Drooping of Apical Convex Rib-vertebral Angle in Adolescent Idiopathic Scoliosis of More Than 40 Degrees

A Prognostic Factor for Progression

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Study Design: It is a retrospective analysis on radiograms of 113 adolescent idiopathic scoliosis (AIS) patients with a curve of 40 degrees or more at the time of presentation.

Objectives: Our aim was to find out the prognostic factor for the curve progression for this group.

Summary and Background: There is general consensus in favor of operation when the curve is more than 40 degrees for AIS. There are number of reports on the prognostic and etiologic factors for the progression of scoliosis. Rib-vertebral angle (RVA) became a topic of interest regarding the progression of scoliosis for many researchers since Mehta introduced it in 1972.

Methods: There were 113 AIS patients (95 females and 18 males) who had a curve of more than 40 degrees at the time of presentation, with an average age of 12 years and 10 months. We measured RVA on the convex and concave sides at the apex and 12th vertebrae and measured rib-vertebral angle difference (RVAD) using Mehta's method at each follow-up. We also measured the drooping value of the convex rib after bracing and at final follow-up.

Results: Of the 113 patients, 84 responded to bracing and in 29 the curve progressed despite bracing at final follow-up. The average drooping of rib at the apex on the convex side was 11 degrees, which progressed compared with 0.12 degrees in those who responded to treatment. On analyzing the results we could not find any relationship in 12th vertebrae but there was a significant relationship between the drooping value of convex apical rib (RVA Cx) after bracing and curve progression, which is similar to RVAD. There was no relationship between curve progression and initial angle, age, Risser sign, or menarchal status at presentation.

Conclusions: From our study, we conclude that a large number of curves can be treated with bracing; however, when we notice drooping of the convex apical rib along with RVAD, the curve will likely progress.

Key Words: adolescent idiopathic scoliosis, curve more than 40 degrees, bracing, drooping of convex RVA and RVAD, curve progression

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The nonoperative treatment for adolescent idiopathic scoliosis (AIS) using a brace was first suggested by Blount and Moe.[1] Since then there has been a number of reports regarding the conservative treatment of AIS[2–6] and each report states a different point about the indications of treatment. Lonstein and Winter[7] demonstrated that the Milwaukee brace was effective in halting the progression of the curve in their series of 1020 patients. The general consensus on the conservative method is in favor of operation when the curve is more than 40 degrees. Many authors recommend an observation below 20 to 25 degrees of the curve, bracing between 25 to 40 degrees of curve, and surgical correction at more than 40 degrees of curve in AIS.[2,3,7–9] There are a number of reports on the prognostic and etiologic factors[8,10–12] for the progression of scoliosis, like severity of initial curve,[2,8] age, family history, skeletal maturity,[9] Risser sign,[3] vertebral rotation,[13] and RVA, etc., in the literature explaining why the curve progresses beyond 40 degrees even with bracing.

Since Mehta[14] introduced the measurement of rib-vertebral angle (RVA) in 1972, it has become a topic of interest regarding the progression of scoliosis for many researchers.[12,14,15] In their opinion, at a larger curve the rib starts drooping and becomes more oblique so that the correctional force of the brace cannot be transferred to the vertebral body. In our practice, most of the patients with a curve of 40 to 50 degrees look cosmetically acceptable and the pelvis and shoulder of such patients are well balanced. These findings made us reluctant to choose the operative option for such patients; rather we refer them for bracing treatment. Many such patients exhibited arrest of progression of the scoliosis curve with

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bracing and few demonstrated partial correction of curve maintained even after full maturity. These findings led us to a novel idea that patients who have a more horizontal apical RVA on the convex side, perpendicular to vertebral body, often respond to nonoperative treatment even with an initial curve more than 40 degrees.

On the basis of these findings, we retrospectively analyzed RVAs on radiograms of 113 patients with AIS, who had a curve of more than 40 degrees and were treated conservatively with bracing. We compared our findings with those of patients of AIS with curves of more than 40 degrees in whom bracing was not successful and they ultimately underwent operation. The purpose of our study was to determine the difference in RVA between a controlled and a progressed group from conservatively treated AIS patients and also to recognize the patients who will succeed with conservative treatment on presentation having a curve more than 40 degrees.

