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ORIGINAL ARTICLE

Patterns of short-term and long-term surgical outcomes and prognostic factors for cervical ossification of the posterior longitudinal ligament between anterior cervical corpectomy and fusion and posterior laminoplasty

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Abstract

To compare short-term and long-term surgical outcome patterns between anterior cervical corpectomy and fusion (ACCF) and laminoplasty (LP) in patients diagnosed with cervical ossification of the posterior longitudinal ligament (OPLL) and identify factors affecting surgical outcomes based on follow-up duration. During short-term follow-up period, surgical outcomes between ACCF and LP were similar. However, there were several reports that long-term surgical outcomes were superior in the ACCF compared with LP. Surgical outcomes between ACCF and LP according to follow-up period changed. This study enrolled 70 patients who underwent ACCF and 63 patients who underwent LP between 2005 and 2012. Patterns of surgical outcomes were analyzed in accordance with surgical procedures. Furthermore, these patients were divided into two subgroups in respect of follow-up duration: the short-term group (less than 48 months) and the long-term group (more than 48 months) group. Occupying ratio, type of OPLL, shape of ossified lesion, cervical sagittal alignment, grade of signal intensity on MRI, and Japanese Orthopedic Association (JOA) score were examined. Surgical outcomes of ACCF went into reverse at 48-month follow-up period. In the short-term group, JOA recovery rate had no difference between ACCF and LP. In the long-term group, the ACCF recovery rate (78.5 ± 31.0) was significantly higher than the LP recovery rate (48.4 ± 54.9) ($P = 0.008$). In the short-term group, old age ($p = 0.011$), hill shape ($p = 0.013$), and high grade of MRI signal intensity ($p = 0.040$) had negative effects on recovery rate. On the other hand, in the long-term group, LP ($p = 0.021$) and a high grade of MR signal intensity ($p = 0.017$) independently and negatively affected recovery rate. Long-term surgical outcomes of ACCF became better than those of LP at more than 48-month follow-up period. High-grade MRI signal changes and the LP surgical procedure were independent negative factors for long-term surgical outcomes in patients with OPLL. Direct decompression of the spinal cord with ACCF provides better long-term stable neurologic outcomes than LP.

Keywords Long-term outcome · Prognostic factor · Cervical ossification of longitudinal ligament · Anterior cervical corpectomy and fusion · Laminoplasty

Introduction

Ossification of the posterior longitudinal ligament (OPLL) has been recognized as an important clinical disease entity that can cause cervical compressive myelopathy [20]. Surgical decompression is the primary treatment for patients with severe cervical compressive myelopathy who are diagnosed with OPLL. Various factors are considered in determining the optimal therapeutic strategy for OPLL, such as age, occupying ratio, type of OPLL, shape of ossified lesion, cervical alignment, and intramedullary increased signal intensity on MRI. The surgical approach is mainly dichotomized to anterior cervical corpectomy and fusion (ACCF) or laminoplasty (LP).

ACCF has an advantage over LP in terms of direct and immediate decompression effect on the spinal cord, especially in patients with OPLL with a high occupying ratio or kyphotic cervical alignment [11]. LP can provide indirect and wide

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decompression of multiple segments more easily and safely than ACCF [16]. However, the risk of delayed neurologic deterioration due to the progression of OPLL or kyphosis should be carefully considered [1].

Most studies on surgical outcomes of OPLL have provided conclusions about the superiority of either surgical approach because each one has its own advantages, disadvantages, and limitations on their last follow-up period [9, 13, 14, 17]. There were several reports that long-term surgical outcomes were superior in the ACCF compared with LP [5, 14]. However, surgical outcomes between ACCF and LP according to follow-up period changed [18]. Therefore, the purpose of this study is to compare short-term and long-term surgical outcome patterns between ACCF and LP in patients diagnosed with cervical OPLL and identify factors affecting surgical outcomes.

Materials and methods

Patient selection

Among 352 patients who underwent decompression surgery for cervical OPLL at our hospital between 2005 and 2012, we included only patients with OPLL inducing cervical compressive myelopathy. Patients with a history of trauma, infection, tumor, or previous surgery were excluded. We enrolled patients who received either ACCF or open-door LP. All patients with more than 12-month post-operative follow-up were included. Finally, 70 patients were enrolled in the ACCF group and 63 patients were enrolled in the LP group.

