MEDICAL SCIENCE MONITOR

CLINICAL RESEARCH

e-ISSN 1643-3750
© Med Sci Monit, 2020; 26: e919281
DOI: 10.12659/MSM.919281

Received: 2019.08.09
Accepted: 2019.10.30
Available online: 2020.01.21
Published: 2020.02.04

A Retrospective Study to Compare the Efficacy of Preoperative Halo-Gravity Traction and Postoperative Halo-Femoral Traction After Posterior Spinal Release in Corrective Surgery for Severe Kyphoscoliosis

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Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
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Source of support: This study was funded by the Natural Science Foundation of Youth Fund Projects of Jiangsu Province (No. BK20170126), Funding for the Postdoctoral Science Foundation of China (No. 2017M610323) and the Jiangsu Postdoctoral Research Funding Program (No. 1701018C)

Background: This retrospective clinical study aimed to compare the efficacy of preoperative halo-gravity traction with postoperative halo-femoral traction after posterior spinal release in corrective surgery for patients with severe kyphoscoliosis.

Material/Methods: A retrospective clinical study included patients who underwent elective corrective surgery for severe kyphoscoliosis (N=60) between 2013 and 2015. Two patient groups were compared, the postoperative halo-femoral traction after posterior spinal release (R-HF) group (N=30) and the preoperative halo-gravity traction (HGT) group (N=30). Demographic and clinicopathological data included age, gender, Cobb angle, degree of spinal curvature, history of osteotomy, and etiological factors. Patients in the two study groups were matched. Postoperative surgical outcome was evaluated by the radiographic coronal Cobb angle, global kyphosis, coronal balance, and the sagittal vertical axis (SVA). Clinical outcome was assessed using the Scoliosis Research Society Outcomes Questionnaire (SRS-22).

Results: The preoperative Cobb angle was similar between the R+HF group and the HGT group (123.5±12.7° *vs.* 123.1±14.1°; P=0.909). Following postoperative traction, a significantly higher correction rate was found in the R+HF group than the HGT group (31.8±7.8% *vs.* 19.3±12.9%; P=0.001). The postoperative correction rate in the R+HF group was significantly higher than the HGT group (44.7±7.8% *vs.* 39.0±12.8%; P=0.042). In both study groups, the postoperative SRS-22 scores were significantly improved with no statistical difference between the two groups, and no neurological complications occurred.

Conclusions: Patients with severe kyphoscoliosis who underwent postoperative halo-femoral traction after posterior spinal release achieved satisfactory radiographic correction.

MeSH Keywords: **Postoperative Complications • Scoliosis • Traction**

Full-text PDF: https://www.medscimonit.com/abstract/index/idArt/919281

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Background

The treatment of severe kyphoscoliosis can be challenging. The use of three-column osteotomy has been used as the standard surgical technique for several decades. However, three-column osteotomy can be associated with serious complications that include spinal cord injury and paralysis [1,2]. To reduce the risks of neurological complications, spinal traction has been used to improve three-dimensional deformity and vertebral rotational abnormalities [3]. Preoperative halo-gravity traction has long been shown in previously published studies to correct kyphoscoliosis and to minimize the risks of neurological complications [4,5].

Halo-femoral traction after spinal release, combined with a second-stage posterior correction procedure, has also been proposed for the treatment of severe kyphoscoliosis [6]. A spinal release may be performed through either anterior or posterior approach. Because the anterior spinal release is associated with impaired postoperative respiratory function and more intraoperative complications [7–9], the posterior release before traction and correction surgery is preferred in clinical practice. However, the efficacy of halo-femoral traction after posterior spinal release combined with posterior spinal correction surgery in severe spinal deformity has rarely been reported previously.

Therefore, this retrospective study was conducted at our center and aimed to compare the efficacy of preoperative halo-gravity traction with postoperative halo-femoral traction after posterior spinal release in corrective surgery for patients with severe kyphoscoliosis.

Material and Methods

Study design and ethical approval

This study was approved by the Institutional Review Board (IRB). Informed consent was obtained from all participants included in the study. This retrospective clinical study included patients who underwent elective corrective surgery for severe kyphoscoliosis (N=60) between 2013 and 2015. Two patient groups were compared, the postoperative halo-femoral traction after posterior spinal release (R-HF) group (N=30) (mean age, 21.9±4.5 years), and the preoperative halo-gravity traction (HGT) group (N=30). The patients in the two groups were matched by age, gender, etiology, spinal curvature pattern, Cobb angle, and type of osteotomy.

