16	18		
Age, Years	55.95 ± 9.22	57.63 ± 8.80	$t = -0.849$	0.399
Duration of symptoms, Months	16.89 ± 5.21	18.00 ± 4.79	$t = -1.02$	0.313
Period of follow-up, Months	12.39 ± 4.18	12.15 ± 6.65	$t = 0.197$	0.197
Surgical segment			$\chi^2 = 0.038$	0.981
2	11	10		
3	19	18		
4	14	12		

Note: + indicated positive DM, - indicated negative DM.

TABLE 2 Preoperative clinical evaluation

	DM(+)	Pain symptoms	DM(-)	Statistic	P value
Neck pain, no (%)	8(18.2%)		10(25%)	$\chi^2 = 0.58$	0.447
Radiating pain, no (%)	26(59.1%)		13(32.5%)	$\chi^2 = 5.956$	0.015
myelopathy symptoms					
Numbness, no. (%)	29(66.0%)		15(37.5%)	$\chi^2 = 6.779$	0.009
Weakness, no. (%)	35(79.5%)		27(67.5%)	$\chi^2 = 1.573$	0.210
High signal in spinal cord	27(61.3%)		15(37.5%)	$\chi^2 = 4.773$	0.029
Knee-jerk reflex (hyperfunction)	9(20.5%)		24(60%)	$\chi^2 = 14.27$	<0.001
Ankle clonus (hyperfunction)	11(25%)		24(60%)	$\chi^2 = 10.56$	0.001
Hoffman sign positive	13(29.5%)		19(47.5%)	$\chi^2 = 2.864$	0.091
Babinski sign positive	1(2.2%)		2(5%)	$\chi^2 = 0.447$	0.603
Preoperative clinical scores					
JOA	11.090 ± 2.49		12.28 ± 2.43	$t = 2.205$	0.030
Nurick	2.84 ± 0.86		2.33 ± 1.02	$t = 2.509$	0.014
VAS	4.48 ± 2.01		3.03 ± 1.12	$t = 4.041$	0

Note: + indicated positive DM, - indicated negative DM.; Abbreviations: JOA, Japanese orthopedic association; VAS, visual analogue scale/score

rate of less than 75%. The above results indicated that poor clinical recovery might relate closely to worse preoperative clinical manifestations.

The ROC Curve for Clinical Scores

The ROC curve suggested DM as a good indicator for preoperative clinical scores (Fig. 1). The sensitivity of DM relative to preoperative VAS score was 65.00%, and specificity was 75.00%. The area under curve (AUC) of DM predicting preoperative VAS score was 0.740

($P = 0.0002$; 95% confidence interval [CI], 0.634–0.846). For the JOA score, DM was found to have a sensitivity of 68.18%, specificity of 52.50%, and the AUC was 0.639 ($P = 0.029$; 95% CI, 0.520–0.757). In addition, for Nurick score, the sensitivity was 95.45% and the specificity was 25%, with the AUC of 0.642 ($P = 0.025$; 95% CI, 0.523–0.762).

For the preoperative JOA score in isolation, the ROC curve indicated that DM had a sensitivity of 56.82%, specificity of 70% for the sensory function of the upper extremity,

