Spinal Cord (2015) 53, 488–493

www.nature.com/sc

ORIGINAL ARTICLE

Quantitative magnetic resonance imaging analysis correlates with surgical outcome of cervical spondylotic myelopathy

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Study design: Prospective study.
Objectives: To investigate whether preoperative and postoperative changes of signal intensity (SI) and transverse area (TA) of the spinal cord reflect the surgical outcome in patients with cervical spondylotic myelopathy (CSM).
Setting: The Second Hospital of Tangshan, Tangshan, Hebei, China.
Methods: In 45 consecutive prospective patients, magnetic resonance imaging (MRI) was performed preoperatively and 3 months postoperatively. The Japanese Orthopedic Association (JOA) scale was used to quantify the neurological status at admission and of at least 12-month follow-up. Preoperative and postoperative TA of the spinal cord at the site of maximal compression and grayscale of signal intensity (GSI) were measured using the image analysis software. Ratio of transverse area (RTA) and ratio of grayscale of signal intensity (RGSI) were used to assess the extent of spinal cord re-expansion and extent of SI regression. Preoperative status and postoperative recovery were assessed in relation to MRI parameters preoperatively and postoperatively using univariate and multivariate analysis.
Results: Higher baseline JOA scores were associated with larger TA. Greater recovery rate was associated with larger preoperative and postoperative TA, along with greater RTA. Recovery rate negatively correlated with RGSI and age. Higher baseline JOA score was associated with greater recovery rate. RGSI negatively correlated with RTA. Multivariate stepwise regression analysis showed that the optimal combination of surgical outcome predictors included age, postoperative TA and RGSI.
Conclusion: Quantitative MRI analysis in CSM may provide reliable information for the prediction of the postoperative outcome of CSM patients. MRI indicators of good outcome include the larger postoperative TA and greater RGSI.
Spinal Cord (2015) **53,** 488–493; doi:10.1038/sc.2014.204; published online 18 November 2014

INTRODUCTION

Cervical spondylotic myelopathy (CSM) is widely recognized as the most common etiology of spinal cord dysfunction and the commonest cause of spinal cord injury in patients aged >55 years.[1] The natural history of CSM is progressive neurological deterioration in the majority of patients. The surgical intervention have been advocated to alter the natural history and improve the prognosis of patients with CSM. How to predict neurological outcomes after surgery is of great importance for the management of CSM patients. Various factors that may influence the surgical outcome include the patient's age, duration of myelopathic symptoms, baseline neurological status, preoperative signal changes on magnetic resonance images and TA of the spinal cord.[2–5]

There is no doubt that magnetic resonance imaging (MRI) is the best radiological modality for examination and evaluation of patients with CSM. MRI can show not only the etiology of myelopathy but also the intramedullary state of the spinal cord in detail,[6,7] thereby helping in both the diagnosis and prognosis of CSM.[8,9]

To date, postoperative MRI has not yet been fully studied in relation to the correlation of morphology or signal change of cervical cord and longer-term prognosis in CSM patients. In our study, we have focused on quantitative analysis of signal intensity (SI) and transverse area (TA) of the spinal cord on T2-weighted MRI preoperatively and postoperatively. The purpose of the present study was to investigate whether preoperative and postoperative changes of SI and TA of the spinal cord reflect the surgical outcome in patients with CSM.

MATERIALS AND METHODS

Approval to conduct this study was obtained from our institutional review board, and informed consent was obtained from each patient. A total of 45 consecutive patients with CSM treated in our institution from January 2011 to June 2011 prospectively enrolled and underwent MRI preoperatively and postoperatively in this study. After excluding 3 patients who were lost to follow-up, 42 cases (follow-up ratio: 93%) were analyzed. In this study, CSM was defined as: (1) the presence of symptoms (numb clumsy hands, unstable gait, bilateral arm paresthesia) and long-tract sign localized to the cervical spinal cord (Hoffman or Babinski sign, hyper-reflexia, clonus and gait dysfunction); and (2) the cervical spine radiography, computed tomography and MRI showed intervertebral disc degeneration and herniation, the posterior vertebral body osteophyte formation and ossification of the posterior longitudinal ligament. Patients with asymptomatic cervical cord compression, prior surgical intervention for CSM, infection, neoplastic disease, rheumatoid arthritis, ankylosing spondylitis, recent or prior neurologic trauma, cerebrovascular accident and concomitant symptomatic lumbar spinal stenosis, who were diagnosed with clinical and imaging manifestations, were excluded from the study.