Radiographic parameters

OPLL of the cervical spine was classified into continuous, segmental, mixed, or localized OPLL, based on preoperative computed tomography (CT) [19]. In addition to these conventional types, the sagittal part of the ossified lesion was classified as a plateau- or hill-shaped [7, 8]. The extent of ossification and space available for the spinal cord were also measured. The occupying ratio of OPLL was calculated as the ratio of the maximum anteroposterior thickness of the OPLL to the anteroposterior diameter of the spinal canal at the corresponding level on CT.

Magnetic resonance imaging (MRI) was performed in all patients before surgery. The presence of intramedullary increased signal intensity (ISI) on MRI was evaluated preoperatively. Some previous reports have mentioned a grading scale for the severity of ISI [21, 23]. To identify whether the severity of intramedullary ISI on MRI reflects the severity of symptoms and surgical outcomes, we used a three-level grading system. According to our previous report [9], we focused on the extent size of ISI on T2-weighted MRI and clinically simplified the grading scale as follows: grade 0, no ISI on T2-weighted MRI; grade 1, ISI on T2-weighted MRI limited to one disc level; or grade 2, ISI on T2-weighted MRI beyond one disc level.

We also evaluated sagittal alignment of the cervical spine on lateral radiographs. The vertebral body angle between the inferior border of the C2 vertebral body and the superior border of the C7 vertebral body was measured using the method described by Cobb. An angle of $\geq 10°$ was considered lordotic, $\geq -5°$ but $< 10°$ was considered straight, and $<= -5°$ was considered kyphotic [3].

Clinical assessment

The Japanese Orthopedic Association (JOA) scoring system was used to evaluate the severity of cervical myelopathy pre- and postoperatively at every follow-up period [22]. We used the JOA recovery rate to assess postoperative improvement in symptoms by using the following formula: (postoperative JOA score − preoperative JOA score)/(17 − preoperative JOA score) × 100% [4].

Statistical analysis

Data analyses were performed using SPSS version 18 for Windows (SPSS, Inc., Chicago, IL, USA). Data were presented as the number of subjects in each group or mean ± SD. Comparison of each independent variable between the 2 groups was performed with the independent-sample Student's *t* test for continuous variables and the chi-square test, linear-by-linear association, or Fisher's exact test for categorical variables. Variable factors were compared according to recovery rate using the independent-sample Student's *t* test and analysis of variance (ANOVA). Multiple linear regression analysis was used to examine the relationships between recovery rate, follow-up duration, and variable factors by the stepwise method. P values < 0.05 were considered statistically significant.

Results

Patients' demographics and radiologic parameters

Demographics and preoperative data for all patients are summarized in Table 1. Seventy patients underwent ACCF and 63 patients underwent open-door LP. There were no statistically significant differences in age, gender, mean preoperative occupying ratio, mean preoperative JOA score, mean space available for spinal cord (SAC), and shape of the ossified lesion in each surgical group. However, we found statistically significant differences between two surgical groups according to mean follow-up duration, the type of OPLL, sagittal

Table 1 Demographics and preoperative variables

	ACCF	LP	*P*
No. of patients	70	63	
M:F	50:20	48:15	0.533
Age at surgery (Mean ± SD, year)	57.2 ± 9.7	55.3 ± 9.1	0.247
Follow-up duration (Mean ± SD, month)	47.9 ± 16.9	40.4 ± 12.3	0.004*
Space available for spinal cord (Mean ± SD, mm)	6.2 ± 1.7	6.0 ± 1.9	0.592
Occupying ration of OPLL (Mean ± SD, %)	56.4 ± 10.3	54.8 ± 14.6	0.474
Preop JOA score (Mean ± SD)	11.9 ± 2.6	12.3 ± 2.3	0.384
JOA Recovery rate (Mean ± SD, %)	75.1 ± 32.3	57.5 ± 49.4	0.015*
Type of OPLL, *n* (%)			< 0.001*
Continuous	11 (15.7)	21 (33.3)	
Mixed	19 (27.1)	25 (39.7)	
Segmental	9 (12.9)	16 (25.4)	
Localized	31 (44.3)	1 (1.6)	
Shape of ossified lesion, *n* (%)			0.360
Hill	40 (57.1)	31 (49.2)	
Plateau	30 (42.9)	33 (50.8)	
Sagittal alignment, *n* (%)			< 0.001*
Lordotic	17 (24.3)	33 (52.4)	
Straight	37 (51.4)	29 (46.0)	
Kyphotic	17 (24.3)	1 (1.6)	
Grade of ISI on MRI, *n* (%)			0.004*
0	15 (21.4)	14 (22.2)	
1	44 (62.9)	24 (38.1)	
2	11 (15.7)	25 (39.7)	

