


# Impact of Various Weights in the Intraoperative Skull-Skeletal Traction on Correction of Adolescent Idiopathic Scoliosis

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## Abstract

**Study Design:** A retrospective study.

**Objectives:** Intraoperative skull-skeletal traction (ISST) facilitates the surgical scoliosis correction, but it is also associated with neurological risk. The objective of the present study was to investigate the impact of various traction weights on neurophysiological change and curve correction in surgery for adolescent idiopathic scoliosis (AIS).

**Methods:** A retrospective review of a consecutive series of posterior spinal fusions for AIS patients undergoing corrections with the use of ISST by 2 surgeons in one institution was performed. Intraoperative prone, post-traction radiographs were performed on all cases. The cases were divided into 2 groups, high and low traction weights, based on whether the weight used was  $\geq 35\%$  or  $< 35\%$  of body weight. The frequency of neurophysiological changes and the curve correction were compared between the 2 groups.

**Results:** The intraoperative correction magnitudes by ISST were significantly larger in the high ISST group than in the low ISST group ( $35^\circ$  vs  $26^\circ$ ,  $P < .001$ ). Changes in motor-evoked potential (MEP) were more frequently observed in the high ISST group ( $47\%$  vs  $26\%$ ,  $P = .049$ ). A multivariate analysis showed that high ISST was associated with 3 times higher risk of MEP change (95% confidence interval = 1.1-8.0,  $P = .03$ ) and higher final postoperative correction rates ( $68\%$  vs  $60\%$ ,  $P = .001$ ).

**Conclusions:** The high ISST for AIS was associated with increased intraoperative and ultimate curve corrections, and potentially facilitated better final correction. However, the high weight group was associated with an increased frequency of intraoperative MEP changes.

## Keywords

adolescent idiopathic scoliosis, intraoperative traction, weight, correction rates, neurophysiological monitoring, motor-evoked potentials

## Introduction

Intraoperative skull-skeletal traction (ISST) is now a common practice in scoliosis surgery, and many studies have shown its effectiveness.<sup>1-10</sup> It provides curve correction with reduction in vertebral rotation and translation prior to incision,<sup>7</sup> and thereby facilitates exposure and can improve final outcome. Moreover, axial traction in general has been shown to provide useful information on the expected correction pre-operatively.<sup>11-14</sup>

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ISST is associated with potential risk of neurological sequelae, and as such, it requires neurophysiological monitoring.<sup>15</sup> It is therefore important to recognize the optimal traction weight that maximizes its effectiveness while maintaining the safety from neurophysiological standpoint. The relationship between the traction weight utilized in surgery and its effect on intraoperative neuromonitoring and curve correction has not been well understood. As such, the optimal traction weight has not been established.

The aim of this study was to investigate the impact of various traction weights on neurophysiological change and pre-precision curve correction in surgery for adolescent idiopathic scoliosis (AIS) in pediatric patients.

## Materials and Methods

### Study Subjects and Indications for ISST

A retrospective review was carried out on of 121 consecutive patients with AIS surgically treated between 2005 and 2009. All surgeries were performed by 1 of 2 surgeons (SJL or RDZ). Indications for ISST and the traction weight were based on surgeon preference. One surgeon (SJL) used ISST with approximately 50% of the patient's body weight for curves with Cobb angle over 70° or cases with small pedicles (44 patients). The actual weight was determined by rounding to the whole number (lbs). The other surgeon (RDZ) routinely used ISST with 26 lbs of weight (41 patients) on all AIS patients regardless of their body weights. Thirty-six patients did not receive ISST. Approval for this study was given by the institutional review board of the Hospital for Sick Children.

### Operative Procedures

Following the induction of general anesthesia, all patients were treated intraoperatively with both skull and bilateral femoral traction. Gardner-Wells skull tongs were applied to the skull just proximal to the pinna in line with the external auditory meatus, and bilateral smooth traction pins were inserted in the distal femurs, just proximal to the patellae. Patients were positioned prone on the Jackson table and traction was initiated after obtaining baseline motor-evoked potentials (MEPs). MEPs to transcranial electrical stimulation were elicited using the Digitimer D185 (Digitimer, Hertfordshire, England), a commercially available electric stimulator that delivers brief (50- $\mu$ s), high-voltage anodal pulse trains. Lower extremity MEPs were recorded from the left and right abdominal rectus, iliopsoas, adductors, rectus femoris, tibialis anterior, and abductor hallucis muscles. Upper extremity MEPs were recorded bilaterally from the first dorsal interosseous muscles and used for control purposes. The femoral traction was applied according to the surgeons' preferences. Pre-incision 3-foot supine PA radiographs were obtained intraoperatively to analyze the correction. Lateral radiographs were not routinely obtained at this point to decrease the patients' radiation exposure. The traction weight was carefully increased if the surgeon