Procedures and outcome measures

Data collection was performed by two of the authors (XW, H-CC) and externally monitored to ensure integrity and completeness. The criteria proposed by the

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Received 21 April 2014; revised 14 September 2014; accepted 12 October 2014; published online 18 November 2014

Japanese Orthopedic Association (JOA) was used to assess neurological status preoperatively and postoperatively of at least 12-month follow-up, and functional recovery rate was calculated by Hirabayashi's formula:[10]

$$\text{Recovery rate} = \frac{\text{Postoperative JOA score} - \text{preoperative JOA score}}{17\ (\text{full score}) - \text{preoperative JOA score}} \times 100$$

MRI interpretation

In all the patients, MRI was performed just before surgery, then again 3 months afterward. In our series, anterior cervical interbody fusion were performed using autograft iliac bone and titanium-based spinal instrumentation to reduce artifact produced by spinal implants. All patients performed high-resolution MRI with a 1.5-Tesla imager (Signa, GE Medical Systems, Milwaukee, WI, USA). T1-weighted images (T1WI) and T2-weighted images (T2WI) of sagittal views of the cervical cord were obtained using a spin echo sequence system for T1WI and a fast spin echo sequence system for T2WI. Slice width was 3 mm, and the acquisition matrix was 512×512. Sequence parameters were repetition time (TR) 1892 ms/echo time (TE) 10.1 ms for T1WI and TR 2700 ms/TE 123 ms for T2WI. Window width and level were set differently in each patient by the MR operators so that the optimal contrast between each tissue could be obtained.

MRI images were anonymous and were analyzed blindly by an experienced neuroradiologist using the image analysis software (Image J, free software, University of Toronto, Toronto, ON, Canada). The preoperative and postoperative TA of the spinal cord at the site of maximal compression were measured on the same axial T2-weighted images (Figure 1), while the preoperative and postoperative grayscale of signal intensity (GSI) were calculated on sagittal T2-weighted images at the same spinal cord level and at nearly the same area (Figure 2). If no increased SI was identified, the GSI will be taken at the site of maximal compression. We use ratio of transverse area (RTA) and ratio of grayscale of signal intensity (RGSI) to assess the extent of spinal cord re-expansion and extent of SI regression, respectively. RTA and RGSI were calculated using the following formula:

$$\text{RTA} = \text{post–operative TA}/\text{pre–operative TA}$$

$$\text{RGSI} = \text{post–operative GSI}/\text{pre–operative GSI}$$

Statistical analysis

Descriptive statistics were used for all variables with distributions assessed for normality. The paired *t*-tests were conducted to compare preoperative and postoperative changes of JOA score, TA and GSI. Association was determined among variables using the Spearman's rank correlation coefficient, and multivariate linear regression models were computed using stepwise regression. Other statistical tests used included analysis of variance and Student's *t*-test for continuous and categorical data, respectively. The Statistical Package for the Social Sciences (version 17.0 for Windows; SPSS Inc, Chicago, IL, USA) was used for statistical analysis. The difference was considered to be statistically significant at the $P < 0.05$ level.

RESULTS

There were 23 men and 19 women. Mean ($\pm$ s.d.) age of this series was 56.7 ± 8.2 years (range, 41–74 years). The duration of symptom ranged from 10 days to 12 years. The mean follow-up period was 16 months (range, 12–23 months). The demographic and diagnostic characteristics of patients are listed in Table 1.

