Eur Spine J (2009) 18:352–356
DOI 10.1007/s00586-008-0852-1

ORIGINAL ARTICLE

The effect of intra-operative skeletal (skull femoral) traction on apical vertebral rotation

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Received: 6 June 2008 / Revised: 2 October 2008 / Accepted: 3 December 2008 / Published online: 24 December 2008

Abstract The study design is a retrospective review of consecutive case series. Our goal was to identify and quantify the effect of skeletal traction on the apical vertebral rotation (AVR). Intra-operative skeletal traction has been used for the correction of large magnitude idiopathic and neuromuscular scoliosis. The ability of skeletal traction to correct the rotational deformity of the spine has not been characterized. Following REB approval, retrospective analysis of 22 (AIS = 14, neuromuscular = 8) consecutive pediatric patients having surgical posterior instrumented correction and fusion for their scoliosis was performed. Intra-operative skeletal traction with approximately 50% body weight was achieved with smooth distal femoral pins. Counter-traction up to 25% was used through Gardner–Wells tongs. The AVR of the major curve was assessed using the Nash–Moe grading system by a radiologist and a senior spine surgeon not involved in the treatment of these cases. Statistical analysis was performed to determine the significance. The overall mean AVR of the major structural curve was 3.1 ± 0.8 and reduced to 2.4 ± 0.6 ($p = 0.0001$) following traction. The AVR decreased by one or more Nash–Moe grades with traction in 14/22 (64%) patients. The Cobb angle corrected from a mean of 88.2° to 49.1° (44.3%, $p = 0.00001$) with traction. The decrease in AVR correlated with the higher magnitude Cobb angles (correlation 0.53, $p = 0.014$). Patients with pre-traction AVR ≥ 3 showed the largest change with traction (3.4–2.5, $p = 0.000004$). There was very good association between the radiologist and the spine surgeon, 0.72(standing films) and 0.63(traction films). The minor structural curve corrected from a mean Cobb of 53.5° to 33.8° (37.8%) with AVR decreasing from a mean of 1.9 to 1.4 ($p = 0.014$). Significant apical derotation occurs with the use of intra-operative skull-skeletal traction in the correction of high magnitude scoliotic curves. This derotation can facilitate spinal exposure, placement of pedicles screws and final correction in these patients.

Keywords Apical vertebral rotation · Traction · Scoliosis · Intra-operative

Introduction

Scoliosis is primarily a torsional deformity of the spine. Nash, Moe and Perdriolle, used the pedicle as a reference point to describe the rotation of the apical vertebra of the scoliotic curve [1]. The Nash and Moe classification has been well described and proven to be reliable in defining apical vertebral rotation (AVR) [2]. Others have described the use of ultrasound, CT and MRI to define the rotational profile of the scoliotic curve [2–6]. The identification of vertebral rotation has become more important with the increasing use of pedicle screw fixation and derotation maneuvers in the surgical management of scoliosis.

Halo-femoral traction has been reported in the literature since 1955, for maintaining intra-operative correction obtained over a long period of sitting or supine traction [7]. The use of intra-operative skeletal traction for the correction of adolescent and neuromuscular scoliosis has been recently described showing excellent correction of the scoliosis with this technique [8]. White and Panjabi have

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proved biomechanically that curves greater than 57° correct better with axial traction as compared to translational maneuvers [9]. It is accepted that traction can decrease the Cobb angle in scoliosis. However, the ability of traction to correct the rotational deformity of the spine has not been characterized.

The authors routinely use intra-operative skull-skeletal traction to facilitate correction in high magnitude scoliotic curves. Our aim was to identify the magnitude of rotational correction obtained with intra-operative skull-skeletal traction.