TABLE 3 Perioperative period and postoperative conditions

	DM(+)	DM(-)	Statistic	P value
Post-JOA	14.86 ± 1.13	15.58 ± 1.13	$t = 0.061$	0.005
Post-Nurick	1.05 ± 0.81	0.65 ± 0.83	$t = 2.206$	0.030
Post-VAS	2.61 ± 1.26	1.65 ± 0.62	$t = -0.627$	0
Recovery rate of JOA	64.8% ± 12.1%	72.6% ± 18.7%	$t = -2.879$	0.024
Recovery rate grouping			$\chi^2 = 7.302$	0.026
<50%	2	2		
<75%	34	20		
>75%	8	18		
Isolated post-JOA upper extremity				
Motor function	3.59 ± 0.58	3.43 ± 0.59	$t = 1.289$	0.201
Sensory function	1.27 ± 0.45	1.73 ± 0.51	$t = -4.311$	0
Lower extremity				
Motor function	3.66 ± 0.53	3.65 ± 0.53	$t = 0.079$	0.938
Sensory function	1.61 ± 0.49	1.88 ± 0.46	$t = -2.498$	0.014
Sensory function in trunk	1.84 ± 0.37	2.03 ± 0.36	$t = -2.319$	0.023
Bladder function	2.89 ± 0.32	2.88 ± 0.33	$t = 0.159$	0.874
Complications				
Wound infection, no. (%)	2(4.5%)	1(2.5%)	$\chi^2 = 0.252$	1.000
Dysphagia, no. (%)	1(2.3%)	1(2.5%)	$\chi^2 = 0.005$	1.000
Hoarseness, no. (%)	4(9.1%)	4(10%)	$\chi^2 = 0.020$	1.000
C5-Palsy, no. (%)	5(11.4%)	3(7.5%)	$\chi^2 = 0.359$	0.715
Length of stay (days)	11.5 ± 3.6	9.7 ± 2.7	$t = 2.466$	0.016
Operation time (min)	155.61 ± 21.66	163.83 ± 28.055	$t = -1.491$	0.135
Blood loss(mL)	107.45 ± 19.03	112.50 ± 23.89	$t = -1.099$	0.275

Note: + indicated positive DM, - indicated negative DM.; Abbreviations: JOA, Japanese orthopedic association; VAS, visual analogue scale/score

TABLE 4 Preoperative isolated JOA score

Isolated Pre-JOA	DM(+)	DM(-)	Statistic	P value
Upper extremity				
Motor function	2.66 ± 0.61	2.65 ± 0.74	t = 0.062	0.951
Sensory function	0.55 ± 0.70	0.98 ± 0.77	t = 2.688	0.009
Lower extremity				
Motor function	2.82 ± 0.97	2.80 ± 0.91	t = 0.088	0.930
Sensory function	0.84 ± 0.71	1.33 ± 0.80	t = 2.937	0.004
Sensory function in trunk	1.59 ± 0.66	1.70 ± 0.65	t = 0.763	0.447
Bladder function	2.64 ± 0.72	2.83 ± 0.50	t = 1.383	0.170

Note: + indicated positive DM, - indicated negative DM.; Abbreviations: JOA, Japanese orthopedic association.

TABLE 5 Clinical characteristics of patients based on the recovery rate of JOA score

	RR < 75%	RR > 75%	Statistic	P value
DM (+)	36	8	$\chi^2 = 7.051$	0.008
DM (-)	22	16		
Duration of symptoms, Months	10.6 ± 5.4	11.6 ± 6.6		0.480
High signal in spinal cord	30	12	$\chi^2 = 2.036$	0.154
Preoperative clinical scores				
Pre-JOA	11.4 ± 2.62	13.0 ± 2.36	t = -2.797	0.011
Pre-Nurick	2.75 ± 0.95	2.21 ± 0.93	t = -2.394	0.020
Pre-VAS	3.46 ± 1.42	3.93 ± 1.93	t = -1.551	0.269
Isolated pre-JOA				
Upper extremity				
Motor function	2.60 ± 0.67	2.79 ± 0.66	t = -1.200	0.237
Sensory function	0.72 ± 0.76	0.83 ± 0.76	t = -0.634	0.527
Lower extremity				
Motor function	2.73 ± 0.97	3.00 ± 0.83	t = -1.180	0.241
Sensory function	0.88 ± 0.76	1.54 ± 0.66	t = -3.956	0
Sensory function in trunk	1.70 ± 0.74	1.83 ± 0.82	t = -0.693	0.472
Bladder function	2.65 ± 0.67	2.92 ± 0.28	t = -1.782	0.078

