Safety and Efficacy of Treatment for Scolios Is Secondary to Spinal Muscular Atrophy Fused to Lumbar 5 Level

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Abstract:

Introduction: Patients with spinal muscular atrophy (SMA) usually have progressive scoliosis. Although fusion of the sacrum or pelvis has been recommended for correcting pelvic obliquity (PO), the procedure is invasive. This study determined as to whether performing instrumentation to the fifth lumbar vertebra (L5) is safe and effective for scoliosis in patients with SMA.

Methods: Twelve patients with SMA underwent posterior spinal fusion and stopping instrumentation at the L5 level. We evaluated age at surgery, the duration of surgery, blood loss, complications, preoperative and postoperative Cobb angles, and PO.

Results: The mean age at surgery was 11.4 years; the mean duration of surgery was 319 minutes, and the mean blood loss was 1170 mL. The Cobb angle improved from 97.3° to 39.1° at 1 month postoperatively (correction rate, 60.9%) and to 42.3° at the final follow-up. PO was corrected from 27.8° to 13.1° at 1 month postoperatively (correction rate, 51.7%) and to 19.8° at the final follow-up. No complications were reported. All patients showed improvement in low back pain, with reduced difficulty while sitting. However, >10% correction loss of PO was observed in 6 patients with high preoperative PO.

Conclusions: The correction rate of scoliosis in SMA patients with posterior spinal fusion and instrumentation to the L5 level was acceptable, and no complications occurred. Scoliosis associated with SMA was more rigid and severer than scoliosis associated with Duchenne muscular dystrophy. Correction rates of the Cobb angle and PO in SMA patients with instrumentation to L5 were similar to those in SMA patients with instrumentation to the sacrum or pelvis. Correction loss of PO was greater in patients with high preoperative PO than in those with low preoperative PO. Instrumentation and fusion to L5 for scoliosis in patients with SMA seems safe and effective, except in cases of high preoperative PO.

Keywords:

Spinal muscular atrophy, Neuromuscular scoliosis, Cobb angle, Pelvic obliquity, Posterior spinal fusion surgery, Correction loss

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Introduction

Spinal muscular atrophy (SMA) is a motor neuron disease that results from the loss of anterior horn cells in the spinal cord and gradually progresses to cause muscle atrophy[1,2]. SMA usually causes progressive neuromuscular scoliosis (NMS), resulting in difficulty in sitting and low back pain. In severe cases, patients with NMS can have deteriorated pulmonary and cardiac function[3]. It has been reported that surgical stabilization and spinal fusion is necessary in patients with progressive NMS[4].

Regarding the surgical strategy for patients with NMS, instrumentation and fusion to the sacrum or pelvis is recommended for correcting and maintaining pelvic obliquity (PO). However, there are concerns about the caudal extent of instrumentation and fusion in terms of the duration of surgery, blood loss, invasion of soft tissue, and risk of complications, including loosening of the iliac or sacral screw[5-7].

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We previously reported that segmental pedicle screw instrumentation and fusion to the fifth lumbar vertebra (L5) and avoidance of lumbosacral fusion are safe and effective for patients with Duchenne muscular dystrophy (DMD) with scoliosis <85° and pelvic obliquity (PO) <15°.8) On the basis of these previous reports, we performed posterior spinal fusion and instrumentation to L5 in every patient with neuromuscular scoliosis (NMS), including those with a high Cobb angle or high PO.

The purpose of the present study was to determine as to whether instrumentation to L5 and avoidance of lumbosacral fusion are safe and effective for NMS in patients with spinal muscular atrophy (SMA).

Materials and Methods

Ethical approval from our institutional review board was obtained for this study, which was conducted in accordance with the ethical principles specified in the 1964 Declaration of Helsinki and its subsequent amendments.

Patient population

Initially, 16 consecutive patients with SMA who underwent posterior spinal corrective fusion surgery for NMS from 2007 to 2015 were enrolled. A minimum 2-year follow-up was required for inclusion in the present study. We excluded 4 patients who underwent fusion surgery with a single rod because of their small spinal structure. The remaining 12 patients (4 boys and 8 girls) who underwent surgery with dual rods were finally included.