judged the correction was insufficient. Neurophysiological monitoring was performed throughout the procedure for all patients. MEP was repetitively tested by a neurophysiology technician and amplitude reductions greater than 50% of baseline were considered significant as alarming criteria.<sup>15</sup> Our response to MEP change has been summarized in the previous report<sup>16</sup>; in essence, after all technical issues were ruled out and all anesthetic factors such as mean arterial pressure, oxygenation, and hemoglobin level were optimized, reduction of the traction weight was performed.<sup>15</sup> Posterior spinal fusions with instrumentations were performed for all the cases. The inferior facets were partially removed but no posterior column osteotomies or anterior releases were performed in any of these cases. Comparisons of the preoperative standing films, the intraoperative post traction radiographs, and the postoperative upright radiographs were to analyze and compared between the low and high weight traction groups. All traction and pins were removed at the conclusion of the surgery just prior to discontinuation of the anesthesia.

### Statistical Analysis

Patients' demographic data (age, sex, body weight, and curve type), as well as Cobb angles measured in the preoperative (upright and side bending films) and postoperative radiographs and intraoperative radiographs after ISST, and electrophysiological (EP) monitoring events were recorded. The frequency of neurophysiological changes and the correction rates were compared between the high and low weight groups.

All statistical analyses were carried out using the IBM SPSS Statistics software program Version 19 (SPSS, Inc, Somers, NY). For the comparisons of the parameters between the groups, Student's *t* test or Mann-Whitney's *U* test was used for continuous variables, and the  $\chi^2$  test was used for categorical data. The risk factor analysis was conducted by a multivariate logistic regression analysis. Correlations between the scores were analyzed by calculating the Spearman's rank correlation coefficient  $\rho$ . For all statistical tests, *P* values <.05 were considered to be significant.

## Results

A total of 121 consecutive patients treated surgically for AIS were retrospectively reviewed. Five patients were excluded as the exact weight utilized in the surgery was not documented. Traction weight ranged from 16 to 70 lbs. Traction by 45% to 54% of body weight was used in 16.5% of the patients (*n* = 20), 35% to 44% of body weight was used in 14.9% (*n* = 18), 25% to 34% of body weight was used in 18.2% (*n* = 22), 15% to 24% of body weight was used in 15.7% (*n* = 19), and 14% of body weight was used in 0.8% (*n* = 1). The patients were divided into 2 groups: high ISST group with traction weight  $\geq$ 35% of body weight (38 patients) and low ISST group with traction of <35% of body weight (42 patients). A third group (*n* = 36) of patients undergoing surgery in the same time period as the study groups, that were treated without ISST, were used

**Table 1.** The Demographic Data and the Results of Correction of the Patients According to the Initial Traction Weight<sup>a</sup>.

	ISST		
	High (n = 38)	Low (n = 42)	No ISST (n = 36)
Age (years)	15 (11-18)	14 (11-17)	15 (12-17)
Gender			
Female	74%	69%	92%
Male	26%	31%	8%
Curve type			
Main thoracic	92%	81%	78%
Thoracolumbar/lumbar	8%	19%	22%
Preoperative major curve (°)	77* (44-112)	69 (50-110)	57 (37-75)
Flexibility index	23% (1% to 90%)	29% (0% to 63%)	23% (0% to 70%)
Traction weight (lbs)	48* (26-70)	28 (16-65)	N/A
Traction weight (% body weight)	44%* (35% to 52%)	24% (14% to 34%)	N/A
Operation time (hours)	7.0 (6.0-8.5)	8.4* (6.5-12.5)	5.0 (4.0-8.0)
Post-ISST major curve (°)	42 (15-81)	44 (21-77)	N/A
Correction magnitude (°)	35* (13-59)	26 (8-39)	N/A
% Correction	46%* (15% to 66%)	37% (14% to 62%)	N/A
MEP changes	47%*	26%	0%
SSEP changes	0	0	0
Final Cobb (°)	25 (10-50); n = 34	28 (5-52); n = 46	18 (4-36)
Correction magnitude (°)	51* (26-77)	42 (23-63)	39 (24-71)
% Correction	68%* (43% to 83%)	60% (33% to 90%)	69% (48% to 95%)

Abbreviations: ISST, intraoperative skull-skeletal traction, N/A, not applicable, MEP, motor-evoked potential; SSEP, somatosensory evoked potential.

