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RESEARCH

Preoperative halo-gravity traction combined with one-stage posterior spinal fusion surgery following for severe rigid scoliosis with pulmonary dysfunction: a cohort study

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Abstract

Background To assess the efficacy of preoperative halo-gravity traction (HGT) in treating severe spinal deformities, evaluating radiological outcomes, pulmonary function, and nutritional status.

Methods This study retrospectively included 33 patients with severe spinal deformity who were admitted to our department from April 2018 to January 2022. All the patients underwent HGT prior to the posterior spinal fusion corrective surgery, with no patients having undergone anterior or posterior release procedures. The correction of deformity, pulmonary function tests (PFTs), and nutritional status data were collected and analyzed before and after HGT.

Results A total of 33 patients (9 males, 24 females) were finally included in this study with an average age of 17.79 ± 7.96 (range 12–29) years. Among them, 20 patients were aged ≤ 16 years. The traction weight started from 1.5 kg and raised to 45.2 ± 13.2% of body weight on average progressively, with the average traction duration of 129 ± 63 days. After traction, the main curve was corrected from an average of 120.66 ± 3.89° to 94.88 ± 3.35°, and to 52.33 ± 22.36° (53%) after surgery(P < 0.05). PFTs also showed a significant increase in FVC%, FEV1%, and MEF% after traction [43.46 ± 14.76% vs. 47.33 ± 16.04%, 41.87 ± 13.68% vs. 45.19 ± 15.57%, and 40.44 ± 15.87% vs. 45.24 ± 17.91%, *p* < 0.05]. Total protein, albumin, and BMI were used as indicators of nutritional status. TP and albumin were significantly improved after traction, from 67.24 ± 5.43 g/L to 70.68 ± 6.98 g/L and 42.40 ± 3.44 g/L 45.72 ± 5.23 g/L, respectively(P < 0.05). No significant difference was found in deformity correction and lung function improvement between patients with traction for more or less than three months (*p* > 0.05). Two patients developed transient brachial plexus palsy during traction.

Conclusions Halo-gravity traction can partially correct spinal deformity, enhance pulmonary function. And HGT has been shown to facilitate an improved nutritional status in these patients. It could be used as a preoperative adjuvant treatment for severe spinal deformity. However, according to the study, a traction period longer than three months may not be necessary.

Keywords Halo-gravity traction, Severe spinal deformity, Pulmonary function, Nutritional status

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Introduction

Severe spinal deformity was defined as a coronal or sagittal deformity characterized by a Cobb angle greater than 90° [1]. Without appropriate treatment, it can lead to curve progression and a decrease in the patient's quality of life, accompanied by cardiopulmonary dysfunction and trunk decompensation [2]. Currently, posterior spine fusion combined with an osteotomy has become the common surgical strategy to treat severe spinal deformity [3, 4]. At the same time, such severe spinal deformities usually combined with high stiffness and require advanced osteotomy to remove deformity factors and improve flexibility. However, neurological deficit often occurs during the release and osteotomy procedure [5]. In addition, such patients often have cardiopulmonary insufficiency, which further increases the risk of surgery and anesthesia [6]. Hence, it is particularly important to perform targeted optimization before surgery in order to improve spinal flexibility and deformity for such patients.

As an effective approach, preoperative traction has been widely used to treat severe spinal deformities [7]. Severe spinal curvatures have traditionally been managed with preoperative Halo spinal traction, including Halo femoral traction (HFT), Halo pelvic traction (HPT), or Halo gravity traction (HGT) [8]. Halo-gravity traction (HGT) is administered in a wheelchair, minimizing prolonged bed rest and enabling patients to engage in daily activities. In recent years, it has been established as a cornerstone in preoperative preparation and essential treatment for severe spinal deformities [9]. While some previous studies have suggested that preoperative Halo gravity traction can effectively correct the curvature of severe spinal deformities and improve patients' pulmonary function, the therapeutic efficacy for severe rigid spinal deformities remains unclear [10, 11]. Moreover, regarding severe spinal deformity, the corrective effect that HGT can achieve as well as the proper traction duration and weight are currently unclear, although Kim et al. [12] indicated that the traction should last more than three months. Meanwhile Caubet suggests that HGT by itself does not improve correction rates or significantly correct severe curves without surgical release [13].