Note: + indicated positive DM, - indicated negative DM.; Abbreviations: JOA, Japanese orthopedic association; VAS, visual analogue scale

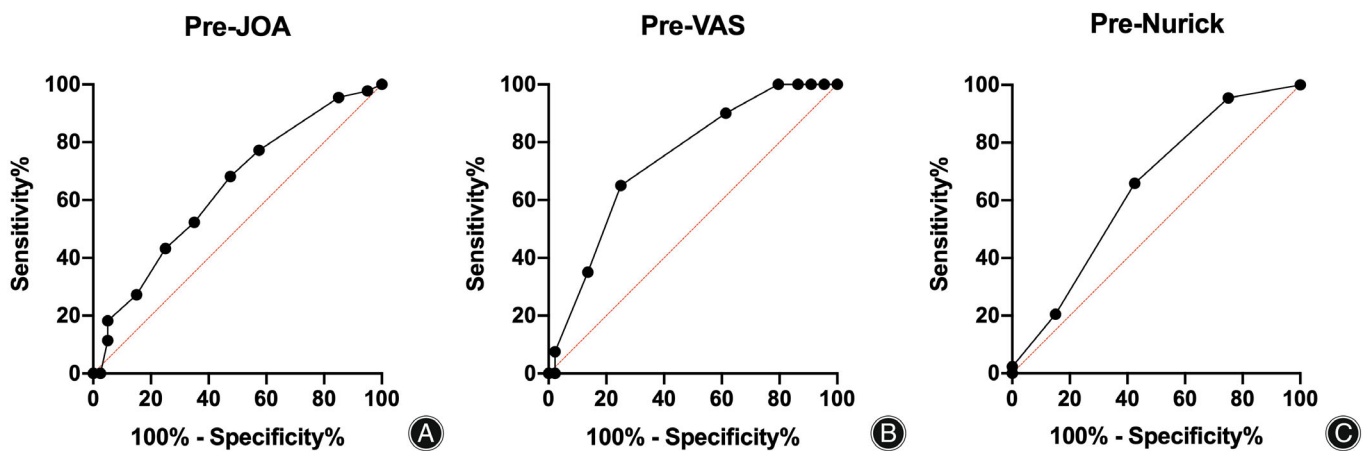
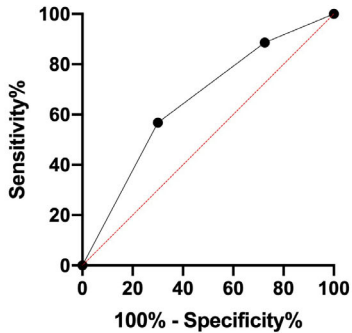
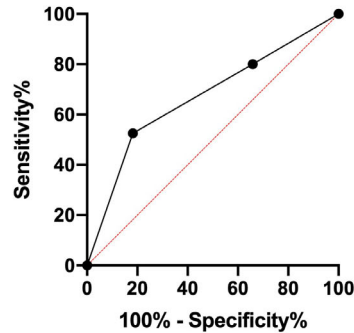


Fig. 1 ROC curve of diabetes mellitus for preoperative clinical scores. (A), ROC curve of DM for preoperative JOA score showed DM is related to preoperative neurological impairment. (B), ROC curve of DM for preoperative VAS showed DM is related to preoperative pain symptoms. (C), ROC curve of DM for preoperative Nurick score showed DM is related to preoperative neurological impairment.