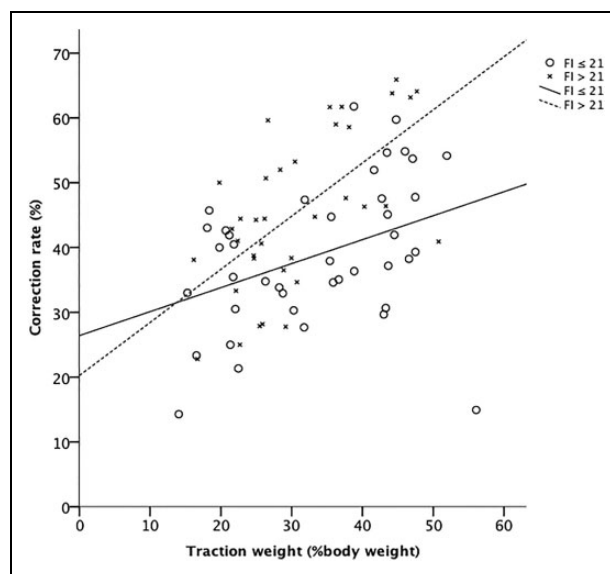
<sup>a</sup>Continuous data are shown as means and ranges.

\*Statistically significant differences between high and low ISST groups.

as a control to the correction techniques used at that time. Patients' demographic data are summarized in Table 1. Preoperative Cobb angle of the major curve was significantly larger in the high ISST group (77°, range 44° to 112°) than the low ISST group (69°, range 50° to 110°,  $P = .007$ ), and the flexibility index (FI: correction rate achieved by side bending) was smaller in the high ISST group (23% vs 29%), but the difference did not reach statistical significance ( $P = .09$ ).