This study aimed to evaluate outcomes of the severe rigid spinal deformity patients who underwent HGT in terms of the corrective outcome, patients' pulmonary function, and nutritional status and to identify the main factors associated with the efficacy of HGT.

Material and methods

Patient selection

A retrospective study was conducted and patients with severe spinal deformity in our institution from April 2019 to January 2021 were consecutively included. All the patients underwent HGT prior to the posterior spinal fusion corrective surgery, with no patients having undergone anterior or posterior release procedures. Inclusion criteria were as follows: (1) severe spinal deformity with the main Cobb angle > 90°; (2) pulmonary function FVC% < 80%; (3) with main curve flexibility < 25% by X-rays after bending. Exclusion criteria were: (1) patients with spinal surgery history before traction; (2) incomplete data on radiography、pulmonary function, and nutrition; (3) patients who could not tolerate HGT. Demographic data of patients was collected, including age, gender, BMI, and deformity etiology. The project was approved by the Beijing Chaoyang hospital Ethics Committee and informed consent was obtained from all patients in the cohort with parental consent also obtained for those under 18 years of age.

Radiographic evaluation

The Picture Archiving and Communication System (PACS) was utilized for radiographic measurements. All enrolled patients underwent full spine X-rays before and after traction, as well as every 4 weeks during the traction process and postoperatively. The duration of traction was determined based on deformity correction observed in monthly full-body radiographs, while considering pulmonary function and nutritional status.

The full spine X-Ray taken at the end of the traction period was used to evaluate the effect of traction on radiographic parameters; All parameters were measured on the communication system (PACS) by two independent spine surgeons, including the main curve Cobb angle, trunk length(T1-S1), coronal and sagittal imbalance(C7PL-CSVL and SVA). We also calculated the flexibility of the main cure:(the Cobb angle of the main curve before traction—the Cobb angle of the main curve in the Bending position) / the Cobb angle of the main curve before traction × 100%); and the deformity correction rate after traction: (the Cobb angle of the main curve before traction-the Cobb angle of the main curve after traction) / the Cobb angle of the main curve before traction × 100%.

Pulmonary function testing

The patients were assessed using a standard ultrasound spirometer in the sitting position (Masterscreen-body/ Diff + IOS + APS, Jaeger, German). Pulmonary Function Testing was measured every 3–6 weeks since the beginning of HGT, with an additional test scheduled prior to cessation of traction. All pulmonary function tests were completed by the same physician with the same equipment, using FVC%, FEV1%, and MEF50% as pulmonary function indicators to evaluate the effect of traction. According to the American Thoracic Society's guidelines for the severity of pulmonary impairment [14]: no pulmonary impairment (FVC %$>$80%); mild (65%$<$FVC%$\leq$80%); moderate (50%$<$FVC$\leq$65%); and severe (FVC$\leq$50%).

According to the severity of pulmonary impairment before traction, the patients were divided into two groups: patients with severe pulmonary function impairment (FVC%$\leq$50%) and patients with mild or moderate pulmonary function impairment (80%$\geq$FVC%$>$50%) [15]. Then we compared their improvement of pulmonary function to assess whether pre-traction pulmonary function could influence the efficacy of HGT.

Scoliosis can lead to deformation of the thoracic cage, resulting in compression of both lungs and impairment of pulmonary function in affected patients. Therefore, based on previous relevant literature and the significance of various pulmonary function parameters, this study selected the assessment of lung volumes using forced vital capacity (FVC), reflecting airway patency with forced expiratory volume in one second (FEV1), and the ventilation function and flow rate of the lungs with maximal expiratory flow at 50% of the FVC (MEF50%).

Nutritional status indicators

Nutritional status was assessed using laboratory results (serum total protein and albumin) and BMI before and after traction [16]. Besides, the patients were separated into two groups: patients with BMI$<$18.5 kg/m2 and patients with BMI$\geq$18.5 kg/m2, depending on the patients' BMI before traction [17]. Nutritional-related variables were compared between two groups after traction.