Materials and methods

Following institutional REB approval, a retrospective review of 22 consecutive patients undergoing surgical correction of their scoliosis with intra operative skull-skeletal traction was performed. 14 patients with adolescent idiopathic scolioisis (AIS) and eight with neuromuscular scoliosis (NMS), having large magnitude (>70°) or inflexible (<15% flexibility index) curves were identified. All surgeries were performed by the senior author (SJL). Following general anaesthesia, Gardiner–Wells tongs were applied to the skull, and bilateral smooth distal femoral traction pins were placed bilaterally (AIS) or unilaterally (NMS with pelvic obliquity). Traction with approximately 50% of body weight was applied through the limbs and 20–25% of body weight was applied through the skull as counter-traction. All patients were monitored throughout the case with motor evoked potentials and somatosensory evoked potentials. Reductions in the weight of traction were made if changes in the neuromonitoring occurred. 3 foot AP and lateral radiographs were performed standing (AIS) or sitting (NMS) pre-operatively. Pre-incision 3 foot PA radiographs with the patient in traction under general anaesthesia were performed in the operating room to determine corrections. Cobb angles were measured and AIS curves were classified according to the Lenke classification [10]. The AVR of the major and minor curves, as characterized by the Nash–Moe classification system, was independently analyzed by a senior spine surgeon (RZ) not associated with the treatment of these patients, and a radiologist (SM) [2]. Results were tabulated and statistical analysis was performed to determine significance. Paired *t* tests were used to compare the AVR on the pre-operative upright films to the intra-operative traction film. Independent *t* tests were used to compare the results of the AIS patients to those of the NMS. Intra-class correlation was used to compare the measurements of the spine surgeon and the radiologist. Because of the high correlation between the spine surgeon and the radiologist, the statistics were performed based on the readings of the senior spine surgeon.

Results

Cobb angles improved from a mean pre-operative of 88.2° (55°–132°) to 49.1° (27°–87°) with traction (44.3%, $p = 0.00001$). Final Cobb angles were 35.7°. The mean AVR, as measured using the Nash–Moe scale was 3.1 (range 2–4) pre-operatively for the major structural curve. This corrected to a mean of 2.4 with intra-operative traction ($p = 0.0001$). The AVR corrected by one or more Nash–Moe grades with traction in 14 out of 22 patients (64%). It was difficult to reliably measure the AVR in the post-operative films due to the presence of pedicle screws in the apical vertebrae. Statistical analysis revealed that the reduction in the AVR correlated very well with the higher magnitude Cobb angles (correlation 0.53, $p = 0.014$). Patients with pre-operative AVR of ≥ 3 showed the greatest change with traction, mean pre-operative of 3.4 reduced to a mean post traction of 2.5 ($p = 0.000001$). Inter observer reliability tests revealed very good association between the spine surgeon as well as the radiologist, results being 0.72 for the standing films and 0.63 for the traction films (Figs. 1, 2, 3).

Statistically significant decreases in AVR were noted in both the AIS and NMS patients. In the AIS group ($n = 14$), the AVR improved from 2.9 ± 0.8 to 2.2 ± 0.4 with traction. The NMS patients ($n = 8$) had decreases of AVR from 3.5 ± 0.5 to 2.6 ± 0.9, following application of the skeletal traction. The pre-operative AVR in the AIS group was statistically less than the NMS group (2.9 vs. 3.5, $p = 0.05$). The post traction AVR, however, was similar between the two groups (2.2 vs. 2.6, $p = 0.16$).

In the AIS patients, the minor structural curve improved from a mean preoperative value of 53.5° to 33.8° (37.8%) with traction and correspondingly, the AVR improved from 1.9 to 1.4 ($p = 0.014$) in these curves. There were no post-operative neurologic deficits in either group (Table 1).

Discussion

Nash and Moe have been credited with the evolution of the three dimensional concept of the scoliotic spine and they used the pedicle as a reference point to measure the degree of rotation of the apical vertebrae [2]. Kuklo et al. [11] showed good intraobserver reliability before surgery (0.74–0.85) using Nash and Moe technique for measuring the AVR, but only fair reliability after surgery (0.50–0.85) because of the presence of instrumentation. They showed fair to poor (0.53–0.59) interobserver reliability for apical Nash–Moe rotation. However, in our series, we have been able to produce good to excellent inter observer reliability (0.72 for the standing films as well as 0.63 for the traction films) in the pre-operative and intra-operative radiographs, due to the absence of instrumentation.