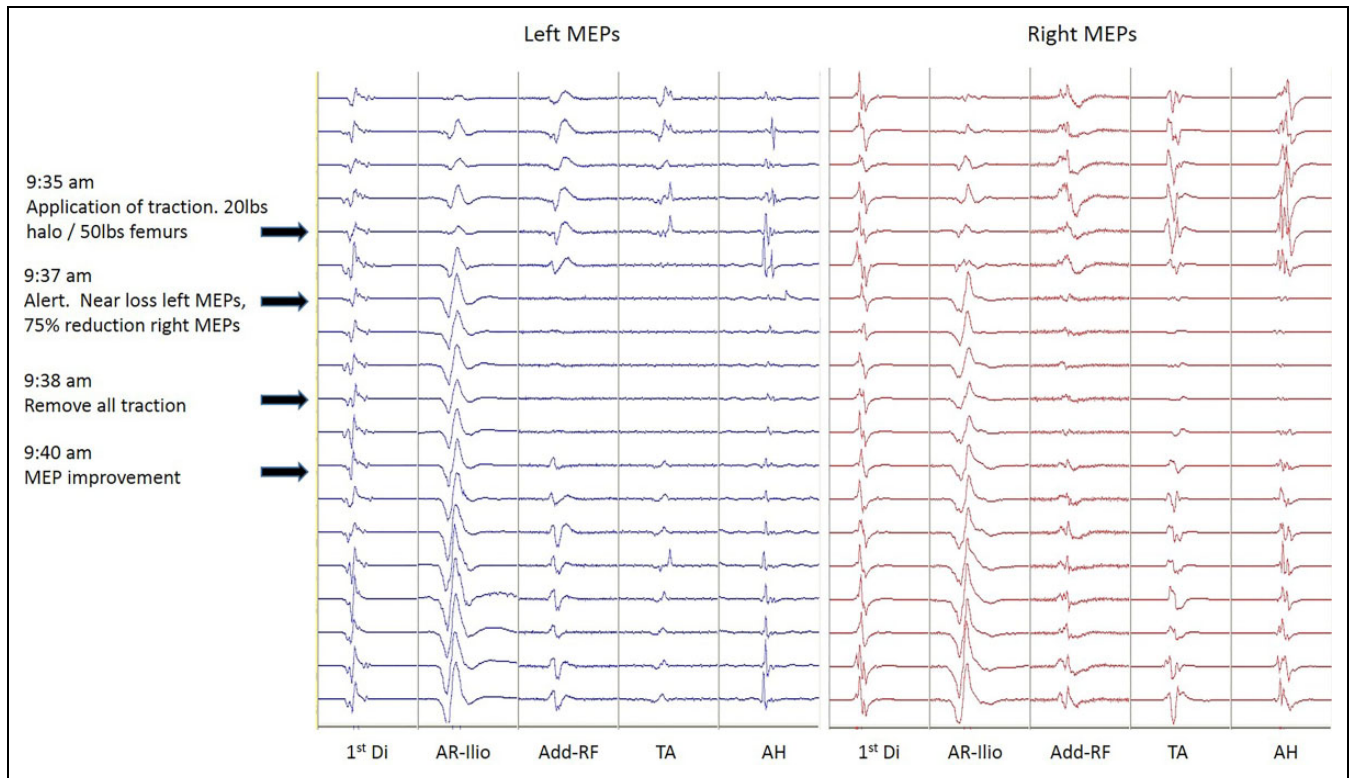
The demographic and radiographic results are summarized in Table 1. Operative time was significantly shorter in high ISST group than in low ISST group (7.0 vs 8.4 hours,  $P < .01$ ). Although Cobb angles after the traction were similar between the 2 groups (42°, high ISST vs 44°, low ISST), the correction magnitudes (35° vs 26°) and the correction rates (46% vs 37%) achieved by ISST were significantly larger in the high ISST group ( $P < .001$  and  $P = .002$ , respectively). The scatter plot depicting the relationship between the correction magnitude and the traction weight (% body weight) is shown in Figure 1. In this figure, the patients were separated into 2 groups based on their flexibility. Bending films were not available in 3 patients. In those with FI < 21% (stiff curve, n = 40), the correlation coefficient  $\rho$  was 0.30 ( $P = .06$ ), whereas in those with FI > 21% (flexible curve, n = 37),  $\rho$  was 0.48 ( $P = .003$ ).

Changes in MEP were recorded in 18 patients in the high ISST group (47%) and compared with 26% in the low ISST group (odds ratio = 2.5; 95% confidence interval = 0.99-6.5,  $P = .049$ ). The timing of MEP change ranged from immediately after the ISST application (5 cases) to 257 minutes later