The study inclusion criteria were patients aged ≥10 years, with a main thoracic vertebral curvature >100° on standing when evaluated by whole spinal X-ray imaging, and >70° on bending sideways, and who had more than two years of postoperative follow-up. Patients with structural deformities of the vertebrae, or with any history of spinal surgery, were excluded from the study.

Surgical procedure for postoperative halo-femoral traction after posterior spinal release (R+HF)

In the R+HF group, the first stage of surgery consisted of posterior spinal release, pedicle screw placement, and Ponte osteotomy. The patient was placed in the prone position, and a midline incision was made. Pedicle screws were placed at the fusion levels, and multiple-segment Ponte osteotomies around the apical region were performed. The patients underwent supine halo-femoral traction in bed, three days after surgery. The pins of the cranial halo were tightened, depending on the skull size, and bilateral femoral supracondylar traction was used as the distal countertraction. The initial traction weight was 2 kg, and the load was gradually increased to a maximum of 30–50% of body weight at a velocity of 2 kg/day. The final traction weight was adjusted according to the tolerance level of each patient. Traction was applied for a minimum of 12 hours per day, with the traction weight reduced to 50% in the night. About three weeks after the traction began, the second-stage posterior spinal correction and fusion was performed (Figure 1).

Surgical procedure for preoperative halo-gravity traction (HGT)

In the HGT group, preoperative HGT was performed in a wheelchair [3]. Six to eight halo pins were placed and tightened to between 6–8 pounds of torque. The exact number of pins and the amount of torque applied was dependent on patient age and bone quality of the cranium. The initial traction load was 2 kg, and the weight was added at 2 kg per day to reach a target of 30–50% of body weight. Adjustment of the traction weight was according to the tolerance of the individual patient. HGT was maintained for more than 12 hours a day. The patients were allowed out of traction for the toilet and hygiene purposes as well as for eating. One-stage posterior spinal correction and fusion surgery was performed when the improvement in curvature reached a plateau (Figure 2). In this study, allograft and autograft bone was used for all patients. Somatosensory potentials (SEPs) and motor-evoked potentials (MEPs) were routinely monitored throughout the study, and a wake-up test was performed before surgical closure.

Radiographic and clinical evaluation

The coronal Cobb angle, global kyphosis, coronal balance, and the sagittal vertical axis (SVA) were measured preoperatively, following traction, immediately following surgery, and at the

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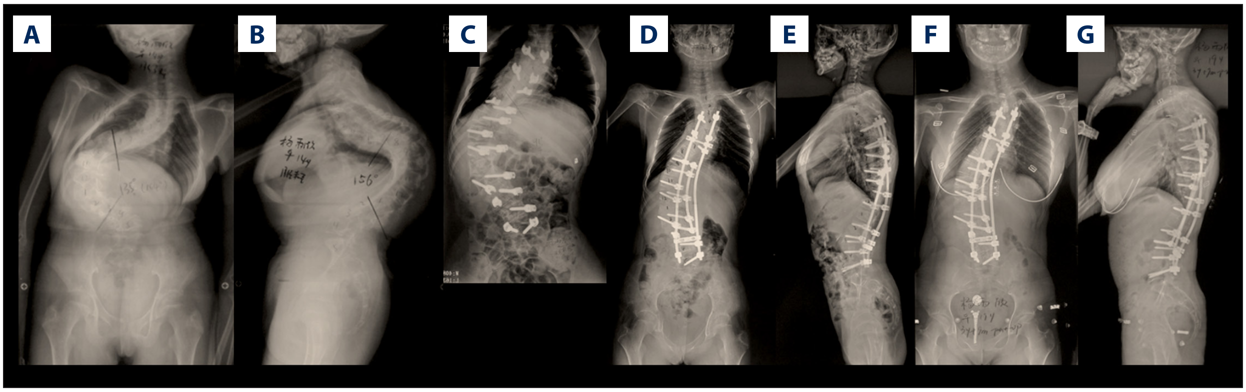

Figure 1. The posteroanterior (PA) and lateral X-ray images of the spine in a 14-year-old girl with severe kyphoscoliosis. A 14-year-old girl with severe kyphoscoliosis (**A, B**). The patient underwent posterior spinal release, halo-femoral traction (**C**), and second-stage posterior spinal fusion. Following surgery, the coronal and sagittal deformities were significantly corrected (**D, E**). The correction was well maintained at a four-year follow-up (**F, G**).