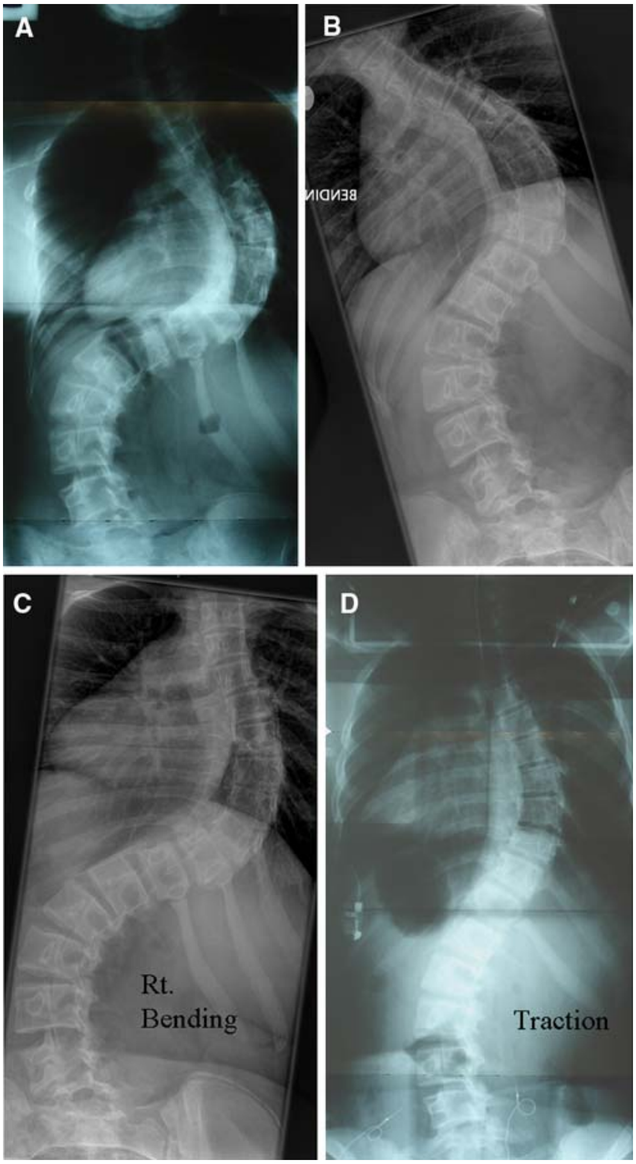

Fig. 1 **a** Patient #4—Standing AP (thoracic curve: 89°; lumbar: 82°). **b** Left bender (thoracic curve: 106°; lumbar curve: 60°). **c** Right Bender (thoracic curve: 80°; lumbar curve: 76°). **d** Intra-op traction film of Lenke 3C curve (thoracic curve: 47°; lumbar curve: 45°)

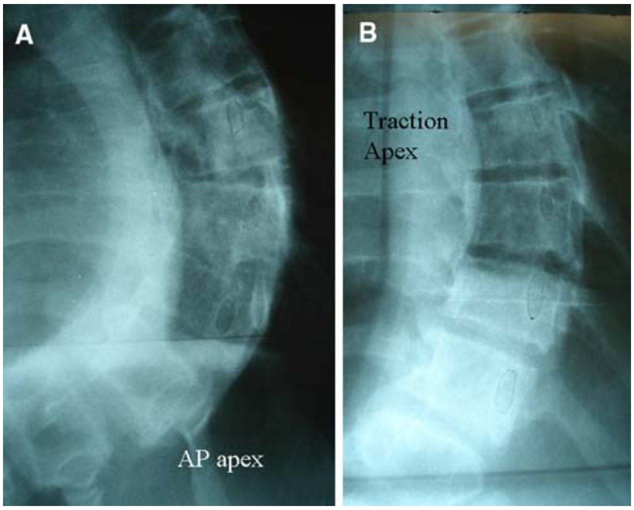

Fig. 2 Close-ups of apex of the thoracic curve. **a** Standing AP. **b** Intra-op traction film. Pedicle in middle segment (Nash–Moe 3) in (**a**) and pedicle migrating to second segment (Nash–Moe 2) in (**b**)