ACCF, anterior cervical corpectomy and fusion; *LP*, laminoplasty; *JOA*, Japanese Orthopedic Association; *OPLL*, ossification of the posterior longitudinal ligament; *ISI*, increased signal intensity; *MRI*, magnetic resonance imaging

*$P < 0.05$

alignment, and grade of ISI grade on MRI. ACCF had longer follow-up duration than LP (47.9 vs. 40.4 months, $P = 0.004$). JOA recovery rate in ACCF was higher than those in LP (75.1 vs. 57.5%, $P = 0.015$). Continuous, mixed, and segmental type of OPLL in LP was more frequent although localized type of OPLL was more frequent in ACCF. Grades 1 and 2 of ISI on MRI were more frequent in LP than those in ACCF ($P = 0.004$).

Relationships between JOA recovery rate and preoperative parameters

Linear regression of the JOA recovery rate between ACCF and LP was shown in Fig. 1. The JOA recovery rate of ACCF progressively increased during the follow-up period. However, the recovery rate of LP progressively decreased during the follow-up period. We found that there was significant difference of JOA recovery rate between ACCF and LP at around 48-month follow-up period ($P = 0.008$) in Fig. 1 and Table 2. At less than 48-month follow-up period, JOA recovery rate between two groups had no difference, whereas JOA recovery rate of ACCF was higher than those of LP at more than 48-month follow-up period (78.5 vs. 48.4, $P = 0.008$). Patients with hill shape and localized OPLL had better JOA recovery rates with ACCF than with LP ($P = 0.006$, $P = 0.005$, respectively). However, between ACCF and LP group, gender, occupying ratio, shape of lesion, type of OPLL except the

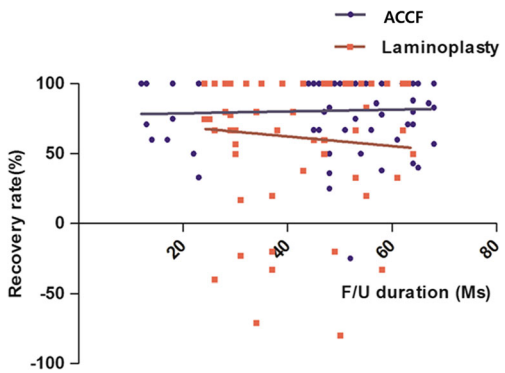

Fig. 1 Linear regression of the recovery rate between ACCF and LP groups, according to follow-up duration

Table 2 Relationship between recovery rate and preoperative variables according to surgical approaches

		JOA recovery rate (%)				
		ACCF		LP		*P*
		N.	Mean ± SD	*N.*	Mean ± SD	
Gender	Male	50	71.4 ± 33.2	48	54.9 ± 52.5	0.064
	Female	20	84.3 ± 28.6	15	65.9 ± 38.4	0.114
Follow-up duration	≤ 48 ms	28	69.9 ± 34.1	44	61.4 ± 47.0	0.410
	> 48 ms	42	78.5 ± 31.0	19	48.4 ± 54.9	0.008*
Occupying ratio (%)	< 60	43	74.7 ± 33.9	35	60.4 ± 46.7	0.121
	≥ 60	27	75.7 ± 30.3	28	53.9 ± 53.3	0.069
Shape	Hill	40	78.4 ± 30.5	31	51.3 ± 49.1	0.006*
	Plateau	30	70.6 ± 34.5	32	63.5 ± 49.7	0.519
Type of OPLL	Continuous	11	87.1 ± 30.1	21	62.5 ± 60.0	0.194
	Mixed	19	80.1 ± 24.8	25	60.1 ± 43.3	0.080
	Segmental	9	51.8 ± 44.2	16	51.8 ± 47.4	0.999
	Localized	31	74.5 ± 31.3	1	−23.0	0.005*
Grade of ISI on MRI	0	15	90.7 ± 27.1	14	73.6 ± 38.0	0.172
	1	44	75.3 ± 29.7	24	70.5 ± 38.7	0.569
	2	11	53.0 ± 38.3	25	36.0 ± 57.4	0.377
Sagittal alignment	Lordotic	17	79.5 ± 29.1	33	62.5 ± 47.1	0.181
	Straight	36	71.4 ± 32.9	29	51.0 ± 52.7	0.061
	Kyphotic	17	78.4 ± 34.9	1	80.0	0.964