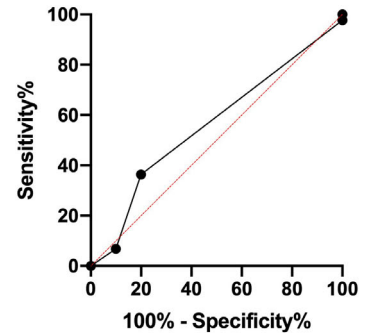
Pre-Sensory function of upper extremity



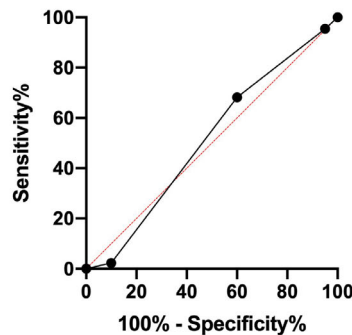
Pre-Sensory function of lower extremity



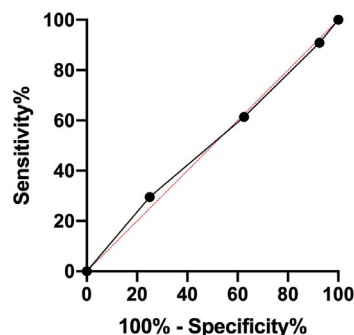
Pre-Sensory function in trunk



Pre-Motor function of upper extremity



Pre-Motor function of lower extremity



Pre-Bladder function

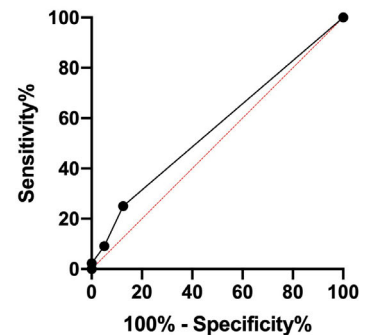


Fig. 2 ROC curve of DM for preoperative sub-score of JOA score showed DM has mainly affected the recovery of sensory function.

and the AUC was 0.654 ($P = 0.015$; 95% CI, 0.536–0.771). For sensory function of lower extremity, the sensitivity was 52.50%, and specificity was 81.82%, with the AUC of 0.671 ($P = 0.007$; 95% CI, 0.553–0.788) (Fig. 2).

The ROC curve of the recovery rate of JOA suggested the sensitivity of DM relative to the recovery rate of JOA score was 45.00%, the specificity was 81.82%, and the AUC was 0.612 ($P = 0.078$; 95% CI, 0.487–0.737) (Fig. 3).

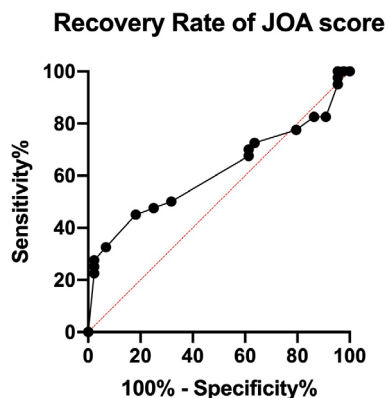


Fig. 3 ROC curve of DM for the recovery rate of JOA score showed DM affected postoperative neurological function recovery.

Perioperative Complications

Among the indicators related to perioperative complications, the DM group's hospitalization duration was longer than that of the non-DM group ($P < 0.05$). There was no significant difference in other indicators.

The Correlation between the Severity of DM and RR of JOA Score

Fig. 4 showed that the severity of DM, such as HbA1c level and duration time of DM, is negatively correlated with neurological function recovery. The recovery rate of the JOA score significantly decreased when the HbA1c level and duration time of DM increased.

Discussion

In recent years, the incidence of DM in the general population has been increasing. By 2030, the number of DM patients is projected to grow to 439 million.⁷ Similarly, CSM is one of the most common spinal diseases and has seen a two-to seven-fold increase in the number of operations compared to the last decades.^{11,12} DM may dampen or promote some neurological symptoms of CSM and may adversely affect surgical outcomes. Kawaguchi *et al.*¹³ reported that DM patients undergoing cervical spine surgery might have worse neurological recovery in the lower extremities, and