Halo-gravity traction protocol

According to the previously published literature, all patients underwent HGT surgery under local anesthesia [18]: 3–5 days after the application of the Halo Ring, the traction utilizing wheelchair suspension started when patients were adapted to the traction devices. The initial traction force was 1.5 kg and increased by 3-5 kg every week based on the patient's comorbidities and tolerability. In the end, the final traction force was equal to 40%-50% of the patient's body weight. Traction was applied while in bed, a wheelchair, or standing apparatus for at least 12 h a day, with the weight lessened by 50–75% to prevent proximal migration toward the head of the bed when the patient was sleeping in bed.

During the traction period, the pins were sterilized, and the nerve function was evaluated every day, including cranial nerve exams, strength, and sensation in the upper and lower extremities [19].

If any neurological disorders occurred, traction weight was reduced or removed until symptoms resolved. The duration of traction depended on progressive curve correction, as evidenced by monthly radiographs, while also considering the patient's pulmonary and nutritional status (Fig. 1).

Statistical analysis

All statistical analyses were performed using SPSS statistical software program package (SPSS version 22.0). Deformity correction rate and pulmonary function improvement rate were expressed as percentages; Continuous variables were reported as means ± standard deviations (SD). Continuous variables were first examined for normality, and nonparametric tests such as the Mann- Whitney test for two groups and Kruskal–Wallis test for more than two groups were considered. A paired t-test was used to compare the differences between pre-HGT and post-HGT Cobb angle, pulmonary function, and nutritional status. Figures were generated using GraphPad Prism 8.0(GraphPad Software, LLC).

Result

A total of 33 patients (9 males, 24 females) were finally included in this study with an average age of 17.79 ± 7.96 (range 12–29) years. Among them, 20 patients were aged$\leq$16 years (Table 1). The diagnosises of 33 patients included congenital scoliosis(n=11), idiopathic scoliosis(n=20), neurofibromatosis type I(NF-I) associated scoliosis (n=2). The average height of patients was 139.4 ± 14.9 cm and the initial average BMI was 17.2 ± 3.9 kg/m^2. After traction, the average height was 146.1 ± 13.3 cm, with an average increase of 6.7 ± 5.0 cm ($p<0.05$). Besides, the body weight after

Fig. 1 A patient undergoing Halo-gravity traction with a Halo ring and a wheelchair: the traction rope, traction pulley, and the patient's spine are aligned in a straight line, achieving the traction aim by increasing the weight

Table 1 Paired t-test of Radiographic variables

	Pre-traction	Post-traction	*P-value*
Major Cobb angle (°)	120.7 ± 3.9	94.9 ± 3.4	< 0.05
C7PL-CSVL (mm)	27.3 ± 16.6	24.3 ± 18.2	0.315
SVA (mm)	38.6 ± 24.6	25.6 ± 19.3	< 0.05
AVT (mm)	84.8 ± 35.6	74.4 ± 36.4	< 0.05
T1-S1 length(mm)	253.1 ± 52.9	288.4 ± 60.1	< 0.05

Parameters are presented as mean ± SD. *SVA* sagittal vertical axis, *AVT* Apical Vertebra Translation, *Trunk length* T1-S1 length

traction significantly increased from 33.8 ± 10.0 kg to 38.1 ± 10.1 kg ($p < 0.05$). The patients' BMI after traction was 17.7 ± 3.7 kg/m^2, with an average increase of 0.5 kg/m^2, but no statistically significant difference was observed ($p > 0.05$).

All patients reached their maximum traction weight within four weeks, with an average traction weight of 45.2 ± 13.2% of patient body weight, and the average traction duration was 129 ± 63 days. No patient in our study underwent anterior release surgery before traction.

In this study, patients were divided into two groups according to whether the traction time exceeded three months. We compared the improvement of deformity, lung function, and nutritional status between the two groups. Figure 2 showed the improvement of total protein was better in patients with traction for more than three months ($p < 0.05$). However, there was no difference in deformity and pulmonary function correction between the two groups ($p > 0.05$).

Radiographic evaluation

Before traction, the mean major coronal curvature of patients measured 120.7±3.9°, with average flexibility of 21.4±14.3%. Before traction, the coronal balance (C7PL-CSVL) was mean 27.3±16.6mm, and the sagittal balance (SVA) measured mean 38.6±24.6mm, with an average T1-S1spinal length of 253.1±52.9mm. Table 1 shows the results of the radiographic analyses.

