VERTEBRAL GROWTH AFTER POSTERIOR SPINAL FUSION FOR IDIOPATHIC SCOLIOSIS IN SKELETALLY IMMATURE ADOLESCENTS

THE EFFECT OF GROWTH ON SPINAL DEFORMITY

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We studied 29 girls and one boy with adolescent idiopathic scoliosis who were at Risser grade 0 at the time of posterior spinal fusion and were followed until maturity (mean 7.8 years). We used serial radiographs to measure the ratio of disc to vertebral height in the fused segments and to detect differential anterior spinal growth and assess its effect on scoliosis, vertebral rotation, kyphosis, and rib-vertebral-angle difference (RVAD).

From one year after surgery to the latest review, the percentage anterior disc height decreased by nearly one-half and the percentage posterior disc height by nearly one-third in the fused segments (p < 0.001). There was a 4° increase in mean Cobb angle (p < 0.001), 11 patients (37%) having an increase of between 6° and 10°. There was a significant increase in mean apical rotation by 2° (p = 0.005), and four patients (13%) had an increase of between 6° and 16°. There was little change in kyphosis. There was an increase in mean RVAD by 4° (p = 0.003), seven patients (23%) showing a reduction by 1° to 7°, and 11 (37%) increases of between 6° and 16°.

Spinal growth occurs after posterior fusion in adolescents who are skeletally immature, as a result of continued anterior vertebral growth. There is some progression of scoliosis, vertebral rotation, and RVAD, but little change in kyphosis. The increase in deformity is not enough to warrant the use of combined anterior and posterior fusion. The findings are relevant to the management of progressive curves, the timing and extent of surgery, and the prognosis for progression of deformity in this group of patients.

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Progressive increase in rotational deformity of the spine and trunk has been reported after successful posterior fusion in skeletally immature patients. This ‘crankshaft phenomenon’ is said to be inevitable because of continued growth of the anterior elements (Dubousset, Herring and Shufflerarger 1989). To avoid this, it has been recommended that anterior fusion be added to posterior fusion. Such a procedure produces an increased risk of complications and morbidity but combined anterior and posterior fusion has been recommended for paralytic and congenital scoliosis (DeWald and Faut 1979; Leong et al 1981; Winter 1981; McMaster 1987).

The effect of growth after spinal fusion in infants and juvenile patients with idiopathic scoliosis has been described by Hefti and McMaster (1983), but apart from the report of Dubousset et al (1989) we are unaware of other investigations of skeletally immature patients at Risser grade 0 at the time of surgery. Dubousset et al (1989) reviewed 14 idiopathic and 26 paralytic curves in patients under 13 years of age and found significant increases in scoliotic and rotational deformity which led them to advocate combined anterior and posterior fusion.

It is important to establish whether such extensive surgery is necessary in patients with adolescent idiopathic scoliosis. We aimed to investigate the presence of differential anterior spinal growth in such patients, and the effect of growth on an already deformed spine.

PATIENTS AND METHODS

We reviewed the records of all patients under the age of 14 years with adolescent idiopathic scoliosis who had
undergone posterior spinal fusion with instrumentation since 1973 at the Duchess of Kent Children’s Hospital. We then selected those who were at Risser grade 0 at the time of surgery, had no radiological evidence of pseudarthrosis and had been reviewed clinically and radiologically until maturity.

There were 30 patients (29 girls and one boy) who met these criteria. Their mean age at operation was 12.4 years $\pm$ 1.1 (10.3 to 14). Twenty-three had right thoracic curves, six had thoracolumbar curves, and one had a left lumbar curve; 28 had had Harrington instrumentation and two Luque segmental instrumentation. Autologous iliac crest bone graft had been used in all, and postoperatively a plaster jacket had been worn for 6 to 9 months. There were no cases of rod breakage or cutting-out of hooks.

**Radiographic measurements.** We measured scoliosis on standing anteroposterior radiographs using Cobb’s method (1948). The flexibility of the curve was recorded as the difference between the Cobb angle in standing and supine bending radiographs divided by the angle in the standing film. Vertebral rotation was measured on standing anteroposterior radiographs by Perdriolle’s method (1979) using a template. The sagittal spinal curve (kyphosis) was determined on the standing lateral radiograph as the angle between the superior end-plate of the uppermost and the inferior end-plate of the lowermost vertebra in the fused segment. Rib-vertebral angle and rib-vertebral-angle differences (RVAD) were also measured (Mehta 1972).