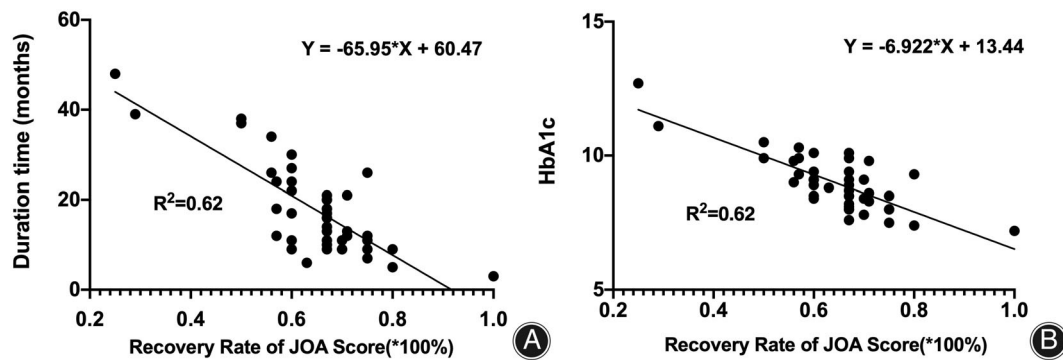


Fig. 4 The recovery rate of the JOA score was significantly negatively correlated with the severity of DM. (A), The duration time of DM was negatively correlated with the recovery rate of the JOA score. (B) The HbA1c level was negatively correlated with the recovery rate of the JOA score.

Dokai *et al.*⁹ said that the DM group showed poorer recovery of sensory and motor function in the lower extremities postoperatively and a negative correlation between preoperative HbA1c levels and recovery of patients with DM. Kim *et al.*¹⁴ also showed that compared to those without DM, the postoperative recovery rate of JOA of DM patients has no significant improvement. The results above indicated that the low recovery rate of neurological function was caused by diabetic polyneuropathy. The previous study has shown that diabetic polyneuropathy involves not only the peripheral nerve but also the spinal cord.¹⁵ This kind of damage may cause a particular impact on the patient's signs and symptoms, obscuring the surgeon's judgment of the patient's preoperative condition. Therefore, we conducted this study for a better preoperative diagnosis and surgical prognosis of DM patients.

In this study, we can clearly find that DM has a serious impact on the preoperative neurological function of patients, including the incidence of neurological symptoms and clinical scores, mainly reflected in the occurrence of sensory dysfunction and pain symptom. Through the comparison of HbA1c indicators, we also confirmed that the severity of DM affects the recovery of postoperative neurological function. Our findings may provide some new insights for the treatment of CSM in the future, that is, preoperative neurological dysfunction and surgical neurological recovery after ADF may be closely related to DM.

The Effects on Preoperative Neurological Function

Our current study showed that the DM group had a significantly higher ratio of upper extremities pain than the non-DM group. The cause may also be diabetic polyneuropathy, one of the main symptoms reported to be the pain in the extremities.¹⁶ Meanwhile, the preoperative VAS score of the DM group was considerably higher than that of the non-DM group. Furthermore, the postoperative VAS score showed that the DM group had more residual pain symptoms. In contrast, the nerve root pain in CSM patients without DM was usually relieved after the surgical release of nerve root

compression. No other researchers have proposed relevant views on postoperative pain control in DM patients after cervical spine surgery, and further studies are necessary to confirm our results. Based on the researchers' conclusions about the effect of glycemic control on the symptoms of DM, it reminds the surgeon to strictly control the DM patient's blood sugar during the perioperative period, otherwise, the patient's pain symptoms cannot be adequately relieved.^{9,17,18}

To determine the effect of DM on preoperative neurological function in CSM patients, we assessed the JOA score of the patients. And we further analyzed the isolated JOA score to obtain the effects of DM on specific preoperative neurological function in CSM patients. The results show that the main affected items are the sensory function of the upper and lower extremities. In the study by Machino *et al.*,⁸ preoperative lower extremity sensory function scores in the DM group were lower than that in the non-DM group, and the postoperative recovery rate of upper extremity sensory function of patients in the DM group was significantly lower. Kawaguchi *et al.*¹⁹ have also reported that the recovery rate of lower extremity sensory function was poor in the DM group after CSM surgery. Compared with their results, although our research mainly discussed the influence of preoperative symptoms and signs, the interference of DM on the neurological function, especially the sensory function of CSM patients, is worthy of our attention.