JOA, Japanese Orthopedic Association; *ACCF*, anterior cervical corpectomy and fusion; *LP*, laminoplasty; *ms*, months; *OPLL*, ossification of the posterior longitudinal ligament; *ISI*, increased signal intensity; *MRI*, magnetic resonance imaging

*$P < 0.05$

localized type, ISI grade on MR, and sagittal alignment did not significantly affect JOA recovery rate in Table 2.

Relationship between JOA recovery rate and preoperative variables according to follow-up duration of each surgical procedure

Table 3 shows the relationship between JOA recovery rate and preoperative parameters according to surgical approaches in short-term and long-term groups.

In the short-term group, patients with localized OPLL had better recovery rates with ACCF than with LP ($P = 0.009$). However, between ACCF and LP in short-term group, gender, occupying ratio, shape of lesion, type of OPLL except the localized type, ISI grade on MR, and sagittal alignment did not significantly affect JOA recovery rate.

In the long-term group, both men and women had higher JOA recovery rates in ACCF compared to LP (men, $P = 0.044$; women, $P = 0.027$). If the occupying ratio was less than 60%, ACCF produced a significantly higher JOA recovery rate than LP ($P = 0.039$). In addition, if the ossified lesion was hill-shaped and mixed type, ACCF had a higher JOA recovery rate than LP (hill-shaped and mixed type, $P < 0.001$, respectively). ACCF also produced better JOA recovery rates than LP in patients with straight preoperative sagittal alignment in long-term group ($P = 0.043$).

Factors affecting recovery rate

We compared recovery rate and preoperative variables with multiple linear regression modeling using the stepwise method based on follow-up duration, as shown in Table 4. In the short-term group (less than 48 months), old age ($P = 0.011$), hill shape ($P = 0.013$), and high MR grade of ISI ($P = 0.040$) had independent, negative effects on the recovery rate. In the long-term group (more than 48 months), LP ($P = 0.021$) and high MR grade of ISI ($P = 0.017$) had independent, negative effects on recovery rate.

Discussion

In our study, the overall JOA recovery rate was also significantly higher in ACCF group than in LP at last follow-up. In terms of the pattern of JOA recovery rate between ACCF and LP, the JOA recovery rate of ACCF also progressively increased during the follow-up period. However, the JOA recovery rate of LP progressively decreased during the follow-

Table 3 Relationship between recovery rate and preoperative variables, according to surgical approach