Surgical procedure

All surgeries were performed under general anesthesia. Spinal cord function was monitored using motor-evoked potentials. Autotransfusion was performed using preoperative storage, and intraoperative collection was used during the surgical procedure. An incision was made on the midline of the back, and the spinal structure was exposed from the upper thoracic spine to the sacrum. After removing all soft tissues, posterior instrumentation was performed with pedicle screws, hooks, and sublaminar cables (Nesplon Cable System, Alfresa Corp., Tokyo, Japan). Fusion levels in all cases were from T3 or T4 to L5. After placement of the instruments, local autograft bone was obtained from the spinous processes, laminae, and transverse processes of the vertebrae. Spinal deformities in all the patients were corrected using two combined techniques, including a cantilever technique and a rod rotation technique, as previously reported[8]. After correction, all laminae and facet joints were decorticated, and local autograft bone mixed with bioresorbable bone graft was placed. The wound was sutured in three layers, and two drainage tubes were placed.

Clinical endpoints

We examined the duration of surgery, intraoperative blood loss, and perioperative complications in all the cases. We reviewed all intraoperative complications related to surgery and anesthesia and postoperative complications during hospitalization. Postoperative complications were defined as complications of grade I or higher, according to the Clavien-Dindo classification. Additionally, the Cobb angle and PO were recorded preoperatively, at 1 month postoperatively, and at the final follow-up. The Cobb angle of the curves and PO were measured in the coronal plane. PO was defined as an angle subtended by a line drawn between the most proximal points on the iliac crest and a line drawn parallel to the lower end of the radiograph, as previously reported[9]. The correction rates of the Cobb angle or PO at 1 month postoperatively or the final follow-up were calculated using the following formula:

Correction rate (%) = (postoperative angle - preoperative angle) / preoperative angle × 100

In addition, correction loss rate of the Cobb angle or PO was calculated using the following formula:

Correction loss rate (%) = (postoperative angle at the final follow-up - postoperative angle at 1 month postoperatively) / preoperative angle × 100

Results

Patient characteristics are described in Table 1. All patients with SMA type 2 were included. Their mean age at surgery was 11.4 years, the duration of follow-up was 39.0 months, the duration of surgery was 319 minutes, and intraoperative blood loss was 1170 mL. There were no perioperative complications, including neurological complications or instrumentation failures (Table 1). All patients reported that their difficulty in sitting was alleviated and their back pain had diminished postoperatively. The radiographic findings of a representative patient in this study are shown in Fig. 1A-F

Details of the radiographic measurements of all the patients are shown in Table 2. In the coronal plane, the mean preoperative Cobb angle was 97.3° (range 56-132°), and the mean 1-month postoperative Cobb angle was 39.1° (range 13-88°). At the final follow-up, the Cobb angle was 42.3° (range 21-86°). Correction rates of the Cobb angle at 1 month postoperatively and at the final follow-up were 60.9% and 57.2% respectively. There were no cases with >10% correction loss of the Cobb angle. The mean preoperative PO was 27.8° (range 6-58°), and the mean 1-month postoperative PO was 13.1° (range 2-41°). At the final follow-up, PO was 19.8° (range 2-45°). The correction rates of PO at 1 month postoperatively and at the final follow-up were 51.7% and 32.7%, respectively. Six patients had >10% of correction loss of PO. In 4 of these patients, the preoperative PO was >30°.

Discussion

In the present study, the mean preoperative Cobb angle in patients with NMS secondary to SMA was 97.3°, and after

Table 1.

Case No.	Sex (M/F)	Age (year)	SMA Type	Follow (month)	Operative time (min)	Blood loss (ml)	Complication
1	F	9	2	28	270	850	-
2	F	12	2	26	275	1400	-
3	F	12	2	50	330	1440	-
4	M	14	2	91	290	910	-
5	M	9	2	80	244	740	-
6	F	11	2	42	350	2840	-
7	F	16	2	21	400	970	-
8	M	11	2	34	280	1080	-
9	F	10	2	24	405	1126	-
10	F	12	2	24	338	770	-
11	M	11	2	24	405	1255	-
12	F	10	2	24	243	630	-
Mean	M:4 F:8	11.4		39.0	319	1170	