Surgical Prognosis of DM Patients Undergoing ADF

Even though the JOA score is considered the most comprehensive traditional measure of the degree of spinal cord injury quantified,²⁰ the scoring system is based solely on the subjective assessment of the patients and may affect the accuracy of the results. Thus, the JOA score alone is insufficient to quantify the results effectively. Therefore, to better reduce the error in assessing the effect of spinal cord function, we simultaneously calculated the Nurick score of both groups. The preoperative Nurick score of the DM group was higher than that of the non-DM group. In a follow-up of 113 patients over 2 years, Kusin *et al.*²¹ found a significant

difference in postoperative Nurick score but no significant difference in preoperative score. The limitation of Kusin *et al.*'s²¹ study was that they only evaluated patients' Nurick scores. However, we also performed statistical analyses of preoperative clinical manifestations to confirm the neurological function effects of spinal cord injury caused by DM. The results stem from the injury effect of DM itself on the spinal cord and peripheral nerves. Previous studies have examined the spinal cord and peripheral nerve of patients with long-term DM and found that spinal cord changes, atrophy of the medullary, peripheral nerve degeneration, and the accompanying neurogenic muscular atrophy and other manifestations.²²⁻²⁴ In addition, studies have shown that sensory/motor evoked potentials in DM patients with polyneuropathy extend in the spinal cord structure.²⁵ Nakanishi *et al.*²⁶ found that the peripheral conduction time of patients with CSM and DM was significantly longer, suggesting that DM may damage the peripheral nerves of such patients. These results directly indicate that diabetes can cause a variety of spinal cord and nerve damage. Due to diabetic polyneuropathy, the symptoms produced have many similarities with CSM. In addition to the more severe symptoms in the DM group, the decreased hyperreflexia may give us some diagnostic inspiration. Second, a vital differentiation point is that the symptoms of diabetic polyneuropathy mostly appear in the lower extremities first and affect the upper extremities later, while CSM symptoms are often the first to appear in the hands.²⁷ The severity of DM is also correlated with postoperative neurological recovery to a certain extent. We detected the linear correlation between HbA1c level and duration time of DM in the DM group. The better the HbA1c level was controlled, the higher the postoperative neurological recovery rate was.

There have been many studies on surgical prognosis, most of which suggest that the recovery rate of neurological function after cervical surgery in the diabetic group is inferior. Our results are similar to that.^{10,19-21} In particular, the results that need to be paid attention to are reflected in the difference in sample size between the two groups after we divided them into the excellent recovery rate group (>75%) and the non-excellent recovery rate group (<75%) according to the recovery rate of JOA score (the proportion of DM patients in the group less than 75% was significantly higher). In addition, the preoperative score of the excellent recovery rate group was at a better level, and there was a significant difference in the preoperative sensory score of the lower extremity between the two groups in the isolated JOA score. These results suggested that the patients whose postoperative efficacy could not reach the expectation were mostly DM patients. Their overall status was relatively poor, especially in the sensory function of the lower extremity. This proves the negative effect of DM on the spinal cord and nerve from another perspective. Patients with DM have poor preoperative neurological function and a low recovery rate of postoperative neurological function.^{9,14} For patients undergoing cervical surgery with DM, the solution of spinal cord compression through surgery may not be able to improve neurological

function effectively, and the symptoms are severely affected by blood sugar. In Tanishima *et al.*'s study, after 61 patients were treated with cervical surgery, the recovery rate of JOA in the group with good glycemic control was significantly higher than that in the poor control group at the one-year follow-up.¹⁷ In the past, many researchers have proposed a correlation between DM and surgical wound infections.^{28,29} However, there was no significant difference between the perioperative indicators between the DM and the non-DM groups in our current study, which does not mean that our results are problematic. The low incidence of perioperative period complications in our surgical patients was mainly due to the guidance of the specialist. Before the surgery, we carried out strict glycemic control for patients with DM and preventive antibiotics and albumin. The glycemic level of patients is critical, which affects the overall status of DM patients preoperatively and the recovery of neurological function of patients postoperatively, and has a direct impact on the occurrence of wound infection and other complications in the perioperative period.