The mean JOA score rose from 9.45 ± 1.92 preoperatively (range 7–13) to 13.94 ± 1.95 (range 11–17) postoperatively. The mean

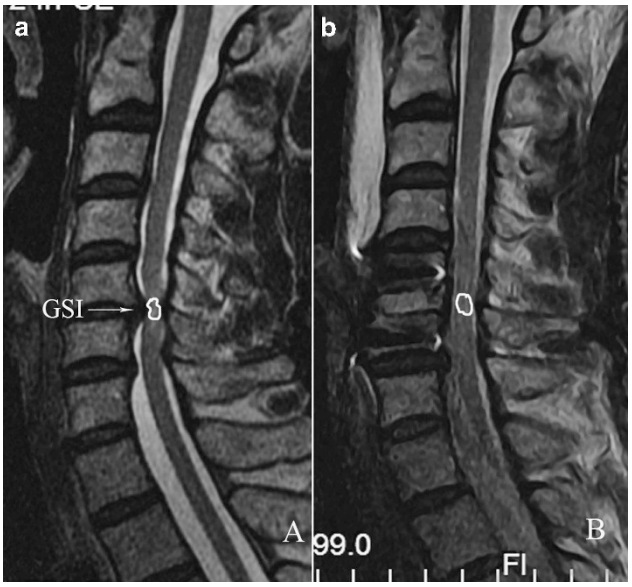

Figure 2 The GSI was calculated on sagittal T2-weighted images at the same spinal cord level and nearly same area preoperatively (**a**) and postoperatively (**b**). Note that there is some artifact, but the spinal canal and cord are readily visualized.

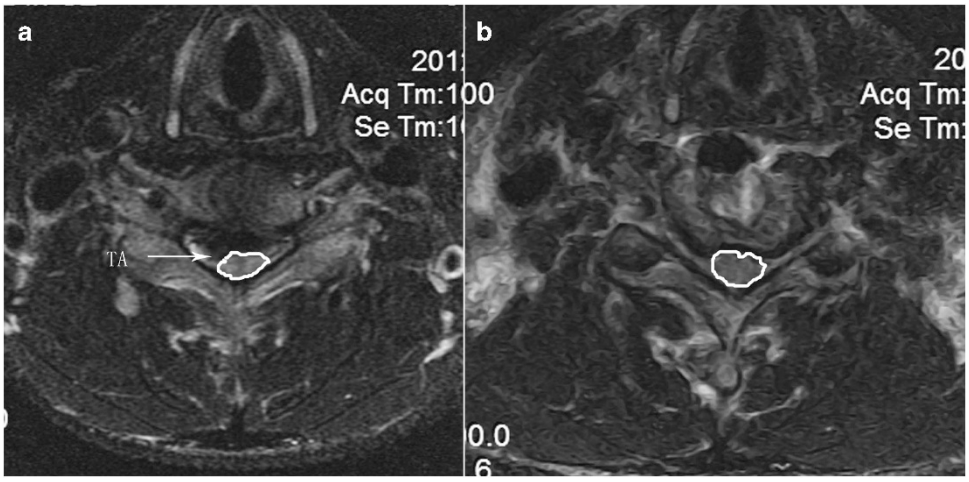

Figure 1 The TA of the spinal cord at the site of maximal compression were measured on the same axial T2-weighted images preoperatively (**a**) and postoperatively (**b**).

Table 1 Characteristics of patients with cervical spondylotic myelopathy in this series