	JOA recovery rate									
	Short-term group (≤ 48 months)					Long-term group (> 48 months)				
	ACCF		LP			ACCF		LP		
	N	Mean ± SD	*N*	Mean ± SD	*P*	*N*	Mean ± SD	*N*	Mean ± SD	*P*
Gender										
Male	19	66.2 ± 32.8	34	58.8 ± 48.7	0.560	31	74.6 ± 33.6	14	45.3 ± 61.6	0.044*
Female	9	77.8 ± 37.3	10	70.2 ± 41.6	0.683	11	89.5 ± 19.4	5	57.2 ± 33.6	0.027*
Occupying ratio (%)										
< 60	20	71.8 ± 32.5	25	66.4 ± 46.4	0.659	23	77.2 ± 35.6	10	45.4 ± 46.2	0.039*
≥ 60	8	65.1 ± 39.8	19	54.8 ± 48.2	0.601	19	80.2 ± 25.2	9	51.8 ± 66.0	0.109
Shape										
Hill	16	79.6 ± 27.5	22	66.0 ± 41.4	0.264	24	77.7 ± 33.0	9	15.1 ± 49.8	< 0.001*
Plateau	12	57.0 ± 38.8	22	56.7 ± 52.5	0.988	18	79.7 ± 29.0	10	78.4 ± 41.5	0.925
Type of OPLL										
Continuous	5	95.0 ± 11.2	12	66.1 ± 49.9	0.227	6	80.5 ± 40.0	9	57.8 ± 68.2	0.477
Mixed	6	62.0 ± 28.4	18	75.1 ± 37.2	0.440	13	88.4 ± 18.6	7	21.4 ± 34.3	< 0.001*
Segmental	2	0	13	44.5 ± 49.6	0.240	7	66.6 ± 38.1	3	83.3 ± 16.5	0.495
Localized	15	74.0 ± 30.8	1	− 23	0.009*	16	75.0 ± 32.7	0		
Grade of ISI on MRI										
0	5	92.0 ± 17.9	8	76.6 ± 27.0	0.287	10	90.0 ± 31.6	6	69.5 ± 51.9	0.339
1	17	69.5 ± 36.2	17	73.8 ± 38.5	0.740	27	78.9 ± 24.9	7	62.4 ± 41.0	0.184
2	6	52.7 ± 31.4	19	43.9 ± 55.7	0.719	5	53.4 ± 49.3	6	11.0 ± 60.4	0.241
Sagittal alignment										
Lordotic	8	90.9 ± 17.0	22	69.2 ± 41.4	0.165	9	69.3 ± 34.7	11	49.0 ± 56.5	0.359
Straight	12	53.9 ± 33.1	21	52.3 ± 52.7	0.926	24	80.2 ± 29.8	8	47.6 ± 56.5	0.043*
Kyphotic	8	72.9 ± 39.0	1	80	0.868	9	83.2 ± 32.4	0		

JOA, Japanese Orthopedic Association; *ACCF*, anterior cervical corpectomy and fusion; *LP*, laminoplasty; *N*, number; *OPLL*, ossification of the posterior longitudinal ligament; *ISI*, increased signal intensity; *MRI*, magnetic resonance imaging

*$P < 0.05$

up period. We found that the pattern of long-term JOA recovery rate had a significant difference of JOA recovery rate between ACCF and LP at around 48-month follow-up period ($P = 0.008$). As in a previous prospective study on long-term surgical outcomes of OPLL after ACCF or LP, the JOA score and the JOA recovery rate were better in ACCF after a longer follow-up [18]. These results imply that stable long-term clinical outcome depends on complete removal of the compressive lesion through an anterior approach in accordance with results of previous report [6].

Several reports indicated that ACCF produced better outcomes when the occupying ratio is over 60% or when the OPLL is hill-shaped [2, 8]. This was concordant with our findings, which were statistically significant only in the long-term group ($P < 0.001$, Table 3). Furthermore, when the occupying ratio was over 60%, there was no significant difference in short-term JOA recovery rate between the ACCF and LP groups. When the occupying ratio was less than 60%, ACCF produced a higher long-term JOA recovery rate than LP ($P = 0.039$). Because the mean follow-up period was longer in the ACCF group (47.9 ± 16.9 months) than that in the LP group (40.4 ± 12.3 months, $P = 0.004$), direct decompression may provide the better JOA recovery rate over a longer duration period in cervical OPLL.

In multiple regression modeling, old age, hill shape, and high ISI grade on MR correlated with lower recovery rates in the short-term follow-up group. LP and high ISI grade on MR predicted a lower recovery rate in the long-term follow-up group. ACCF has disadvantages, such as long operation time, blood loss, CSF leakage, and others [11]. Elderly patients are vulnerable to post-operative complications because they often lack resilience and present with other chronic diseases. Therefore, age may affect short-term surgical outcomes more than long-term outcomes. Elderly patients should receive careful perioperative management to improve surgical outcomes. ACCF should be the first choice of treatment for

Table 4 Multiple linear regression analysis of recovery rate according to follow-up period