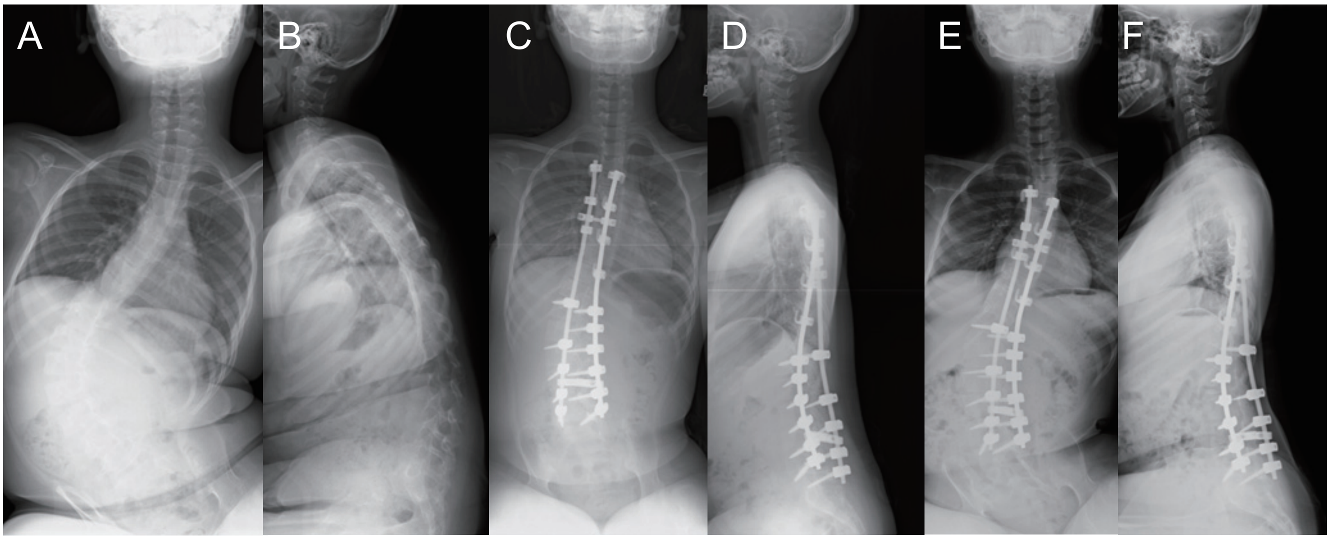

Figure 1. Radiographs of a 10-year-old girl with scoliosis secondary to spinal muscular atrophy. Preoperative frontal view (A) at 1 month postoperatively and (C) at the final follow-up (24 months postoperatively) (E); and preoperative lateral view (B) at 1 month postoperatively, (D) at the final follow-up (24 months postoperatively), and (F) in the sitting position. Cobb angles were 87° preoperatively, 28° at 1 month postoperatively, and 33° at the final follow-up. The correction rates of the Cobb angle were 67.8% at 1 month postoperatively and 62.1% at the final follow-up. Pelvic obliquity (PO) was 30° preoperatively, 11° at 1 month postoperatively, and 13° at the final follow-up. The correction rates of PO were 63.3% at 1 month postoperatively and 56.7% at the final follow-up.

instrumentation to L5, correction rates of the Cobb angle were 60.9% at 1 month postoperatively and 57.2% at the final follow-up. The mean preoperative PO was 27.8°, and correction rates of PO were 51.7% at 1 month postoperatively and 32.7% at the final follow-up. More than 10% correction loss of PO was observed in 6 patients with high preoperative PO.

Granata et al. reported that NMS secondary to SMA type 2 increased by 8° annually without any treatment[10]. In patients with severe NMS, surgical stabilization of the spine is strongly recommended to maintain or improve respiratory function[11,12]. Regarding the surgical strategy for NMS secondary to SMA, multiple authors have reported several techniques for spinal stabilization, including the Harrington rod technique[13,14], Luque technique[1,13-15], Galveston technique[15], and ISOLA system[4]. Recently, due to the development of spinal instrumentation, including pedicle screws, segmental instrumentation and fusion of the sacrum or pelvis is the mainstay of surgery for NMS[4], and is recommended for correcting and maintaining PO[16,17]. However, there is still some controversy regarding whether fusion of the sacrum or pelvis is necessary during surgery for NMS. Several authors have reported that extending the fusion level to the sacrum or pelvis can lead to higher blood loss, technical difficulty, and some complications[5-7,18]. Sengupta et al. reported that lumbar fixation to L5 for NMS is adequate if the surgery is performed early and in patients with smaller curves and minimal PO[18]. The surgical outcomes for NMS secondary to

Table 2.