Patient no.	*Age/sex*	*Duration of symptom*	*Etiologies of myelopathy*	*Levels of maximal compression*	*Surgical technique*
1	59/F	10 years	Disc herniation (C3 ~ C6)+CSCS+OPLL	C4/5	Laminoplasty
2	57/F	6 months	Disc herniation (C4/5)	C4/5	ACDF (C4/5)
3	48/F	7 years	Disc herniation (C5/6)	C5/6	ACDF (C5/6)
4	54/M	1 year	Disc herniation (C3 ~ C7)+CSCS	C5/6	ACDF (C5/6)
5	51/M	6 months	Disc herniation (C3 ~ C7)	C4/5	Laminoplasty
6	51/M	10 months	Disc herniation (C3 ~ C7)+CSCS	C4/5	Laminoplasty
7	72/M	4 months	Disc herniation (C4 ~ C7)+CSCS	C4/5	Laminoplasty
8	42/M	2 years	Disc herniation (C3 ~ C7)+CSCS	C5/6	Laminoplasty
9	66/F	7 months	Disc herniation (C5/6)	C5/6	ACDF (C5/6)
10	58/F	6 months	Disc herniation (C4/5)	C4/5	ACDF (C4/5)
11	60/M	3 years	Disc herniation (C3 ~ C7)+OPLL	C3/4	Laminoplasty
12	61/M	1 year	Disc herniation (C5 ~ C7)+CSCS	C5/6	ACCF (C5 ~ C7)
13	64/M	2 years	Disc herniation (C3 ~ C6)+CSCS	C4/5	Laminoplasty
14	50/F	7 months	Disc herniation (C5/6)+CSCS	C5/6	Laminoplasty+ACDF (C5/6)
15	54/F	3 years	Disc herniation (C5/6)	C5/6	ACDF (C5/6)
16	64/M	3 years	Disc herniation (C3 ~ C7)	C4/5	Laminoplasty
17	74/M	2 years	Disc herniation (C3 ~ C7)+CSCS	C4/5	Laminectomy with instrumented fusion
18	59/F	3 years	Disc herniation (C3 ~ C6)+CSCS	C3/4	Laminoplasty
19	63/M	3 months	Disc herniation (C3 ~ C7)+CSCS	C4/5	Laminoplasty
20	53/M	1 year	Disc herniation (C5/6, C6/7)	C5/6	ACCF (C5 ~ C7)
21	54/M	1 month	Disc herniation (C3 ~ C7)+CSCS	C4/5	Laminoplasty
22	42/M	4 months	Disc herniation (C4/5)+CSCS	C4/5	ACDF (C4/5)
23	62/F	11 years	Disc herniation (C3 ~ C7)	C4/5	Laminoplasty
24	43/F	3 weeks	Disc herniation (C5/6)	C5/6	ACDF (C5/6)
25	60/F	12 years	Disc herniation (C4/5)+CSCS	C4/5	Laminoplasty+ACDF (C4/5)
26	41/F	2 weeks	Disc herniation (C3 ~ C6)	C3/4	Laminoplasty+ACCF (C3 ~ C5)
27	55/M	5 years	Disc herniation (C4 ~ C6)+CSCS	C4/5	Laminoplasty+ACCF (C4 ~ C6)
28	56/M	2 years	Disc herniation (C4 ~ C7)	C5/6	Laminoplasty
29	47/F	1 year	Disc herniation (C3 ~ C7)+CSCS	C4/5	Laminoplasty
30	51/M	6 months	Disc herniation (C4 ~ C6)	C4/5	ACCF (C4 ~ C6)
31	58/M	6 months	Disc herniation (C5/6)	C5/6	ACDF (C5/6)
32	56/F	5 years	Disc herniation (C4 ~ C7)+CSCS	C4/5	Laminoplasty
33	65/F	1 year	Disc herniation (C3 ~ C7)+OPLL	C5/6	Laminoplasty
34	41/M	4 years	OPLL	C5/6	Laminectomy with instrumented fusion
35	57/F	1 year	Disc herniation (C3 ~ C7)	C4/5	Laminoplasty
36	63/M	1 year	Disc herniation (C3 ~ C7)	C4/5	Laminoplasty
37	67/M	10 days	Disc herniation (C4 ~ C7)	C4/5	Laminoplasty
38	62/M	2 years	Disc herniation (C3 ~ C5)	C3/4	ACCF (C3 ~ C5)
39	64/M	4 months	Disc herniation (C4 ~ C7)+CSCS	C5/6	Laminoplasty+ACDF (C5/6)
40	69/F	2 years	Disc herniation (C3/4)	C3/4	ACDF (C3/4)
41	56/M	1 year	Disc herniation (C3/4)	C3/4	ACDF (C3/4)
42	54/F	1 year	Disc herniation (C4/5)	C4/5	ACDF (C4/5)

Abbreviations: ACCF, anterior cervical corpectomy and fusion; ACDF, anterior cervical decompression and fusion; CSCS, congenital spinal canal stenosis; OPLL, ossification of the posterior longitudinal ligament.

recovery rate with the JOA score was 61.4%. There was a significant difference between preoperative and postoperative JOA score in this series ($t=-18.89$; $P<0.001$), showing statistically significant improvement at the clinical symptoms and JOA scores. The anterior approach (discectomy/corpectomy with instrumented fusion) for cervical spinal surgery was performed in 16 patients, posterior approach (either laminoplasty or laminectomy with instrumented fusion) was performed in 21 patients, and combined posterior–anterior approaches was performed in 5 patients. All patients had adequate cord decompression as confirmed by MR images at 3 months after surgery. None of them required revision surgery for inadequate cord decompression. The type of surgical procedure was not associated with recovery rate ($F=0.383$, $P=0.684$). The mean recovery rate was $61.96\pm19.49\%$ in males and $60.76\pm19.30\%$ in females. There was no significant difference between sex groups ($t=0.200$; $P=0.843$). Summary of the clinical outcome and MRI parameters are listed in Table 2.