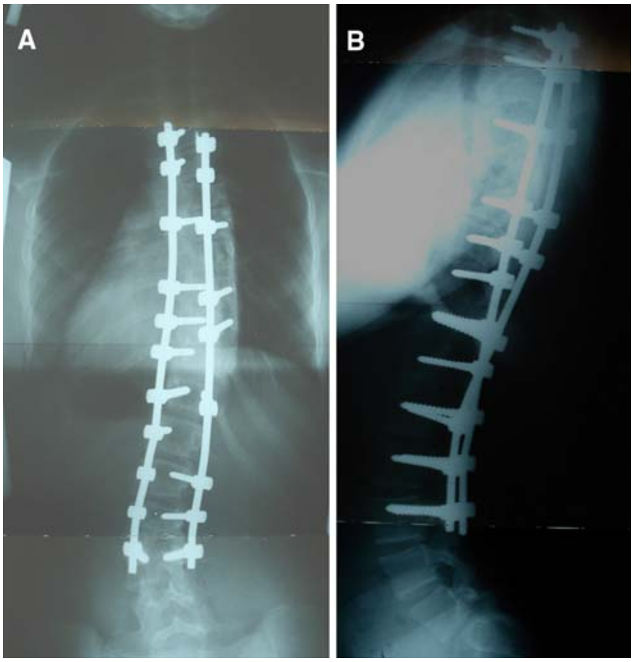

Fig. 3 Final construct: **a** standing AP, **b** lateral view

To date, the Nash–Moe grading scale remains the gold standard and has been recommended for routine use by all deformity surgeons, by the Scoliosis Research Society [12]. While CT scan would be the gold standard for assessment of the apical vertebral rotation, it requires a high level of exposure to ionizing radiation and higher cost [13]. It would be impractical in this setting with the need for intra-operative imaging. Perdriolle and Vidal [14] chronicled the three dimensional evolution of the morphology of the scoliotic spine, observing 221 patients with untreated idiopathic thoracic and thoracolumbar scoliosis from the first months of life to maturity. They also developed the scoliosis torsion meter for assessment of the AVR on coronal radiographs [1]. The assessment of vertebral rotation assumes significant importance based on the fact that correction of the scoliotic curve requires physiological realignment of the spine in all three dimensions. Newer pedicle screw based instrumentation systems have been developed which claim three-dimensional correction of the spine, using global as well as segmental vertebral derotation techniques [15]. Also, in order to be able to instrument these rotated pedicles, the surgeon must be aware of the

Table 1 Patient characteristics, Cobb angles and AVR data

No.	Sex	Age (y + m)	Dx	Spine surgeon				Radiologist	
				Cobb Pre	Cobb Trac.	AVR Pre	AVR Trac.	AVR Pre	AVR Trac.
1	F	16 + 11	AIS	70	39	2	2	2	2
2	M	13 + 5	AIS	59	44	2	2	2	2
3	M	14 + 11	AIS	93	66	4	3	4	3
4	F	12 + 7	AIS	89	47	3	2	3	2
5	F	11 + 10	AIS	90	33	4	3	3	3
6	F	12 + 3	AIS	107	57	2	2	2	2
7	F	12 + 10	AIS	103	52	3	2	3	2
8	F	17 + 11	AIS	55	29	3	2	3	2
9	F	14 + 9	AIS	85	46	3	3	3	2
10	F	13 + 0	AIS	78	27	2	2	2	2
11	F	15 + 10	AIS	77	35	3	2	3	2
12	M	15 + 9	AIS	88	74	4	4	3	3
13	F	14 + 8	AIS	95	59	3	2	3	2
14	F	15 + 3	AIS	74	36	2	2	3	2
15	M	17 + 10	N/M	101	87	4	3	4	4
16	M	17 + 11	N/M	72	50	3	2	2	2
17	F	13 + 8	N/M	110	47	3	2	4	3
18	M	14 + 4	N/M	88	38	3	3	4	3
19	F	12 + 9	N/M	70	32	3	2	2	1
20	M	11 + 4	N/M	105	49	4	2	4	2
21	M	16 + 11	N/M	99	65	4	3	4	3
22	M	16 + 8	N/M	132	69	4	2	4	3
				88.2	49.1	3.1 ± 0.8	2.4 ± 0.6	3.1 ± 0.8	2.4 ± 0.7