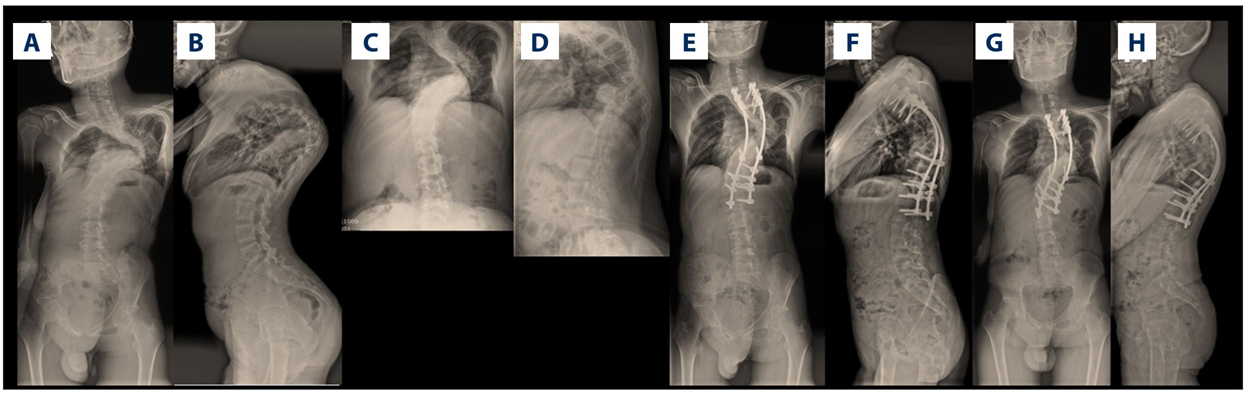

Figure 2. The posteroanterior (PA) and lateral computed X-ray images of the spine in a 16-year-old man with severe kyphoscoliosis. A 16 year-old male with severe kyphoscoliosis (**A, B**). The patient underwent preoperative halo-gravity traction for three weeks (**C, D**). Following surgery, the coronal and sagittal deformities were significantly corrected (**E, F**). At a two-year postoperative follow-up, no significant correction loss was found (**G, H**).

final follow-up, for both study groups. The preoperative bending radiograph determined spinal curve flexibility. The clinical outcome was evaluated by the Scoliosis Research Society Outcomes Questionnaire (SRS-22) scores [10].

Statistical analysis

Data were analyzed using the SPSS version 19.0 statistical software package (SPSS, Inc., Chicago, IL, USA). Continuous data were compared using Student's t-test. Comparisons of categorical variables was performed with the chi-squared (χ^2) test or Fisher's exact test. A P-value <0.05 was considered to be statistically significant.

Results

Patient demographics and clinicopathological data

In this retrospective study, two matched patient groups were compared, the postoperative halo-femoral traction after posterior spinal release (R-HF) group (N=30) and the preoperative halo-gravity traction (HGT) group (N=30). The general demographic and clinicopathological data for each study participant obtained at the initial clinic visit are summarized in Table 1.

There were no differences between the two study groups in terms of demographic and clinicopathological factors (all, P>0.05). In the R+HF group, the mean maximum mass of the halo-femoral traction was 13.1±2.1kg (32% of body weight), and the mean duration was 21.7±2.6 days. In the HGT group, HGT was applied with a similar maximum traction load of 14.6±3.8kg (34.4% of body weight) (P=0.063) and the mean duration of 22.9±3.9 days (P=0.167). Similar total time of surgery

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Table 1. The demographics and clinicopathological data in the two groups of patients studied, the postoperative halo-femoral traction after posterior spinal release (R-HF) group and the preoperative halo-gravity traction (HGT) group.