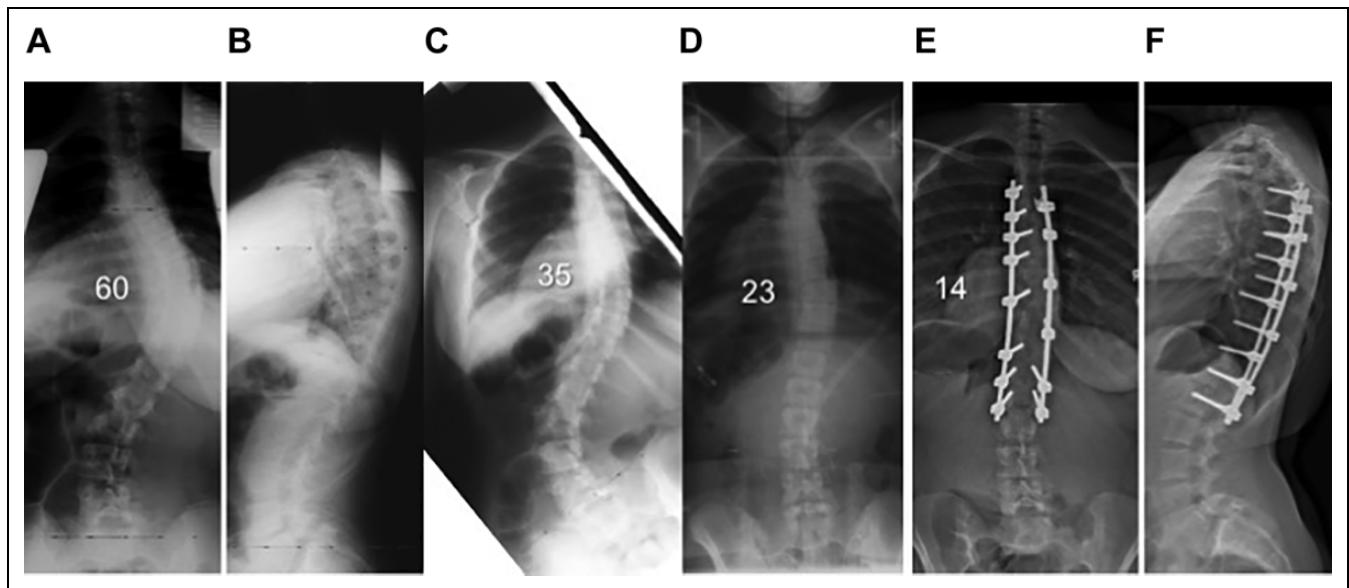


**Figure 1.** Scatter plot showing the relationship between traction weight and post-ISST correction. Two groups are depicted separately according to flexibility index (FI). The solid line shows the fit line for the flexible curves with FI of 21% or less (stiff curve), and the broken line shows the fit line for the stiff curves with FI more than 21% (flexible curve).

(mean = 106 minutes). A multivariate analysis was performed using patients' age, sex, preoperative curve type, Cobb angle of major curve, FI, and high ISST as the independent variables. By the stepwise multiple logistic regression analysis, high ISST



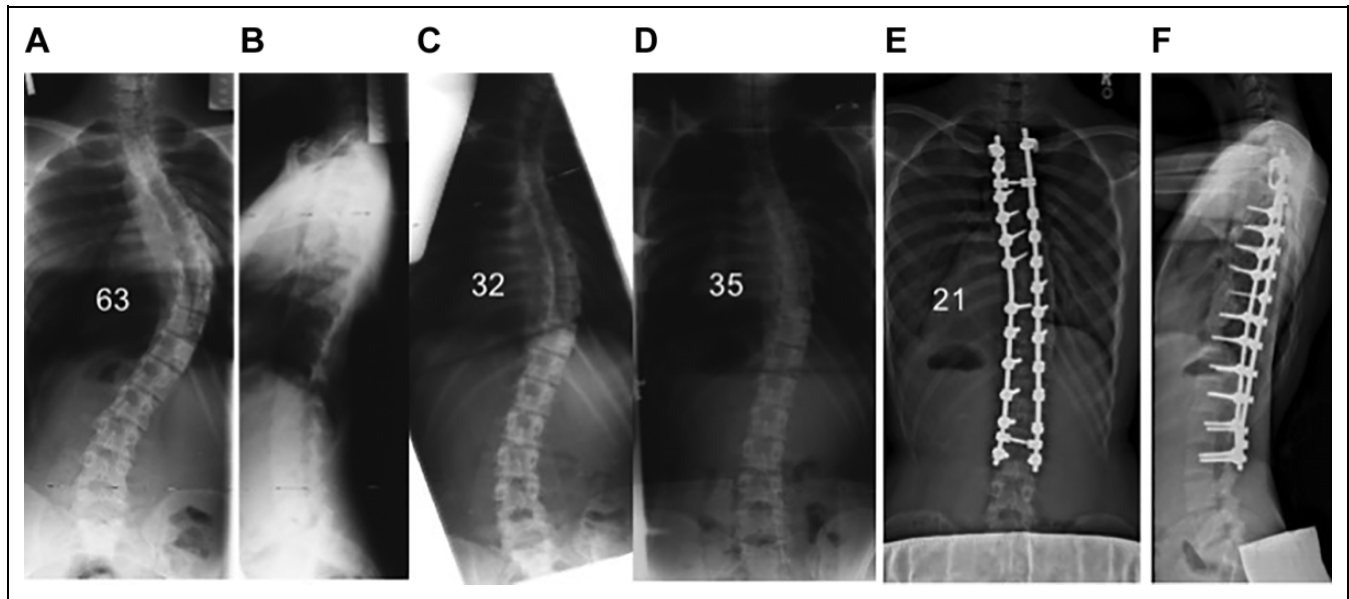
**Figure 2.** A case presentation with its MEP (motor-evoked potential) recordings. Left MEP was almost lost and right MEP reduced to 25% after the application of traction. Both amplitudes recovered after the removal of the weight.