Case No.	Cobb					PO				
	Pre Ope (°)	Post Ope 1M (°)	Correction rate (%)	Final F/U (°)	Correction loss rate (%)	Pre Ope (°)	Post Ope 1M (°)	Correction rate (%)	Final F/U (°)	Correction loss rate (%)
1	72	24	66.7	23	-1.4	10	6	40.0	5	-10.0
2	108	30	72.2	33	2.8	6	6	0.0	5	-16.7
3	132	88	33.3	86	-1.5	40	26	35.0	42	40.0
4	75	49	34.7	55	8.0	34	9	73.5	30	61.8
5	56	16	71.4	21	8.9	8	4	50.0	4	0.0
6	90	13	85.6	21	8.9	18	6	66.7	15	50.0
7	123	68	44.7	75	5.7	45	20	55.6	26	13.3
8	114	43	62.3	50	6.1	35	15	57.1	32	48.6
9	95	37	61.1	37	0.0	26	11	57.7	18	26.9
10	130	41	68.5	41	0.0	58	41	29.3	45	6.9
11	85	32	62.4	33	1.2	24	2	91.7	2	0.0
12	87	28	67.8	33	5.7	30	11	63.3	13	6.7
Mean	97.3	39.1	60.9	42.3	3.7	27.8	13.1	51.7	19.8	19.0

Correction rate (%): Correction rate at at 1 month postoperatively

Table 3.

	N	Diagnosis	LIV	Cobb angle			PO		
				preoperative angle (°)	postoperative angle (°)	correction rate (%)	preoperative angle (°)	postoperative angle (°)	correction rate (%)
Chong HS et al. 2010	11	SMA	sacrum/pelvis	80.7	39	48.3	14.3	7.8	N/A
Fujak A et al. 2012	24	SMA	sacrum: 22 L5: 2	83	39	54	28	10	N/A
Holt JB et al. 2017	16	SMA	pelvis: 15 L5: 1	78	25	65	22	5	78
Alexander WM et al. 2013	24	DMD	N/A	56.4	21.6	61.7	N/A	N/A	N/A
Pesenti S et al. 2016	30	DMD	pelvis	39.1	13	79.4	12.8	2.2	87.7
Takaso M et al.	20	DMD	L5	70	15	77	13	5	62
The present study	12	SMA	L5	97.3	39.1	60.9	27.8	13.1	51.7

LIV: The Lowest Instrumented Vertebrae
PO: Pelvic Obliquity
DMD: Duchenne Muscular Dystrophy
SMA: Spinal Muscular Atrophy

SMA in previous reports are shown in Table 3[4,19,20]. Compared to previously reported data, the surgical outcome in terms of radiographic measurements in the present study was acceptable, without any perioperative complications. However, >10% correction loss of PO was observed in 6 patients who had high preoperative PO in the present study. We previously reported that 2-year outcomes for segmental pedicle screw instrumentation and fusion to L5 was good and effective in patients with DMD scoliosis <85° and PO < 15°[8]. Based on these results, instrumentation and fusion to L5 for scoliosis in patients with SMA seems safe and effective, except in patients with high preoperative PO. However, in the current study, some cases showed acceptably low correction loss rates even in patients with Cobb angle >85° or PO >15°. The amount of PO that can be considered safe and effective for instrumentation to L5 in patients with SMA remains unclear.

With regard to differences between NMS secondary to SMA and DMD, the surgical outcomes for NMS secondary to DMD in previous reports are shown in Table 3[8,21,22]. The mean preoperative Cobb angle in the present study was more than that in previous reports of DMD. In addition, the correction rate of the Cobb angle in the present study was less than that in our previous study of DMD that used the same surgical strategy, including fusion only to L5[8]. On the basis of these findings, we inferred that scoliosis associated with SMA could be more rigid and severer than scoliosis associated with DMD, as reported previously.

There are some limitations in this study. First, this study was a small case series without controls. Therefore, we could not compare our findings with the outcomes of cases of instrumentation to the sacrum/pelvis. In addition, we could not determine the cut-off values of preoperative Cobb angle and PO for cases in which instrumentation to L5 would be effective. Second, we did not evaluate clinical findings, such as sitting balance or clinical scores. Therefore, the postoperative Cobb angle and PO values associated with effective sitting balance and improved clinical scores, and the effect of correction loss on clinical findings remain unclear. In the future, a study with a larger sample size, along with evaluation of clinical findings, is necessary to understand the limitations of the surgical strategy, including segmental pedicle screw instrumentation and fusion to L5 in patients with NMS.

In conclusion, although scoliosis associated with SMA tended to be more rigid and severer than scoliosis associated with DMD, instrumentation and fusion to L5 for scoliosis in patients with SMA appears to be safe and effective, except in patients with high preoperative PO.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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