rotational profile of the vertebrae, more so at the apex. Also, it has been suggested that reduced AVR may be a marker for occult intrathecal abnormalities [16].

Statistical analyses examining the relation between axial rotation and Cobb angles were performed by Villemure and Labelle [17], and have revealed that vertebral wedging and axial rotation increase with curve progression in the thoracic spine. This was very well reflected in our study. We were able to identify good correlation between the reduction in the AVR and the higher magnitude Cobb angles (correlation 0.53, $p = 0.014$).

Overall mean AVR correction from pre-operative grade of 3.1 to intra-operative grade of 2.4 (22.6%) and 3.4–2.5 (28.6%) in the high AVR curves (3 or 4). Spontaneous correction of the apical vertebral rotation due to change of posture from standing to supine has been reported by Yazici et al. [13]. However, the Cobb angles reported in their study ranged from 35° to 102°, with a mean of 55.7°, with no report on the degree of flexibility. Our study had much larger curves, with Cobb angles ranging from 59° to 132°, with a mean of 88.2°. However, the authors do acknowledge the possibility of some degree of postural correction in the Cobb angles as well as the apical vertebral rotation in the supine position. We noted a mean of 44% correction in the Cobb angle with traction, a magnitude greater than would be expected by the postural change alone.

Patients with a pre-operative AVR of ≥3 grades showed the greatest change with traction. In this subset of patients, the mean preoperative grade of 3.4 was reduced to a mean post traction grade of 2.5 ($p = 0.000001$). This finding was however, in contradiction to previous findings by Tredwell et al. [18]. They utilized intra-operative stereophotogrammetry to analyze helical motion during the correction of scoliosis. They found the maximum correction of rotation occurred at the top and bottom vertebrae, whereas the apical vertebra rotated the least in the structural curve. However, we found major improvements in the apical vertebral rotation using our technique of intra-operative skeletal traction.

In our series, the cases with AVR of 2 stayed the same with the exception of one reading. While we felt all cases derotated with traction, the degree of change in rotation of cases with an AVR of 2 was not detectable using the

Nash–Moe system. This is either because the derotation was minimal or because the Nash–Moe classification is not adequately sensitive to detect changes less than a full grade. Consequently, smaller magnitudes of derotation could not be quantified in our data.

We found multiple advantages using intra-operative traction in the operative technique [8]. The correction of the deformity obtained by traction facilitated the exposure and the instrumentation, especially the pedicle screw insertion. Operating on a corrected deformity facilitated rod insertion and minimized the need for multiple techniques of deformity correction. These benefits are difficult to quantify.

Conclusion

The study demonstrated that significant apical vertebral derotation occurs with intra-operative skeletal traction in the correction of high magnitude scoliotic curves. The derotation obtained may facilitate the technical challenges such as spinal exposure, placement of pedicle screws and final correction in these patients. The Nash–Moe method of apical vertebral rotation grading showed very good inter observer reliability in our study that recorded changes on the radiographs without instrumentation. We found the Nash–Moe grading system to be reliable in detecting rotational changes in the higher rotated curves (AVR $\geq$3).

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