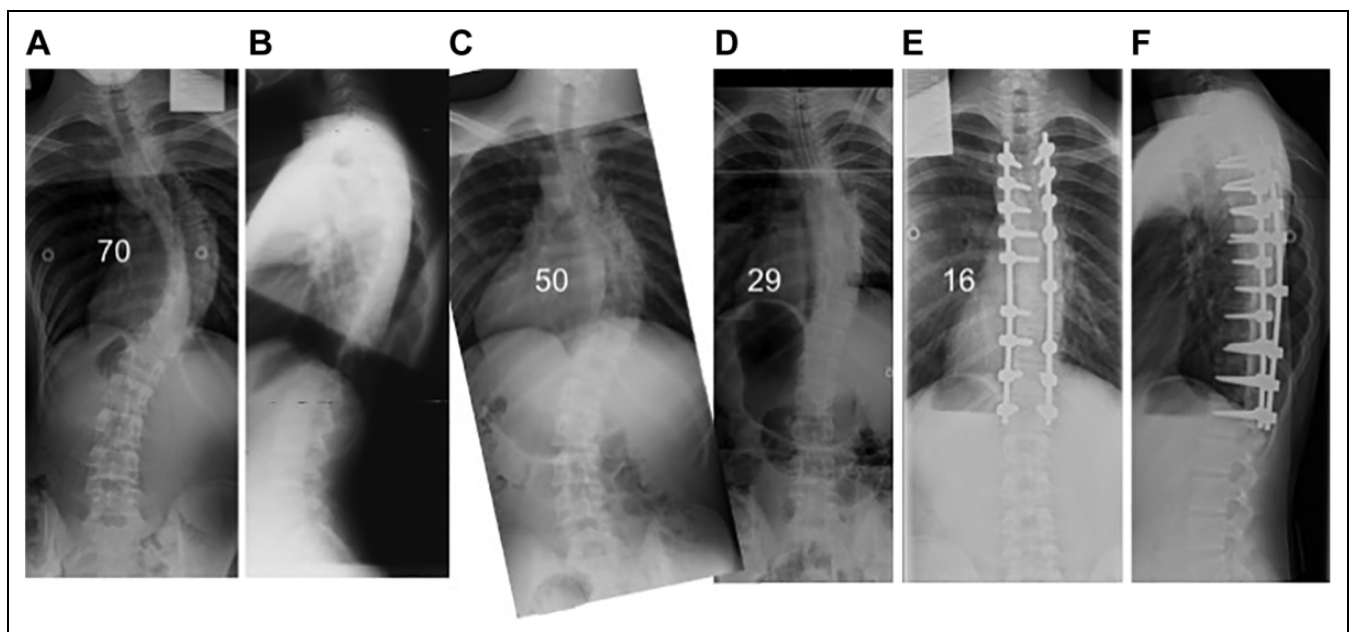
**Figure 3.** Radiographic images of a case of in the high ISST (intraoperative skull-skeletal traction) group. An 18-year-old female patient with adolescent idiopathic scoliosis (AIS; Lenke 1A, flexibility index [FI]: 42%). (A) Preoperative standing AP. (B) Preoperative standing lateral. (C) Side bending film. (D) Intraoperative post-ISST AP; 35% of body weight applied. (E) Postoperative standing AP. (F) Postoperative standing lateral.

was the only variable that remained statistically significant (odds ratio = 3.0; 95% confidence interval = 1.1-8.0;  $P = .03$ ). MEP amplitudes were returned to the baseline with decrease of weight in all cases. A case presentation is shown

in Figure 2. No patient had postoperative neurological deficits. No MEP change was reported in the no ISST group. No changes in the somatosensory evoked potentials (SSEP) occurred in any of the patients.