Postoperative complications related to cervical spine surgery occurred in 2 (4.8%) of the 42 patients—1 patient had cerebrospinal fluid leak after anterior cervical surgery, which resolved at 8 days postoperatively, and 1 patient had C5 palsy after laminectomy with instrumented fusion, which resolved at 3 months postoperatively. No patients showed neurological deterioration at 12-month follow-up.

Correlation of baseline JOA with patients' demographics and MRI

Mean ($\pm$s.d.) preoperative TA of this series was $50.09\pm10.01\,mm^2$ (range, 32.87–65.13 mm^2). Larger TA was associated with higher baseline JOA score ($r=0.383$, $P=0.012$).

Table 2 Summary of the clinical outcome and MRI parameters of this series

Patient no.	JOA		Recovery rate (%)	TA (mm^2)		RTA	GSI		RGSI
	Preoperative	Postoperative		Preoperative	Postoperative		Preoperative	Postoperative	
1	8	13	55.56	38.79	43.44	1.12	38.07	54.72	1.44
2	9	14	62.50	47.53	65.91	1.38	48.73	49.15	1.01
3	10	15	71.43	35.14	38.13	1.09	71.08	76.90	1.08
4	7	10	30.00	62.31	69.34	1.11	49.44	78.27	1.58
5	13	16	75.00	57.34	75.23	1.31	57.84	52.63	0.91
6	8	16	88.89	51.36	66.79	1.30	89.86	50.62	0.56
7	8	12	44.44	34.91	38.40	1.10	78.23	90.09	1.19
8	13	16	75.00	58.78	66.49	1.13	70.50	66.52	0.94
9	9	15	75.00	45.61	69.74	1.53	44.43	44.81	1.00
10	12	16	80.00	60.90	79.68	1.31	70.17	43.00	0.61
11	8	11	33.33	33.65	36.34	1.08	79.12	120.26	1.52
12	10	12	28.57	39.16	43.56	1.11	59.57	72.05	1.21
13	12	16	80.00	55.41	76.44	1.38	74.05	55.16	0.74
14	7	12	50.00	40.57	48.36	1.19	69.34	88.25	1.27
15	11	14	50.00	48.66	55.96	1.15	69.32	72.79	1.05
16	11	13	33.33	43.91	46.58	1.22	66.74	81.45	1.15
17	7	10	30.00	35.86	36.89	1.06	81.37	94.24	1.16
18	9	12	37.50	56.42	63.19	1.12	51.45	63.28	1.23
19	7	13	60.00	55.46	67.23	1.21	60.53	59.11	0.98
20	10	14	57.14	60.08	78.20	1.29	66.39	55.57	0.84
21	9	16	87.50	53.24	71.03	1.33	37.43	45.68	1.22
22	8	15	77.78	52.42	55.04	1.05	48.50	51.73	1.07
23	8	14	66.67	37.40	52.07	1.39	58.70	34.86	0.59
24	11	16	83.33	61.47	84.37	1.37	46.35	43.18	0.95
25	7	14	70.00	62.89	74.39	1.18	57.70	59.96	1.04
26	14	16	66.67	48.36	49.32	1.02	65.24	48.71	0.75
27	12	16	80.00	64.37	74.45	1.11	57.73	46.50	0.81
28	7	11	40.00	38.61	45.56	1.18	80.03	95.24	1.19
29	7	10	30.00	32.87	34.18	1.04	68.92	95.11	1.38
30	10	17	100.00	61.34	77.29	1.26	66.85	50.07	0.75
31	9	15	75.00	57.43	78.54	1.37	51.78	45.92	0.89
32	11	16	83.33	58.57	86.35	1.47	47.25	46.44	0.98
33	9	12	37.50	35.29	43.87	1.24	62.89	89.75	1.42
34	10	15	71.43	48.63	71.48	1.47	46.86	46.77	0.99
35	9	15	75.00	65.13	91.79	1.41	79.54	50.92	0.64
36	11	14	50.00	46.81	52.02	1.09	60.47	57.28	0.95
37	8	14	66.67	51.87	61.21	1.18	56.43	47.06	0.83
38	7	11	40.00	36.74	37.81	1.03	79.56	89.45	1.12
39	9	14	62.50	56.75	69.45	1.22	41.18	46.43	1.13
40	12	16	80.00	56.78	69.27	1.22	71.50	68.00	0.95
41	10	14	57.14	58.35	68.27	1.17	58.92	59.51	1.01
42	10	15	71.43	54.32	74.37	1.37	58.22	37.08	0.63