	R+HF Group	HGT group	P-value
No. (male)	30 (13)	30 (13)	1.000
Age	22.0±4.3 (16–34)	21.9±4.7 (16–34)	0.932
Body weight (kg)	41.5±7.9	42.4±10.1	0.373
Fused segment	14.4±1.1	14.4±1.2	0.910
Number of Ponte osteotomies	6.2±1.8	6.3±1.7	0.941
Etiology			1.000
– Idiopathic scoliosis	17 (57%)	17 (57%)	
– Chiari malformation syndrome	10 (33%)	10 (33%)	
– Other neuromuscular scoliosis	2 (7%)	2 (7%)	
– Marfan's syndrome	1 (3%)	1 (3%)	
Initial Cobb angle	123.5±12.7 (102–156)	123.1±14.1 (97–159)	0.909
Bending Cobb angle	105.7±13.8 (79–148)	108.2±14.5 (82–142)	0.497
Initial global kyphosis	97.5±19.8	90.8±21.6	0.216
Initial coronal balance (mm)	16.2±11.0	17.9±9.7	0.528
Initial sagittal vertical axis (mm)	26.6±20.1	29.3±24.5	0.643
Traction mass (kg)	13.1±2.1	14.6±3.8	0.063
Time of traction (days)	21.7±2.6	22.9±3.9	0.167
Total time of surgery (min)	378.1±67.3	347.8±69.5	0.092
Total blood loss (ml)	2087.5±721.8	1596.7±828.9	0.018
Mean follow-up (months)	31.4±7.4 (24–54)	34.4±9.7 (24–54)	0.183

was found in the R+HF group (378.1±67.3 min), and the HGT group (347.8±69.5 min), respectively (P=0.092). However, total blood loss was significantly reduced in the HGT group compared with the R+HF group (2087.5±721.8 ml *vs.* 1596.7±828.9 ml) (P=0.018). The mean postoperative follow-up period between the two study groups were not significantly different, and for the R+HF group, this was 31.4±7.4 months, and for the HGT group, the mean postoperative follow-up period was 34.4±9.7 months (P=0.183).

Radiographic evaluation of the R-HF group and the HGT group

The mean preoperative radiographic parameters showed no difference in the coronal Cobb angle between the two study groups and were 123.5±12.7° in the R+HF group, and 123.1±14.1° in the HGT group. At the end of traction treatment and immediately preceding fusion, the coronal Cobb angle was corrected to a mean of 84.2±14.5° in the R+HF group, and to 99.3±17.1° in the HGT group (correction mean, 31.8±7.8% *vs.* 19.3 ±12.9%) (P=0.001). After surgery, the mean major coronal curve decreased to 68.3±13.6° in the R+HF group, and to 75.1±20.9° in the HGT group, with a mean percentage correction of 44.7±7.8% and 39.0±12.8% for the two study groups (P=0.042). At the last follow-up, in the R+HF and HGT groups, the mean coronal curve was 69.6±14.8° and 77.3±21.4° (P=0.111), respectively. In the sagittal plane, global kyphosis improved from a mean of 97.5±19.8° preoperatively to 51.4±11.2° after surgery in the R+HF group. and from 90.8±21.6° to 55.2±21.3° in the HGT group (mean correction, 47.3±11.0% *vs.* 39.2 ±16.0% (P=0.026).

At two years following surgery, the mean kyphosis in the R+HF and HGT groups was 50.8±11.8° and 55.9±22.7°, respectively. Coronal balance, the mean distance between the C7 plumb line and the central sacral vertical line, was similar in each group before surgery (16.2±11.0 mm in the R+HF group, and

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Table 2. The radiographic parameters in the two groups of patients studied, the postoperative halo-femoral traction after posterior spinal release (R-HF) group and the preoperative halo-gravity traction (HGT) group.

		Preoperative	Post traction	Postoperative	Last follow-up	P-value (preoperative *vs.* post traction)	P-value (Preoperative *vs.* Postoperative)	P-value (postoperative *vs.* final follow-up)
R+HF group	Coronal Cobb angle	123.5±12.7	84.2±14.5	68.3±13.6	69.6±14.8	0.000	0.000	0.724
	Global kyphosis	97.5±19.8		51.4±11.2	50.8±11.8		0.000	0.841
	Coronal balance	16.2±11.0		18.2±17.8	16.2±13.4		0.603	0.625
	Sagittal vertical axis	26.6±20.1		27.1±18.5	21.2±16.3		0.921	0.195
HGT group	Coronal Cobb angle	123.1±14.1	99.3±17.1	75.1±20.9	77.3±21.4	0.000	0.000	0.689
	Global kyphosis	90.8±21.6		55.2±21.3	55.9±22.7		0.000	0.902
	Coronal balance	17.9±9.7		18.6±16.7	16.4±15.3		0.843	0.597
	Sagittal vertical axis	29.3±24.5		30.6±26.4	24.2±21.5		0.844	0.308

Table 3. Comparison of the complications in the two groups of patients studied, the postoperative halo-femoral traction after posterior spinal release (R-HF) group and the preoperative halo-gravity traction (HGT) group.