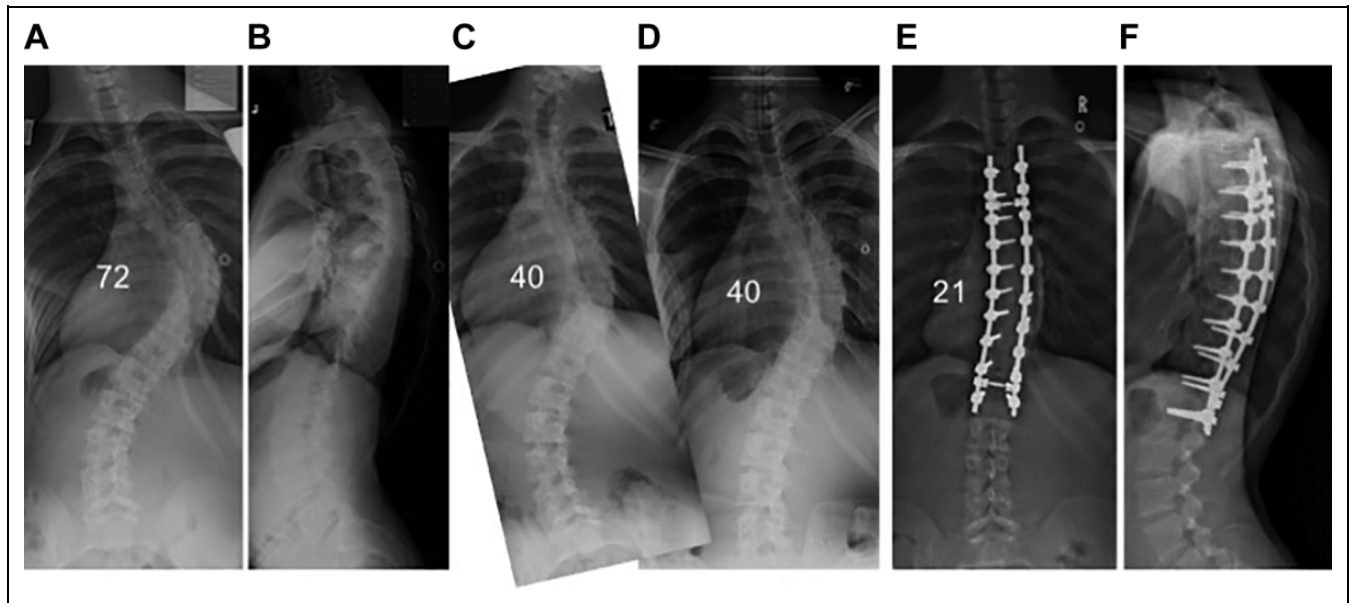
**Figure 4.** Radiographic images of a case of in the low ISST (intraoperative skull-skeletal traction) group. A 17-year-old female patient with adolescent idiopathic scoliosis (AIS; Lenke IA, flexibility index [FI]: 49%). (A) Preoperative standing AP. (B) Preoperative standing lateral. (C) Side bending film. (D) Intraoperative post-ISST AP; 26% of body weight applied. (E) Postoperative standing AP. (F) Postoperative standing lateral.



**Figure 5.** Radiographic images of a case of in the high ISST (intraoperative skull-skeletal traction) group. A 15-year-old male patient with adolescent idiopathic scoliosis (AIS; Lenke IA, flexibility index [FI]: 29%). (A) Preoperative standing AP. (B) Preoperative standing lateral. (C) Side bending film. (D) Intraoperative post-ISST AP; 47% of body weight applied. (E) Postoperative standing AP. (F) Postoperative standing lateral.

After the post-ISST radiographs were obtained, the traction weight was decreased in 13 patients, and was increased in 3 patients. With these adjustments, 34 patients subsequently received the high ISST ( $\geq 35\%$  of body weight), and 46 patients received the low ISST ( $< 35\%$  of body weight). The comparisons of the final radiographic outcomes were made based on this grouping (Table 1). The mean final postoperative Cobb angle of the major curve was

$25^\circ$  in the high ISST group and  $28^\circ$  in the low ISST group ( $P = .14$ ), but the correction magnitudes and the correction rates were larger in the high ISST group ( $51^\circ$  vs  $42^\circ$ ,  $P < .001$ ;  $68\%$  vs  $60\%$ ,  $P = .001$ ). Differences between the effectiveness of ISST with the high and low traction weight for the similar curves (Figure 3 vs Figure 4, and Figure 5 vs Figure 6) are shown in the radiographic images of illustrative cases.



**Figure 6.** Radiographic images of a case of in the low ISST (intraoperative skull-skeletal traction) group. A 17-year-old male patient with adolescent idiopathic scoliosis (AIS; Lenke 1A, flexibility index [FI]: 44%). (A) Preoperative standing AP. (B) Preoperative standing lateral. (C) Side bending film. (D) Intraoperative post-ISST AP; 20% of body weight applied. (E) Postoperative standing AP. (F) Postoperative standing lateral.