MATERIALS AND METHODS

We have performed retrospective analyses of 113 AIS patients with an average age of 12 years and 10 months (range: 10 y, 2 mo to 15 y) who presented to our outpatient clinic between 1998 and 2005. There were 95 female and 18 male patients in our study. Radiograms were taken for all patients in standing position before and during bracing and at final follow-up. Patients with AIS were selected for study if the following criteria were met: (1) the curve was a primary thoracic or thoraco-lumbar curve; (2) patients with double curves in whom the major curve was the thoracic curve; (3) the Cobb angle of curve was 40 degrees or more before bracing; (4) patients who had not received any earlier treatment; and (5) patients who were regular in their follow-up. We followed patients till the Risser stage 4 or 5, that is, skeletal maturity.

We treated all patients with a curve of 40 degrees or more with thoracolumbosacral orthotics brace. We measured Cobb's angle, pelvic obliquity, and Risser staging at each follow-up. Our criteria for discontinuation of brace were full maturity and Risser staging of 4 or 5. From our clinical records and stored radiograms of all follow-ups, rib-vertebral angle on concave (RVA Cv) and convex (RVA Cx) sides and rib-vertebral angle difference (RVAD) were measured using Mehta's RVA method[14] at both apex and 12th vertebrae. From these measurements we calculated the drooping value of RVA on convex side at the apex after the application of the brace in patients and at final follow-up for all patients. Therefore, we could derive a formula for the drooping value of RVA Cx as follows: dropping value = RVA Cx before bracing − RVA Cx at final follow-up.

We divided the patients in 2 groups: group A whose curve remained under control with bracing and group B whose curve progressed despite bracing and/or eventually underwent surgery. We analyzed the significance of the drooping value in RVA Cx at prebracing, postbracing, and at final follow-up using the analysis of variance test. We have also analyzed the RVA on both concave and convex sides for all the patients along with RVAD. Statistically, we compared the prebracing and final follow-up of Cobb's angle using paired t test and unpaired t test to find out the difference between the RVA in groups A and B at different stages of follow-up. χ^2 test was used to find out the role of initial Risser staging and menarchal status of female patients in the progression of the curve. A P value of less than 0.05 was accepted for the study to be statistically significant for all tests.

RESULTS

The average follow-up of the patients was 34 ± 13 months. Average age at the time of bracing and at final follow-up was 12.10 ± 1.9 years and 15.10 ± 2.6 years, respectively. The average Cobb's angle was 43 degrees (range: 40 to 56 degrees) prebracing and 40 degrees (range: 17 to 55 degrees) at final follow-up. Of the 113 patients, 53 patients were between Risser stages 0 and 2 at the time of bracing and 60 patients were between Risser stages 3 and 5; and of them 16 and 13 patients, respectively, progressed ($P = 0.300$). One hundred and eight patients attained maturity before the discontinuation of the brace whereas 5 patients are still with a brace. Of 95 females, 43 female patients were in the premenarcheal stage and 52 were in postmenarcheal stage before the initiation of treatment. Fifteen and 14 females exhibited progression of the curve in the premenarcheal and postmenarcheal groups, respectively ($P = 0.401$). Of the 113 patients treated conservatively with bracing, 84 patients did not show curve progression and only 29 patients exhibited progression of the curve by more than 5 degrees at final follow-up. So we divided the study into 2 groups: group 1 comprise the patients who responded to bracing and group 2 comprising patients who did not respond to bracing at final follow-up (Figs. 1, 2).

The average values of Cobb's angles, convex RVA, concave RVA, and RVAD at apex and 12th rib at prebracing, during bracing, and at final follow-up are shown in Table 1 for groups 1 and 2. The average drooping value in RVA on the convex side at apex (RVA Cx drooping value) was found to be 0.12 degrees in group 1 and 11.3 degrees in group 2, which exhibited a statistically significant ($P = 0.0003$) change with the analysis of variance test in group 2 but not in group 1 ($P = 0.93$). A similar test also showed significant change in RVAD at the apex in group 2 ($P = 0.007$) whereas not in group 1 ($P = 0.28$). Comparing the RVAD, RVA Cv, and RVA Cx at the apex between groups 1 and 2 using unpaired t test (Table 1) also explains the fact that before bracing there was no statistically significant difference in the curves between groups 1 and 2, but after bracing the curves of the patients in group 2 showed significant difference in RVA Cx and RVAD at the apex and that would explain their role in the progression of the scoliosis angle. These findings at the 12th rib on both concave and convex sides did not reveal any significant difference when compared for prebracing and final follow-up results between groups 1 and 2.