Limitations

There are also some limitations to this study. First, this study is a retrospective study, and errors may occur in the inclusion of patients or recording of patient data, which may affect the experimental results. Second, compared with other relevant research, the sample size of this study is relatively small, which increases the systematic error of the experimental results. In addition, although we have concluded that DM patients have significantly poor postoperative neurological function recovery, the results are indirect. We will control the general baseline conditions of patients before surgery to get direct evidence for differences in postoperative neurological recovery in future research. Furthermore, this study observed the manifestations caused by neurological damage in patients with diabetes, and our main reference criterion was neurological functional symptoms. However, we lacked neuroelectrophysiological studies on diabetic polyneuropathy; we will carry out a prospective study immediately, including the neuro-electrophysiological study and the peripheral blood vessels study.

Conclusion

This present study revealed that the neurological impairment caused by DM in patients undergoing cervical spine surgery does not only affect postoperative functional recovery but also interferes with the preoperative clinical manifestations, especially the sensory function in the upper and lower limbs.

Author Contributions

Jialin Jiang designed this study. Jialin Jiang and Kaiqiang Sun finished the paper draft. Feng Lin, Mincheng Lu, and Le Huan conducted the methodology. Ximing Xu, Jingchuan Sun, and Jialin Jiang did the analysis. Jiangang Shi and Yongfei Guo did the supervision. All authors contributed to manuscript preparation. All authors read and approved the final manuscript.

Acknowledgments

We would like to thank the reviewers for their thorough review of our manuscript, especially under the severe circumstances of the COVID-19 worldwide epidemic.

Funding Information

This study was supported by National Natural Science Foundation of China (81972092) and Foundation of Innovative Clinical Project of Changzheng Hospital (2020YLCYJ-Y07).