Abbreviations: GSI, grayscale of signal intensity; JOA, Japanese Orthopedic Association; MRI, magnetic resonance imaging; RGSI, ratio of grayscale of signal intensity; RTA, ratio of transverse area; TA, transverse area.

Mean ($\pm$s.d.) preoperative GSI of this series was 61.86 ± 12.89 (range, 37.43–89.86). A trend toward a greater GSI was noted in patients with a lower baseline JOA, but this was not statistically significant ($r = -0.07$, $P = 0.659$). Sex, age and duration of the symptom were not associated with baseline JOA score.

Correlation of postoperative outcomes with patients' demographics and MRI

Mean ($\pm$s.d.) postoperative TA of this series was $61.62 \pm 15.89\ mm^2$ (range, 34.18–91.79 mm^2). There was a significant difference between preoperative and postoperative TA in this series ($t = -9.60$; $P < 0.001$). Greater recovery rate was associated with larger preoperative ($r = 0.545$, $P < 0.001$) and postoperative TA ($r = 0.715$, $P < 0.001$), along with greater RTA ($r = 0.581$, $P < 0.001$).

Mean ($\pm$s.d.) postoperative GSI of this series was 62.48 ± 19.72 (range, 34.86–120.26). There was no significant difference between preoperative and postoperative GSI in this series, but preoperative and postoperative GSI was significantly different when comparing the patients with RGSI < 1 and those with RGSI $\geqslant 1$, respectively. When comparing MRI parameters and clinical outcome between patients with RGSI < 1 and those with RGSI $\geqslant 1$, the means of baseline JOA score, recovery rate and preoperative TA were significantly different

(Table 3). With the RGSI increased, the recovery rate began to decrease. There was a significant negative correlation between RGSI and recovery rate ($r=-0.673$, $P<0.001$).

There was a significant negative correlation between age and recovery rate ($r=-0.310$, $P=0.046$). Higher baseline JOA score was associated with greater recovery rate ($r=0.434$, $P=0.004$). Sex and duration of symptom were not associated with recovery rate.

Multivariate stepwise regression analysis including all the preoperative and postoperative MRI parameters showed that the optimal combination of surgical outcome predictors included age, postoperative TA and RGSI. The multiple regression equations are as follows (adjusted $R^2=0.642$, $P<0.0001$):

$$\text{recovery ratio } (\%) = 88.75 - 0.46\times(\text{age}) + 0.52\times(\text{post-operative TA}) - 32.73\times\text{RGSI}.$$

Table 3 Comparison of clinical outcome and MRI parameters between patients with RGSI < 1 and those with RGSI ⩾ 1

	RGSI < 1 (n = *20*)	*RGSI ⩾ 1* (n = *22*)	P-*value*
Age	54.9 ± 8.5	58.4 ± 7.8	$t=1.36$; $P=0.182$
Duration of symptom (month)	29.9 ± 38.0	22.9 ± 31.6	$t=0.639$; $P=0.526$
Preoperative GSI	62.8 ± 11.2	61.1 ± 14.4	$t=-0.451$; $P=0.655$
Postoperative GSI	50.3 ± 8.4	73.6 ± 20.6	$t=4.715$; $P<0.001$
P	$t=5.075$; $P<0.001$	$t=-5.55$; $P<0.001$	
Preoperative TA	55.6 ± 6.7	45.0 ± 9.9	$t=-0.4026$; $P<0.001$
Postoperative TA	71.6 ± 11.4	52.5 ± 13.9	$t=-4.843$; $P<0.001$
P	$t=-10.12$; $P<0.001$	$t=-5.734$; $P<0.001$	
Preoperative JOA	10.5 ± 1.9	8.5 ± 1.3	$t=-3.93$; $P<0.001$
Postoperative JOA	15.3 ± 1.0	12.7 ± 1.8	$t=-5.56$; $P<0.001$
P	$t=-13.99$; $P<0.001$	$t=-12.88$; $P<0.001$	
Recovery rate (%)	73.8 ± 11.3	50.2 ± 18.0	$t=-5.023$; $P<0.001$