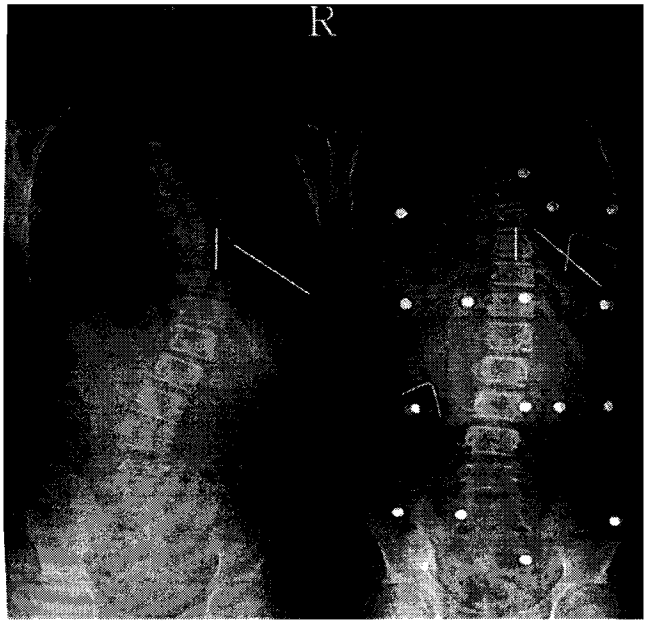

FIGURE 1. The anteroposterior radiogram of whole spine in a 13-year-old man with adolescent idiopathic scoliosis with initial Cobb's angle 50 degrees, which is well-treated with bracing. However, before bracing RVA Cx is 55 degrees, which drooped to 45 degrees after the bracing, which indicates further progression of scoliosis even after initial correction with the brace. Here RVA Cx is measured by Mehta's method. And RVA Cx drooping value is calculated as (RVA Cx before bracing – RVA Cx at final follow-up) = (55 to 45) = 10 degrees. RVA Cx indicates rib-vertebral angle on convex side.

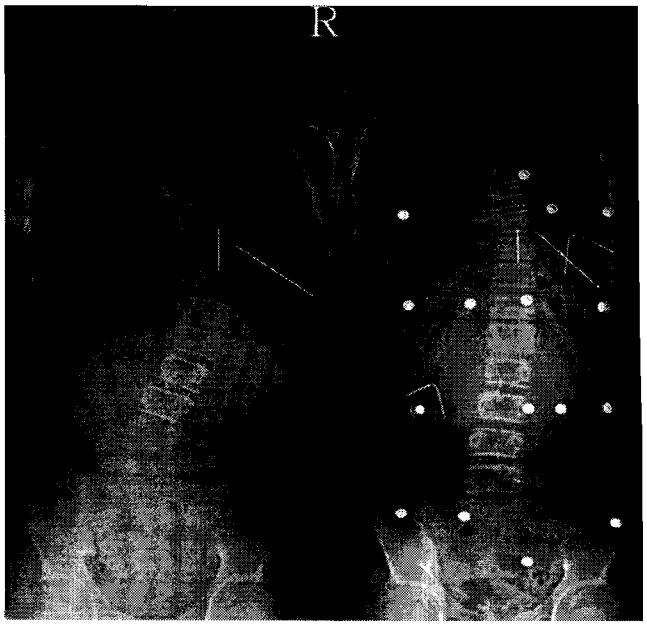

FIGURE 2. The anteroposterior radiogram of whole spine in a 13.5-year-old girl with adolescent idiopathic scoliosis with initial Cobb's angle 52 degrees, which is well-treated with bracing. Before bracing RVA Cx was 72 degree, which remained constant at 73 degrees after the bracing that indicates no progression of scoliosis after initial correction with the brace. Here RVA Cx is measured by Mehta's method. And RVA Cx drooping value is calculated as (RVA Cx before bracing – RVA Cx at final follow-up) = (72 to 73) = – 1 degree. RVA Cx indicates rib-vertebral angle on convex side.