Pulmonary function test

The FVC% of 33 patients improved to an average of 47.3 ± 16.0% after traction ($p < 0.05$). The pre-FEV1% and the pre-MEF% were improved to 45.2 ± 15.6% ($P < 0.05$) and 45.2 ± 17.9% ($P < 0.05$), respectively (Table 2).

In this study, there were 13 patients with mild to moderate pulmonary function impairment (80% ≥ FVC% > 50%) and 20 patients with severe pulmonary function impairment (FVC% ≤ 50%). Comparing the improvement rate of pulmonary function between the two groups, the patients with severe pulmonary function impairment had more significant improvement after traction (d = 16.7 ± 0.6, $p < 0.05$), as shown in Fig. 3.

Table 2 Paired t-test of Pulmonary function and Nutritional status analysis variables

	Pre-traction	Post-traction	*P-value*
Pulmonary function			
FVC%	43.5 ± 14.8	47.3 ± 16.0	< 0.05
FEV1%	41.9 ± 13.7	45.2 ± 15.6	< 0.05
MEF%	40.4 ± 15.9	45.2 ± 17.9	< 0.05
Nutritional status			
TP (g/L)	67.2 ± 5.4	70.7 ± 6.9	< 0.05
ALB (g/L)	42.4 ± 3.4	45.7 ± 5.2	< 0.05
BMI (kg/m2)	17.2 ± 3.9	17.7 ± 3.7	0.323

Parameters are presented as mean ± SD. *TP* Total Protein, *ALB* albumin

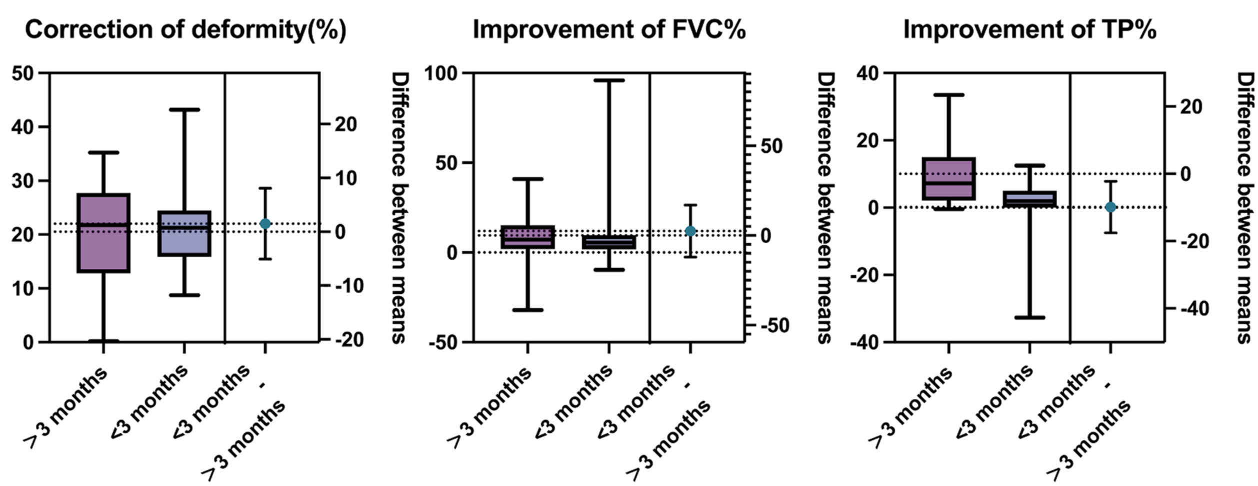

Fig. 2 Comparison of improvement of deformity, FVC% and TP% between patients with traction > 3 months and < 3 months. Unpaired t-test, $P < 0.05$