Abbreviations: GSI, grayscale of signal intensity; JOA, Japanese Orthopedic Association; MRI, magnetic resonance imaging; RGSI, ratio of grayscale of signal intensity; TA, transverse area.

Correlation of TA with GSI

A trend toward a greater preoperative GSI was noted in patients with a smaller preoperative TA, but this was not statistically significant ($r=-0.285$; $P=0.067$). However, There was a significant negative correlation between postoperative GSI and postoperative TA ($r=-0.693$, $P<0.001$); RGSI also negatively correlated with RTA ($r=-0.461$; $P=0.002$).

All the scatterplot in relation to MRI parameters and clinical outcome are listed in Figure 3.

DISCUSION

Our study systematically assessed the variability between preoperative and postoperative findings in evaluating the surgical outcome of CSM using quantitative MRI analysis. The present study suggests that: (1) the findings on MRI performed 3 months after CSM surgery correlate with longer-term prognosis in CSM patients and is more reliable than preoperative MRI in prediction of surgical outcome; (2) the extent of SI regression and spinal cord re-expansion closely correlate with surgical outcome; and (3) the degree of spinal cord compression, in the form of TA of the spinal cord, correlates with SI of the spinal cord and functional outcome. Furthermore, our results reinforce the consensus that age and baseline JOA scores correlates strongly with functional outcomes after surgery but not duration of symptom.

Clinical significance of SI of the spinal cord on MRI

MRI may depict not only the etiology of spinal cord compression but also changes in SI that indicate the underlying histopathological features.[6,7] SI changes of the spinal cord on MRI in CSM patients are thought to reflect pathological changes in the spinal cord and to be indicative of the prognosis.[11,12] With development in MRI techniques

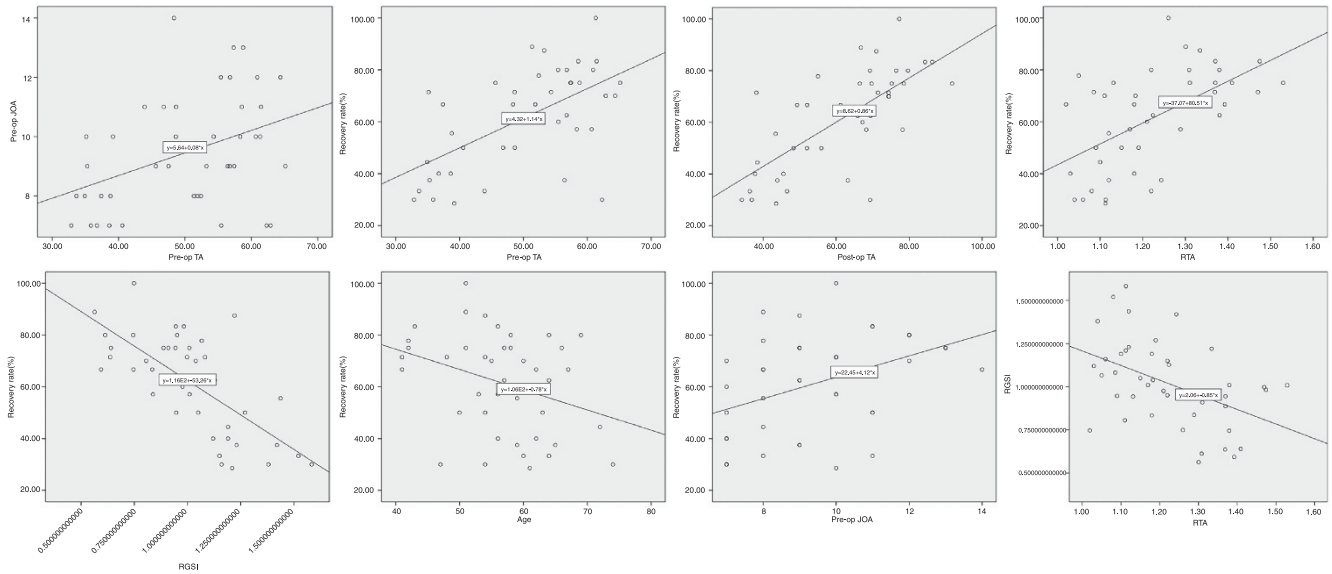

Figure 3 The scatterplots in relation to MRI parameters and clinical outcome.