Comparisons of Risser staging and menarcheal status in females at presentation between groups 1 and 2 were not able to explain any statistically significant correlation ($P = 0.30$ for Risser staging and $P = 0.401$ for menarcheal status) with progression. In addition, there was no significant correlation between age of initiation of treatment and progression of curve ($P = 0.4229$; χ^2 test).

DISCUSSION

Results from our study confirm that patients with an initial curve of more than 40 degrees can be successfully treated with bracing. Postbracing drooping of the convex rib at the apical side indicates progression of the curve, which is equally important as RVAD at the apex. Curve progression does not depend upon the initial curve, Risser staging, or menarchal status of patient at presentation.

The general consensus regarding treatment of AIS is that bracing should be considered when Cobb's angle is between 25 and 39 degrees.[4–7,9,16] Most of the authors suggest operative treatment when curve is more than 40 to 45 degrees. Conservative treatment with bracing is usually advised when the curve is less than 40 degrees according to the literature. The prediction of the progression of the curve in AIS is an ongoing exercise to find out the perfect indicator during the course of the disease. In the literature there are several nonradiologic markers that can predict the progression of the scoliosis curve such as age at the onset or initiation of treatment,[3] menarcheal status in female,[3] sex of patient, family history, etc. Regarding the radiologic factors many authors have given different markers showing the progression of the curve[7–9,14,15,17] when the curve is less than 40 degrees. We did not find any significant study of conservative treatment in AIS when the curve is more than 40 degrees. One study[8] on the factors influencing the outcome in bracing large curves stated that patients with double curves in which the thoracic curve is > 35 degrees and the lumbar-pelvic relationship angle is more than 12 degrees, are significantly more likely to demonstrate curve progression. However, in our clinical practice, we have seen cases with a curve of more than 40-degree Cobb's angle, which respond to conservative treatment with bracing and do not progress even after discontinuation of bracing after maturity. And most of such cases do not have an lumbopelvic relationship angle of more than 12 degrees, as in our series the average pelvic obliquity was 2 degrees. These findings were quite interesting, contrary to the literature, and hence we have performed our study in

TABLE 1. Rib-vertebral Angle on Concave and Convex Side and Rib-vertebral Angle Difference at Both Apex and 12th Vertebrae With Drooping Angle RVA Cx at Apex

Group 1 Angle (Degrees) ± SD (Range)	Side and Time of Angle Measurement	*P*, *t* test	Group 2 Angle (Degrees) ± SD (Range)
Apex: before bracing			
86.71 ± 10.21	RVA concave	0.693	85.74 ± 12.79
70.01 ± 10.91	RVA convex	0.492	71.70 ± 11.04
16.69 ± 9.65	RVAD	0.269	14.26 ± 9.51
Apex: during bracing			
88.24 ± 9.36	RVA concave	0.217	85.44 ± 10.87
69.36 ± 11.53	RVA convex	0.398	67.20 ± 8.82
18.88 ± 11.20	RVAD RVA concave	0.087	18.24 ± 9.35
Apex: final follow-up			
86.13 ± 10.05	RVA concave	0.34	83.88 ± 10.59
69.89 ± 11.48	RVA convex	0.0002	60.38 ± 9.2411
16.24 ± 11.43	RVAD	0.0079	23.32 ± 10.91
T12: before bracing			
44.82 ± 13.32	RVA concave		50.06 ± 19.29
57.05 ± 10.25	RVA convex		60.72 ± 14.61
−12.22 ± 18.41	RVAD		−10.65 ± 23.50
T12: during bracing			
43.51 ± 13.59	RVA concave		50.15 ± 18.34
58.33 ± 10.34	RVA convex		56.48 ± 8.02
−14.82 ± 18.50	RVAD		−6.33 ± 24.96
T12: final follow-up			
42.77 ± 14.34	RVA concave		45.15 ± 19.04
57.00 ± 11.40	RVA convex		55.48 ± 12.25
−14.19 ± 20.49	RVAD		−10.33 ± 28.45
0.12	Drooping angle for apical RVA Cx		11.32
$P = 0.93$			$P = 0.0003$

Drooping value for RVA Cx = RVA Cx before bracing − RVA Cx at final follow-up.