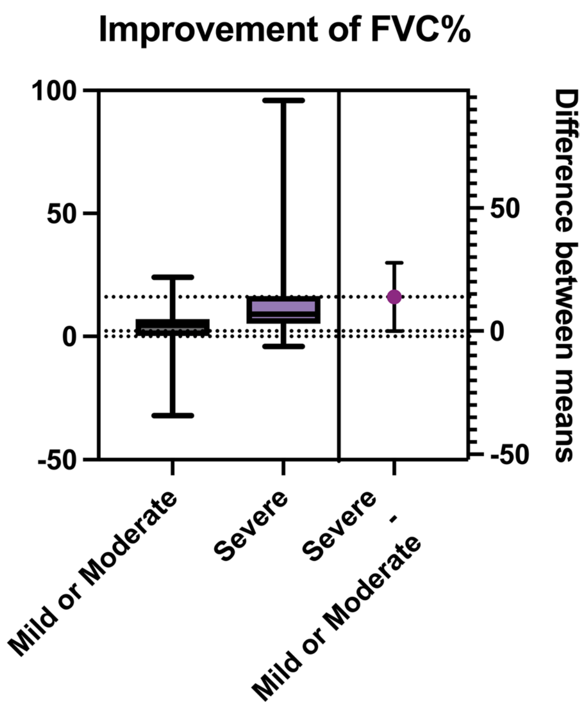

Fig. 3 Comparison of improvement of FVC% between Severe and Mild/Moderate pulmonary function impairment. Unpaired t-test, $P < 0.05$

Nutritional status

We analyzed nutrition-related indicators such as total protein, albumin, and BMI before and after traction. The pre-traction serum total protein was mean 67.2 ± 5.4 g/L, and serum total protein after traction was mean 70.7 ± 6.9 g/L ($p < 0.05$). The pre-traction albumin was mean 42.4 ± 3.4, and the albumin after traction was improved to 45.7 ± 5.2 g/L ($p < 0.05$). Although our study showed that BMI was improved after traction (17.2 ± 3.9 kg/m2 vs. 17.7 ± 3.7 kg/m2), the difference was not statistically significant ($p > 0.05$), as shown in Table 2**.**

Besides, the present study also compared the improvement rate of Total Protein between the patients with BMI > 18.5 kg/m2 and < 18.5 kg/m2 before traction. And the result showed that the patients with BMI < 18.5 kg/m2 had a more significant improvement in TP after traction (d = 9.0 ± 3.8, $p < 0.05$).

Additionally, this study conducted a subgroup analysis of scoliosis etiology, comparing improvements in main curve deformity, pulmonary function, and nutritional status between 11 patients with congenital scoliosis and 20 patients with idiopathic scoliosis. The results indicated that after HGT traction, patients with idiopathic scoliosis showed greater improvement in main curve deformity and pulmonary function compared to those with congenital scoliosis (23% vs. 20%; 9% vs. 4%), while patients with congenital scoliosis showed better improvement in nutritional status compared to those with idiopathic scoliosis (14% vs. 8%). However, these differences were not statistically significant.

Complications

During the course of this study, a total of two patients developed brachial plexus nerve palsy at 3 and 4 weeks of traction, respectively, manifesting as weakness in shoulder abduction. Symptoms resolved gradually upon reducing traction weight with no residual neurological deficits. Daily dressing changes were performed for pin tracts, preventing traction-related complications such as pin tract infections and epidural hematoma in the remaining patients during the traction period.

Discussion

As time and experience have progressed in treating severe spinal deformities, it has become increasingly common to perform correction surgery via posterior-only approaches in recent years [3–5, 20]. However, patients with severe spinal deformity are generally accompanied by severe pulmonary dysfunction and malnutrition. Significant correction and vertebral column resections can lead to neurologic compromise [5]. Therefore, the severe spinal deformity has always been a challenge for spinal surgeons [6, 21]. Halo-gravity traction was first applied by Stagnara [22] to the preoperative adjuvant treatment of severe spinal deformity, aiming to correct the spinal deformity and increase spine flexibility by releasing the soft tissues. For another, the spinal cord's tolerance for potential injury can be developed by gradually increasing the traction weight before surgery, reducing the difficulty of surgery and the incidence of intraoperative neurological complications [23–25].

According to previous studies, compared to other traction methods, HGT does not necessitate prolonged bed rest and is more tolerable by utilizing the patient's body weight as a counterforce. Patients undergoing HGT with the aid of walkers have shown lower incidences of disuse osteoporosis and other traction-related complications [26, 27]. Some previous studies mixed patients who had undergone anterior release surgery prior to traction or were not associated with respiratory impairment, thus interfering with studies of the improvement in lung function of HGT [25, 28]. Therefore, all individuals included in this study were all patients with varying degrees of respiratory impairment, and those who had experienced spinal release surgery before traction were excluded.