and software, it has now become possible to make qualitative analysis of SI changes and quantitative analysis of spinal cord compression in a more comprehensive method.[13,14] However, quantitative analysis of SI regarding GSI, potentially valuable for the prediction of the outcome of surgical intervention for CSM, has not yet been fully elucidated. Taking into account that MRI images capture various properties of biological architecture of spinal cord, the implementation of quantitative GSI analysis can provide quantitative metrics, relevant to the internal architecture and pathological status of the spinal cord.[15] Statistical analysis demonstrated the existence of statistically significant differences ($P<0.001$) between preoperative and postoperative GSI when comparing the patients with RGSI <1 or those with RGSI $\geqslant 1$. These results may be considered as an indication of the fact that surgical intervention for CSM induces the differentiation of the SI, in terms of the internal architecture of the spinal cord. Data from our study also support the fact that preoperative and postoperative change of GSI, which may, or may not, be visually perceived, closely correlates with surgical outcome. Furthermore, our results reinforce the emerging consensus that the regression of SI postoperatively correlates with better surgical outcomes.[4]

Correlation of SI with spinal cord compression

There were researches suggesting that axial sections based on T2-weighted MRI parameters were more reliable in assessing the degree of cervical spinal cord compression than T1-weighted sequences, and TA was reliable and versatile in assessing spinal cord compression.[5] Consistent with consensus that most studies have reported,[8] data from our study support the fact that TA closely correlates with baseline JOA score and surgical outcome. Trying to correlate TA and GSI on MRI, one would expect TA to be larger in patients with lower GSI on MRI. In our study, as anticipated, patients with lower GSI had the larger TA postoperatively and those with greater RTA (that is, extent of spinal cord re-expansion) had lower RGSI (that is, extent of SI regression). There is neuropathological correlation with SI changes in the form of cystic necrosis, gliosis, myelomalacia and syrinx formation, resulting from mechanical compression and ischemic changes.[13,16,17] However, contrary to expectation, there was no existence of statistically significant correlation ($P=0.067$) between GSI and TA preoperatively. The reasons for this result could be resulted from strong influence of other variance such as age, differences in populations, site of compression and duration of symptoms.

Predictors of surgical outcomes

Regarding predictors of surgical outcomes, the patient's age, duration of myelopathic symptoms, baseline neurological status,[2] preoperative signal changes on magnetic resonance images and TA of the spinal cord at the site of maximal compression have been considered key predictors.[3,4,5,11,18] The current results showed no significant correlations between the preoperative GSI with baseline JOA and recovery rate. However, there was a tendency toward negative correlation. These may result from the small sample capacity or a bias in patient selection. A significant correlation was found between the recovery rate and RGSI. Therefore the current authors could possibly conjecture that SI is not a good indicator of the preoperative functional status, but the extent of SI regression is a reliable predictor of the surgical outcomes. From these results of multivariate stepwise regression analysis, it can be concluded that the predictors of surgical outcomes are postoperative TA of the spinal cord at the site of maximal compression, the extent of SI regression and the age at the time of surgery. MRI indicators of good outcome include the larger postoperative TA and greater RGSI, regarded as greater spinal cord re-expansion and SI regression.

Our study is mainly limited by the susceptibility artifacts on MRI as the result of spinal implant. Previous researches have suggested the extent of artifact on MRI produced by titanium-based spinal implants was significantly less than stainless steel and its alloy.[19] Furthermore, anterior cervical interbody fusion were performed using autograft iliac bone in our series, so the susceptibility artifacts on MRI may be reduced to the maximum extent.

DATA ARCHIVING

There were no data to deposit.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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