RVA indicates rib-vertebral angle; RVA Cx, rib-vertebral angle on convex side; RVAD, rib-vertebral angle differences.

patients of AIS who had a curve more than 40 degrees and had not received any kind of treatment before. Our aim was to find out radiologically the factor that causes progression of the curve in such a group and to decide which curve will progress with bracing.

A study of the effectiveness of thoracolumbosacral orthotics bracing in the conservative treatment of AIS carried out by Fernandez-Feliberti et al[2] noted that the patient group of > 13 years with an initial Cobb's angle > 30 degrees, and which was treated with bracing, improved by at least 5 degrees at the end of follow-up in 86% cases as compared with the similar group that was not treated with bracing. But they did not discuss the factors that are responsible for the success or failure of the treatment in their study. Hanks et al[3] tried to find out the relationship between skeletal maturity and curve progression in their study of 25 patients with curves ranging from less than 20 degrees to more than 40 degrees. According to them, the success rate with bracing in premenarchal age was 74% as compared with 96% for the postmenarchal age. They also noted a gradual increase in the success rate with bracing from 75% in patients with Risser sign 0 to 96% with Risser sign 4. However, in our study comprising 113 patients with curves of more than 40 degrees, we could not find any significant relationship between curve progression and Risser staging or menarchal status. Upadhyay et al[13] described that there is strong association between changes in vertebral rotation and Cobb's angle after the application of the brace and the final outcome. In their opinion, reduction in after brace application indicates good outcome. Olafsson et al[5] noticed that the success of bracing treatment depends upon the initial correction with bracing. If the initial correction is > 50%, the curve will reduce permanently. Their study was restricted to AIS with a curve 24 to 40 degrees. In this study, the initial correction with bracing was found to be only 7 degrees, which is far below the 50% correction. The reason may be that our study group comprises patients having a Cobb's angle of more than 40 degrees.

Since Mehta published the method for measuring RVA[14] and tried to find relationship between curve progression and RVA, many other authors tried to find the factors causing curve progression using the same technique. McAlimdon and Kruse,[18] in their study on intraobserver and interobserver variation during the measurement of RVAD, noted that RVA measurement is highly reproducible and is a valid measurement method. In our study, we also used the same method of measuring the RVA. Mehta[14] noted, in a study on resolving and progressive infantile scoliosis, that most progressive curves have an initial RVAD of 20 degrees or more as compared with the resolving type. Kristmundsdottir et al[15] showed that convex RVA is as important as RVAD. They showed that the curve with convex RVA of less than 68 degrees on the initial radiograph will progress. We agreed with their findings as most of our group 1 patients had a convex RVA of 70 degrees. But contrary to these findings, we also noted an initial convex RVA of 71 degrees in group 2 also, which initially responded to treatment but progressed at final follow-up. These results lead us to an interesting finding that convex RVA gradually decreased in group 2 patients from 71 to 67 degrees in an average of 8 months follow-up and further to 60 degrees at final follow-up. So we can say that the constant watch on convex RVA change or drooping angle of RVA Cx is necessary during the bracing period, and at the point, decrease in curve progress is inevitable. The reason for that, we believe, is that the rib on convex side is perpendicular to the vertebral axis when convex RVA is more than 68 degrees and hence it gives a corrective force to the apex during bracing. When that angle is less than 68 degrees, the rib drops from the perpendicular angle to an oblique angle, and hence it cannot give corrective force to the apex. In measuring the convex RVA with bracing we found that in such patients the rib started drooping and exhibited a decrease in the convex RVA, which indicates the loss of effective correction force to the apex eventually and resulted in the progression of the curve. Our study group 2 had only 29 patients and hence we could not decide the end point of the drooping value for convex RVA at which the curve

will progress and hence we felt that a larger study was required to decide it. Second, we confined our study only to the group that was looking at success with conservative treatment in patients with curves of 40 degrees or more, but felt that similar results can be expected in lower curves also.

To conclude our study, we recommend measuring the drooping value in the apical RVA on the convex side at regular follow-up to check further progression of the curve and deciding other treatment options. Measurement of the drooping value in convex RVA is equally important as that of initial convex RVA or RVAD in the literature.

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