Radiographic evaluation

Although previous studies have suggested that HGT can partially correct spinal deformities, the results vary from study to study. Sink et al. [29] found the main curve Cobb angle was restored by 29° in 19 patients after 6–21 weeks' HGT. Watanabe et al. [18] observed a 32° reduction in the main curve. Whereas the study by Koller et al. [28] showed that the main curve angle of 45 patients with HGT was only reduced by an average of 16°, which may be related to the fact that the skeletal development of included patients was relatively mature, thus it was harder to correct the deformity with traction. In this study, after an average of 129 ± 63 days of HGT, the main curve Cobb angle was corrected from 121° to 95°, and it was reduced to 52.33 ± 22.36° ($P < 0.05$) with an average correction rate of 21% and 53%. Grabalad et al.'s study [11] suggest that preoperative halo-gravity traction (HGT) for spinal deformity correction is a gradual and safe process, assessing spinal cord traction tolerance during traction and providing guidance for subsequent fusion surgery. Additionally, the study finds that prolonged and gradual correction effectively reduces the load on pedicle screw fixation systems, thereby lowering associated fixation-related complications. T1-S1 spinal length and Apical Vertebra Translation (AVT) were improved from 253.10 ± 52.97 mm and 84.75 ± 35.64 mm to 288.43 ± 60.06 mm ($P < 0.05$) and 74.40 ± 36.35 mm ($P < 0.05$), respectively. Sagittal balance was improved from 38.58 ± 24.58 mm to 25.56 ± 19.33 mm. Although the coronal balance was corrected from 27.31 ± 16.60 mm to 24.27 ± 18.23 mm, the difference was not statistically significant ($p > 0.05$). With the partial correction of the main curve and AVT, as well as the improvement of coronal and sagittal balance, the patient's thoracic cage was enlarged to a certain extent, partially reducing the compression of the lungs, which provides suitable conditions for the improvement of lung function.

Pulmonary function

Patients with severe spinal deformities are often accompanied by severe restrictive ventilation impairment due to thoracic developmental disorders that affect the function of the intercostal muscles and diaphragm [30, 31]. Redding et al. [32] found that the development of the pulmonary interstitium is generally completed around the age of 10. Therefore, if there is no intervention for severe spinal deformity in adolescence, nearly 5% of patients will develop chronic respiratory failure in adulthood. In addition, some studies have suggested that the lung compliance of patients with a severe spinal deformity is similar to that of patients with respiratory distress syndrome [33, 34]. Therefore, for patients with severe spinal deformity accompanied by pulmonary function impairment, the pulmonary function should be improved to increase the tolerance of surgery and reduce the risk of postoperative respiratory failure.

The study by Koller et al. [28] showed that after an average of 19 days of HGT, the patient's FVC% increased by 7 ± 8%, including some patients who underwent anterior release surgery before traction. Shimizu et al. [35] observed a 10% increase of FVC% after 28.2 ± 14.4 days of HGT. In this study, after an average of 129 ± 63 days of HGT, the pulmonary function of 33 patients was significantly improved, and the FVC%, FEV1%, and MEF50% were enhanced by 12%, 8%, and 12%, respectively. All observed differences were statistically significant ($p < 0.05$). Furthermore, this study analyzed factors influencing the improvement in lung function among patients. Results indicated that lung function improvement rates were lower in patients with larger Risser signs, but higher in those with greater AVT improvement and longer traction duration. This could be attributed to the completion of lung interstitial development around age 10, and nearly complete respiratory system maturation in patients with a more mature skeleton [32]. In addition, the spinal deformity becomes more challenging to correct with a more mature skeleton, which affects the improvement of thoracic volume [36]. According to some previous studies, HGT can partially correct spinal deformity and expand the thoracic volume to some extent, reducing the compression of the lungs and improving ventilation [29, 37]. And this study provides a basis for the above theory.