Short-term group (≤ 48 months)			Long-term group (> 48 months)		
	JOA recovery rate			JOA recovery rate	
Variable	Unstandardized coefficient (B)	*P*	Variable	Unstandardized coefficient (B)	*P*
Surgical approach	− 9.933	0.406	Surgical approach	− 31.706	0.021*
Sex	11.682	0.288	Sex	13.212	0.242
Age	− 1.385	0.011*	Age	− 0.861	0.111
Type of OPLL	− 6.786	0.191	Type of OPLL	− 2.442	0.640
Alignment	− 4.962	0.522	Alignment	7.504	0.378
Shape of lesion	− 28.002	0.013*	Shape of lesion	11.389	0.279
MRI grade	− 14.761	0.040*	MR grade	− 20.97	0.017*
Occupying ratio	− 3.632	0.165	Occupying ratio	0.593	0.226
Preoperative JOA score	1.789	0.331	Preoperative JOA score	− 3.766	0.133

JOA, Japanese Orthopedic Association; *OPLL*, ossification of the posterior longitudinal ligament; *MRI*, magnetic resonance imaging

*$P < 0.05$

patients with OPLL if the patients are old or if the cervical spine is hypermobile [15].

High ISI grade on MR correlated with lower recovery rates in a multiple regression model. ISI grade on MR independently affected the recovery rate in multiple regression models, regardless of the follow-up period. Preoperative intramedullary ISI on T2-weighted sagittal MR previously correlated with recovery rate [23], which was concordant with our study. ISI grade on MR may reflect neurological damage or indirect spinal cord alteration [10]. A higher preoperative occupying ratio of cervical OPLL was previously significantly associated with intramedullary ISI on MR [9], as was cervical instability [21]. Therefore, the ISI grade on MR is a strong predictor of surgical outcomes in patients with myelopathy due to OPLL, and preoperative MRI is an important predictor of surgical outcome in patients with OPLL.

Due to the single-center retrospective study design, inclusion criteria in both ACCF and LP groups were different, especially that the distribution of the type of OPLL and sagittal alignment were not evenly matched between ACCF and LP. Surgeons usually prefer LP when OPLL is of the continuous type and ACCF when OPLL is localized, or when a patient has kyphotic sagittal alignment on a neutral cervical spine lateral X-ray. Therefore, we could not conclude that ACCF is superior to LP for all OPLL cases. However, in mixed and localized OPLL, ACCF produced a higher recovery rate than LP. These findings suggest that direct decompression of spinal cord with ACCF provides better long-term stable neurological outcomes than LP.

Surgeons usually consider ACCF for patients with OPLL coexisting kyphotic sagittal alignment. If the cervical spine shows straight sagittal alignment, selection of surgical technique is still controversial. In our study, ACCF produced better results than LP in patients with straight sagittal alignment ($p = 0.043$). Previous reports asserted that long-term neurologic deterioration after LP was preceded by kyphotic change. Therefore, follow-up studies should evaluate the effect of surgical procedures (ACCF or LP) on sagittal alignment and clinical outcomes.

This study was a retrospective study without randomization at a single institution. Patient demographics differed between the two surgical groups because surgical indications for ACCF and LP differ. One previous report found that ACCF was safer for patients with one- or two-level OPLL [12]. Another report asserted that ACCF should be the first-line treatment for OPLL in patients with spinal hypermobility [15]. In addition, a higher preoperative occupying ratio of cervical OPLL is significantly associated with intramedullary ISI on MR [9]. For similar reasons, segmental type or hill-shaped OPLL can be associated with ISI on MR. We did not study interactions between preoperative factors such as shape, type, sagittal alignment, and ISI grade on MR. Other factors that can affect surgical outcomes, such as changes in cervical dynamic parameters, presence of instability, complications, and the number of surgical levels, were not studied and can be considered limitations of this study. Thus, a prospective, randomized, and controlled study comparing surgical outcomes between ACCF and LP group is needed.

In conclusion, long-term surgical outcomes of ACCF became better than those of LP at more than 48-month follow-up period. Old age, high ISI grade on MR, and hill-shaped OPLL were independent factors affecting the lower recovery rate after surgical treatment in patients diagnosed with compressive myelopathy due to OPLL. High ISI grades on MR and LP surgery affected long-term follow-up outcomes. Sufficient direct decompression can lead to better surgical outcomes over a long-term follow-up period.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval Approval for the current study was granted by the Institutional Review Board of our institute (approval number, 4-2012-0686).

Informed consent Informed consent was obtained from all individual participants included in the study.

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