	R+HF group	HGT group	P-value
No. of patients	6	7	1.000
Traction-related complications	2	2	1.000
Brachial plexus injury	1	1	1.000
Loosening of the traction pin	1	1	1.000
Peri-operative complications	5	0	0.052
Superficial wound infection	2	0	0.492
Deep venous thrombosis	2	0	0.492
Urinary retention	1	0	1.000
Correction-related complications	2	5	0.424
Pedicle screw misplacement	1	3	0.612
Coronal decompensation	1	2	1.000

17.9±9.7 mm in the HGT group), and immediately after surgery (18.2±17.8 mm in the R+HF group and 18.6±16.7 mm in the HGT group) and at the last follow-up (16.2±13.4 mm in the R+HF group and 16.4±15.3 mm in the HGT group). The sagittal vertical axis (SVA), the distance between the C7 plumb line and the sagittal sacral vertical line, was found to be similar in each group both before and after surgery. The results of the comparative analysis of radiographic findings are shown in Table 2.

Clinical outcomes in the R-HF group and the HGT group

No significant differences were found between the two study groups in each domain of the preoperative Scoliosis Research Society Outcomes Questionnaire (SRS-22) scores. At the last follow-up, the R+HF group and HGT group did not show significant difference in the scores for function (3.5±0.4 *vs.* 3.6±0.5; P=0.161), pain (4.4±0.4 *vs.* 4.5±0.3; P=0.407), self-image (3.6±0.5 *vs.* 3.6±0.4; P=0.536), mental health (4.0±0.5 *vs.* 4.0±0.3; P=0.563), and patient satisfaction (4.5±0.5 *vs.* 4.5±0.3; P=0.744) domains. The mean total scores of the SRS-22 were 3.9±0.2 and 4.0±0.2 in the R+HF group and HGT group, respectively (P=0.616).

Complications in the R-HF group and the HGT group

There were no deaths or neurological complications in the two study groups. There were no neuromonitoring alerts or dural

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lacerations identified during surgery in the two study groups. Postoperative complications were observed in six patients in the R+HF group and seven patients in the HGT group (Table 3). Superficial wound infection occurred in two patients in the R+HF group. Two patients in the R+HF group had deep venous thrombosis and were managed with anticoagulant treatment. There was one case with brachial plexus injury and one case with traction pin loosening in each of the two groups. One patient in the R+HF group and two patients in the HGT group had a coronal decompensation during follow-up. None of these patients received revision surgery. No implant failure or pseudoarthrosis, or nonunion, were observed by the last follow-up of study participants in the two study groups.

Discussion

Recently, the use of three-column osteotomy has become an alternative for the treatment of severe spinal deformities. Qiao et al. reported that three-column osteotomy achieved favorable outcomes in the treatment of severe kyphoscoliosis [11]. However, this method has a high incidence of perioperative complications, which have been reported to be as high as 30.3% [11]. Staged spinal correction, which obviates the need for large corrective forces to re-align the spine, are associated with less operative morbidity and fewer complications than a single-stage procedure and can achieve a satisfactory correction [12]. A previous study showed that traditional preoperative halo-gravity traction (HGT), significantly corrected vertebral deformity in patients with severe kyphoscoliosis [13]. Also, first-stage anterior release followed by halo-femoral traction (HFT) and second-stage posterior instrumentation resulted in a 57.5% major curve correction in severe idiopathic scoliosis [14]. However, anterior procedures through an open thoracotomy or even by an endoscopic approach can have a negative impact on pulmonary function [7].

This retrospective clinical study included 60 patients who underwent elective corrective surgery for severe kyphoscoliosis at a single center between 2013 and 2015. Two patient groups were compared, the postoperative halo-femoral traction after posterior spinal release (R-HF) group and the preoperative halo-gravity traction (HGT) group. To minimize the disadvantages associated with anterior release and the posterior single-stage procedure, our center used an alternative approach in which one large posterior operation was divided into two smaller posterior procedures staged three weeks apart, consisting of posterior release, halo-femoral traction, and posterior spinal fusion (the R+HF group). To our knowledge, the use of halo-femoral traction after posterior spinal release has not been previously evaluated, especially when compared with traditional preoperative HGT in severe kyphoscoliosis.