## Discussion

There were 4 major findings in the present study. First, the ISST with high traction weight was associated with increased risk of MEP change. Second, the ISST with high traction weight resulted in larger intraoperative correction. Third, the MEP changes reverted to baseline with decreasing the traction weight. Last, SSEP was not effective in detecting the neuromonitoring changes seen with the MEP, suggesting anterior ischemia as the main cause of the intraoperative loss in signal. Postoperative final correction was greater in the high weight group; however, technical factors and correction maneuvers may have contributed to this difference.

High ISST was associated with 3 times increased risk of intraoperative MEP change compared with the low ISST. Neurological complication caused by the axial traction for scoliosis has been well described.<sup>17,18</sup> It is believed that the corrective forces can stretch the vascular structures of spinal cord and thereby interfere with blood supply making the spinal motor system vulnerable to ischemic insult.<sup>19</sup> MEP is especially sensitive to spinal cord ischemia. Lewis et al reported that thoracic curve, increasing Cobb angle, and rigidity of major curve are risk factors for MEP changes,<sup>15</sup> but the impact of traction weight has not been previously investigated. In the present study population, the traction weight was the only risk factor among these variables. The high ISST group had greater preoperative curve magnitude and lower flexibility, which may have made them more vulnerable to MEP changes. Furthermore, the group treated without traction did not have any intraoperative MEP changes, further supporting the impact of the traction on the MEP changes. It is of note that all MEP changes were reversed with decreasing the traction weight. Close neurophysiological monitoring with frequent testing of the MEP is essential to detect potential neurological complications when utilizing intraoperative traction for AIS cases.

The relationship between traction load and distraction was reported with viscoelastic property of the spine back in 1975.<sup>20</sup> However, the impact of ISST on scoliosis differs in that this distraction is applied under general anesthesia, and the short-term correction analyzed by intraoperative radiograph is mostly achieved by the elastic property of the spine. Considering this elastic property, we hypothesized 2 parameters will affect the correction rates in theory: traction weight and the curve flexibility. In the present study, the high ISST was associated with significantly better correction, and the scatter plot showed its effectiveness was larger for the flexible curves. In terms of the final correction, good corrections were achieved in all groups without anterior releases or posterior column osteotomies. The postoperative results were dependent on other correction maneuvers (eg, rod rotation, translation, in situ bending, and compression/distraction) that were chosen according to surgeon's preference, and thus we cannot conclude that the high ISST will result in better final corrections. However, we speculate that better correction by ISST might have made the other operative corrective maneuvers technically easier and safer. Furthermore, the use of the traction did not interfere with the ability to perform other correction maneuvers.

There are some limitations in the present study. First, the study design was retrospective and the 2 groups compared were not equivalent. Prospective randomized controlled study will be warranted. Second, the impact of ISST on sagittal parameters was not investigated because intraoperative lateral whole spine radiographs were not routinely obtained. The high ISST may be theoretically associated with the risk of flattening (thoracic hypokyphosis), although Mac-Thiong et al have reported the postoperative thoracic kyphosis was not decreased with the use of ISST.<sup>1</sup> Third, in our database, the amount of blood loss was not recorded. Massive blood loss and associated



decreased hemoglobin level could potentially cause MEP changes, although we did not experience such uncontrollable intraoperative bleeding. Finally, the effectiveness of ISST on the final outcome remains to be clarified. The correction by ISST has potential benefits for easier exposure, pedicle screw insertions in the apical vertebrae, and rod application, but all of these are only subjectively noticed by the surgeons and not yet proven to be directly associated with better final outcome excluding the surgeon's factor. The group without traction had smaller curves and do not represent a direct control to the other groups, but help control for the surgical technique utilized in the correction of the AIS curves. Techniques to improve the flexibility of the spine (posterior column osteotomies, anterior releases) were not utilized in this series.

In conclusion, the high weight ISST for AIS was associated with increased intraoperative and ultimate curve corrections. However, the high weight was associated with an increased frequency of intraoperative MEP alerts that reversed with decreasing or removing the traction weight. These alerts were not associated with any changes in the SSEP. Accurate intraoperative neuromonitoring with MEPs is mandatory if employing intraoperative skull-skeletal traction.


### Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: SL reports personal fees from Stryker, personal fees from Medtronic, personal fees from AOSpine, personal fees from Depuy, personal fees from L&K, outside the submitted work. RZ reports grants from SPINEVISION, outside the submitted work.

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