Nutritional status

Patients with severe spinal deformity will consume more energy than their peers in daily activities due to impaired lung function and reduced blood oxygenation [30]. Besides, poor mobility and lack of necessary exercise also led to low nutritional status and poor surgical tolerance [6]. However, most previous studies indirectly evaluated the nutritional status of patients with severe spinal deformity through BMI instead of plasma protein. The survey of Layer et al. [38] showed that after an average of 97 ± 38 days of HGT, the BMI of 96 patients increased from an average of 17.7 kg/m2 to 19.6 kg/m2. In the present study, the improvement of BMI was not significant ($p > 0.05$), but the total plasma protein and albumin were significantly improved after traction, increasing by 6% and 10%, respectively($p < 0.05$). However, it is worth noting that while there was no significant difference in the improvement of BMI before and after Halo gravity traction, the traction resulted in an increase in both patients' height and weight. Compared with BMI, plasma total protein and albumin were more intuitive and accurate, indicating that HGT can improve the nutritional status of patients with severe spinal deformity but with limiting effects. So other measures are needed to improve the nutritional status before surgery. In addition, the factors that may affect the improvement of nutritional status were analyzed in this study, which showed that the progress of nutritional status after traction was related to the advancement of thoracic volume (AVT) and lung function. This result was consistent with the reasons for the poor nutritional status of patients with severe spinal deformity [6, 30]. However, this does not sufficiently prove whether the improvement in patients' nutritional status is a direct result of HGT or an outcome of the overall treatment received during hospitalization.

Traction duration

Since HGT was used in the clinical treatment of severe spinal deformity, it has remained firmly established about improving deformity, lung function, and nutritional status [39, 40]. The traction duration has always been controversial. Letts et al. [41] believed that most of the correction could be obtained after one week of traction and suggested that the optimal traction duration should not exceed three weeks, which may achieve 96% of the final traction effect. However, some studies [42, 43] believe that only more than six months can get lung function improved significantly. Results of the present study indicate that the improvement of total protein was better in patients with traction for more than three months($p < 0.05$). However, there was no difference in the correction of deformity and pulmonary function between patients with traction for more and less than three months ($p > 0.05$). Shi et al. [44]believed that minimal duration of traction with satisfactory radiographic outcomes was the initial goal of HGT. Therefore, patients may not need to carry out HGT over three months.

Complications

Halo-gravity traction is also associated with potential complications, such as cranial nerve injury and brachial plexus injury [45, 46]. However, current studies believe that this kind of nerve injury is primarily temporary and reversible, of which symptoms can disappear when the traction weight is reduced or the traction is stopped [47, 48]. In addition, patients with diseases such as tethered cord syndrome, Chiari malformation, and congenital atlantoaxial instability should be excluded to avoid nerve damage during traction. In the present study, two patients developed transient brachial plexus injury during traction, and the symptoms resolved when the traction weight was reduced. At the same time, regular disinfection of the traction device is necessary to avoid pin tract or intracranial infection.

Limitation

This study does have several limitations that need to be considered when interpreting the findings: (1) An evident limitation of this study is its retrospective design and small sample size, resulting in incomplete data for some patients, thereby hindering a detailed exploration of the traction effects of HGT, such as deformity correction and improvement in pulmonary function at 4 weeks/8 weeks. Subsequent large-scale prospective studies will be conducted to address this limitation effectively. Based on this study, large-scale prospective studies can be conducted in the future (2) Similar to previous literature, this present study evaluated the included patients with severe spinal deformities of different etiologies. Hence, the improvement effect of HGT on a specific deformity type is still unclear. (3) In addition, due to the small sample size, the effect of age, that is, skeletal maturity, on the traction effect could not be studied.

Conclusion

For severe spinal deformity patients with pulmonary dysfunction, Halo-gravity traction can partially correct the deformity and improve pulmonary function. HGT has been shown to facilitate an improved nutritional status in these patients. So, it can be used as a preoperative adjuvant treatment for severe spinal deformity, but special attention should also be paid to prevent related complications. Moreover, traction for more than three months might not be necessary, according to the present study. It still needs more studies to evaluate its specific traction duration.

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Authors' contributions

J.W. and B.H. wrote the main manuscript text and made a contribution to the analysis of data; #Y.H. guided the research design and revised the manuscript critically; L.Z. prepared the Fig. 1–2; #Y.Z. guided the research design and revised the manuscript critically. All authors reviewed and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study has been approved by the Ethics Committee of Beijing Chaoyang hospital(2022-科-512). All methods were performed in accordance with the relevant guidelines and regulations and written informed consent was obtained from all patients.

Consent for publication

Informed consent to publish was obtained from the participants for publication of the images.

Competing interests
The authors declare no competing interests.

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