In the present study, the patients in the two study groups were matched for age, gender, and clinical factors. There was a significantly improved correction of the coronal Cobb angle in the R+HF group compared with the HGT group. It is possible that the soft tissue release before traction and the multi-segment osteotomy during surgery contributed to the relatively better correction of the spinal curvature. Spinal contracture of soft tissues in patients with severe scoliosis individuals mainly involves the apex vertebra on the concave side [15]. Also, the spontaneous fusion and hyperplasia of the costotransverse joint ligaments, zygapophysial of facet joint ligaments, or intertransverse ligaments, could influence the flexibility of the curvature. Consequently, the posterior release of ligaments and soft tissue near the apex vertebra may reduce the deformity. In the present study, postoperative correction of both coronal and sagittal deformities was significantly improved in the R+HF group, which demonstrated that patients with severe kyphoscoliosis could benefit more from halo-femoral traction combined with posterior spinal release than one-stage preoperative HGT.

There was significantly more blood loss in the R+HF group in this study, which may have been due to the two separate procedures involved, including the steps of exposure and closure. However, these disadvantages were compensated for by the improved radiographic correction rates. Neurological deficits are a concern in patients with severe kyphoscoliosis undergoing three-column osteotomy, with the rates for this complication having been reported to range from approximately 8.5–35% [16–20] . In the present study, no neurological complications were observed in the two study groups. The multisegment Ponte osteotomy was used instead of the three-column osteotomy in the R+HF group, which effectively reduced the difficulty of the surgery, avoided the use of spinal dislocation during the osteotomy, and minimized the risk of perioperative neurological complications. However, the complications associated with the use of traction, including brachial plexus injury and traction pin loosening, were also observed in the R+HF group. The patients in the R+HF group required traction in bed for more than 12 hours per day, which resulted in other complications, including deep venous thrombosis, and urinary retention. Also, the additional surgery using the same incision made healing more difficult. Halo-femoral traction should be performed in the supine position, and the incidence of superficial infection of incision was observed in this study. Therefore, although halo-femoral traction after posterior spinal release helped to achieve a satisfactory postoperative correction rate for the patients with severe kyphoscoliosis and avoided severe neurological complications, there are complications associated with this procedure that should be recognized.

In the present study, in both study groups, there was a significant improvement from the preoperative to the postoperative Scoliosis Research Society Outcomes Questionnaire (SRS-22)

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scores. These findings were consistent with those from previously published studies [21,22]. However, there was no significant difference in the scores of the SRS-22 questionnaire at the last follow-up between the R+HF group and the HGT group. Therefore, it was possible to conclude that although patients undergoing halo-femoral traction after posterior spinal release might suffer from continuous traction in the supine position and the risk of certain complications, the clinical outcome during postoperative follow-up was not significantly affected.

This study had several limitations. The relatively small study sample size, the retrospective nature of the study, and the fact that it was conducted at a single center may have introduced study bias. This study compared the efficacy of preoperative halo-gravity traction with postoperative halo-femoral traction after posterior spinal release, and a posterior correction was not performed, which should be assessed in further studies. However, this was the first study to systematically analyze and compare the radiographic and clinical outcomes of patients with severe kyphoscoliosis undergoing halo-femoral traction after posterior spinal release with traditional preoperative HGT, which showed that halo-femoral traction after the posterior spinal release was an optimal alternative for this patient cohort.

Conclusions

This retrospective clinical study aimed to compare the efficacy of preoperative halo-gravity traction with postoperative halo-femoral traction after posterior spinal release in corrective surgery for 60 patients with severe kyphoscoliosis. Two patient groups were compared, the postoperative halo-femoral traction after posterior spinal release (R-HF) group and the preoperative halo-gravity traction (HGT) group. Patients with severe kyphoscoliosis who underwent first-stage halo-femoral traction after posterior spinal release and second-stage posterior spinal correction and fusion obtained satisfactory radiographic correction of the deformity with the application of relatively fewer osteotomies. Postoperative halo-femoral traction after posterior spinal release may be considered as an alternative for patients with severe kyphoscoliosis.

Conflict of interest

None.

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