References

- Toledano M, Bartleson JD. Cervical spondylotic myelopathy. *Neurol Clin*. 2013; 31:287–305.
- Baron EM, Young WF. Cervical spondylotic myelopathy: a brief review of its pathophysiology, clinical course, and diagnosis. *Neurosurgery*. 2007;60:S35–41.
- Yamazaki T, Yanaka K, Sato H, Uemura K, Tsukada A, Nose T. Cervical spondylotic myelopathy: surgical results and factors affecting outcome with special reference to age differences. *Neurosurgery*. 2003;52:122–6.
- Zhang JT, Wang LF, Wang S, Li J, Shen Y. Risk factors for poor outcome of surgery for cervical spondylotic myelopathy. *Spinal Cord*. 2016;54:1127–31.
- Takasawa E, Sorimachi Y, Iizuka Y, et al. Risk factors for rapidly progressive neurological deterioration in cervical Spondylotic myelopathy. *Spine (Phila pa 1976)*. 2019;44(12):E723–e30.
- Kohno K, Kumon Y, Oka Y, Matsui S, Ohue S, Sakaki S. Evaluation of prognostic factors following expansive laminoplasty for cervical spinal stenotic myelopathy. *Surg Neurol*. 1997;48:237–45.
- Shaw J, Sicree R, Zimmet P. Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes Res Clin Pract*. 2010;87:4–14.
- Machino M, Imagama S, Ando K, et al. Characteristics of residual symptoms after laminoplasty in diabetic patients with cervical spondylotic myelopathy: a prospective cohort study. *Spine (Phila pa 1976)*. 2017;42:E708–E15.
- Dokai T, Nagashima H, Nanjo Y, Tanida A, Teshima R. Surgical outcomes and prognostic factors of cervical spondylotic myelopathy in diabetic patients. *Arch Orthop Trauma Surg*. 2012;132:577–82.
- Guzman JZ, Skovrlj B, Shin J, et al. The impact of diabetes mellitus on patients undergoing degenerative cervical spine surgery. *Spine (Phila pa 1976)*. 2014;39:1656–65.
- Wang M, Kreuter W, Wolfla C, et al. Trends and variations in cervical spine surgery in the United States: Medicare beneficiaries, 1992 to 2005. *Spine*. 2009;34:955–61.
- Lad S, Patil C, Berta S, et al. National trends in spinal fusion for cervical spondylotic myelopathy. *Surg Neurol*. 2009;71:66–9.
- Kawaguchi Y, Matsui H, Ishihara H, Gejo R, Yasuda T. Surgical outcome of cervical expansive laminoplasty in patients with diabetes mellitus. *Spine*. 2000; 25:551–5.
- Kim HJ, Moon SH, Kim HS, et al. Diabetes and smoking as prognostic factors after cervical laminoplasty. *J Bone Joint Surg Br*. 2008;90:1468–72.
- Eaton SE, Harris ND, Rajbhandari SM, et al. Spinal-cord involvement in diabetic peripheral neuropathy. *Lancet*. 2001;358:35–6.
- Ziegler D. Diabetic polyneuropathy. *Internist (Berl)*. 2020;61:243–53.
- Tanishima S, Mihara T, Tanida A, et al. Influence of diabetes mellitus on surgical outcomes in patients with cervical myelopathy: a prospective. *Multicenter Study Asian Spine J*. 2019;13:468–77.
- Nielsen AB, Gannik D, Siersma V, et al. The relationship between HbA1c level, symptoms and self-rated health in type 2 diabetic patients. *Scand J Prim Health Care*. 2011;29:157–64.
- Kawaguchi Y, Matsui H, Ishihara H, et al. Surgical outcome of cervical expansive laminoplasty in patients with diabetes mellitus. *Spine (Phila Pa 1976)*. 2000;25:551–5.
- 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 (Phila pa 1976)*. 2014;39:220–7.
- Kusin DJ, Ahn UM, Ahn NU. The influence of diabetes on surgical outcomes in cervical myelopathy. *Spine (Phila pa 1976)*. 2016;41:1436–40.
- Reske-Nielsen E, Lundbaek K. Pathological changes in the central and peripheral nervous system of young long-term diabetics. II. The spinal cord and peripheral nerves. *Diabetologia*. 1968;4:34–43.
- Selvarajah D, Wilkinson ID, Emery CJ, et al. Early involvement of the spinal cord in diabetic peripheral neuropathy. *Diabetes Care*. 2006;29: 2664–9.
- Selvarajah D, Wilkinson ID, Davies J, Gandhi R, Tesfaye S. Central nervous system involvement in diabetic neuropathy. *Curr Diab Rep*. 2011;11: 310–22.
- Suzuki C, Ozaki I, Tanosaki M, Suda T, Baba M, Matsunaga M. Peripheral and central conduction abnormalities in diabetes mellitus. *Neurology*. 2000;54: 1932–7.
- 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;23:707–14.
- Brown MJ, Asbury AK. Diabetic neuropathy. *Ann Neurol*. 1984;15:2–12.
- Ojo OA, Owolabi BS, Oseni AW, Kanu OO, Bankole OB. Surgical site infection in posterior spine surgery. *Niger J Clin Pract*. 2016;19:821–6.
- Richards JE, Kauffmann RM, Zuckerman SL, Obrebsky WT, May AK. Relationship of hyperglycemia and surgical-site infection in orthopaedic surgery. *J Bone Joint Surg Am*. 2012;94:1181–6.