The growth of the vertebral bodies was recorded by measuring the length of the spine on the lateral radiographs along the anterior and posterior borders of the fused area between the midpoints of the penultimate vertebrae in the fusion mass (Fig. 1). The heights of the intervening discs were measured at their anterior and posterior ends. The sum total of the disc heights was expressed as a percentage of the total length of the fused area and recorded for both anterior and posterior measurements. These ratios for anterior and posterior disc heights eliminated the effects of different magnification of films and errors due to changes in the build of patients over the years. Measurements were made on preoperative, immediate postoperative and annual review radiographs.

**Skeletal maturity.** We used Risser’s method of grading the extent of development of the iliac apophysis on serial films (Risser et al 1966) until the apophysis had completely fused with the iliac crest. We also recorded the standing height before surgery and at each visit, and the date of the menarche.

**Statistical analysis.** All measurements were made by the same observer (ABM) to eliminate interobserver error. Radiographs of ten randomly-selected patients were measured without knowledge of previous readings by two of us (ABM and SSU). Intraobserver and interobserver differences were less than 2° for deformity and less than 2% for vertebral growth. Statistical analysis was performed using SPSS for Windows statistical software package, calculating Pearson’s correlation coefficient, Student’s $t$-test (for paired and unpaired samples) and analysis of variance; $p$ values of less than 0.05 were taken to be significant.

**RESULTS**

The mean preoperative Cobb angle was $54^\circ$ $\pm$ 9 (36 to 70). Maximal voluntary side-bending in the supine position reduced this to a mean of $22^\circ$ $\pm$ 16, giving a mean flexibility of 62%. Thoracic curves had a mean kyphosis of $12^\circ$ $\pm$ 17.5 ($-25$ to 45) and thoracolumbar and lumbar curves had a mean lordosis of $7^\circ$ $\pm$ 15 ($-17$ to 22). The mean rotation of the apical vertebra was $22^\circ$ $\pm$ 9 (0 to 38). Twenty girls had not reached the menarche at surgery, seven had had the menarche within the previous six months, and two between six and 12 months before surgery.

The mean follow-up was 7.8 years $\pm$ 2.9 (4 to 13.7), and Table I summarises the findings at one year after surgery and at latest review.

**Stature.** From one year after surgery to the latest review, the patients’ standing height had increased by a mean of 5 cm $\pm$ 2.5 ($p < 0.001$).
Vertebral body growth. Growth of vertebral bodies had occurred in the fusion mass as reflected by a reduction in percentage disc height at final review in comparison with that at one year postoperatively (Fig. 2). There was a statistically significant reduction in percentage anterior disc height by nearly one-half and in percentage posterior disc height by nearly one-third of the values noted on radiographs taken one year after surgery ($p < 0.001$; Table I). There were no such changes in the unfused segments.

Lateral curvature. From one year postoperatively to latest review, 11 patients (37%) had an increase in Cobb angle of between $6^\circ$ and $10^\circ$; 13 patients (43%) had progression between $1^\circ$ and $5^\circ$ (Fig. 3). The mean increase of $4^\circ$ during this period was statistically significant ($p < 0.001$). Figure 4 shows that a progressive increase in lateral curvature reached its maximum value at nearly four years after surgery.

Ten patients were still at Risser grade 0 one year after operation; in these the mean increase in Cobb angle was $5^\circ$ as against $3^\circ$ in the more mature patients. This difference was not statistically significant.

Vertebral rotation. Between one year postoperatively and latest review, four patients (13%) showed an increase in vertebral rotation of between $6^\circ$ and $16^\circ$, 14 had an increase of $1^\circ$ to $5^\circ$, and ten showed no change or an actual reduction (Fig. 3). The $2^\circ$ difference between mean rotation at one year and latest review was statistically significant ($p = 0.005$). Figure 4 shows a small but steady increase in vertebral rotation for several years postoperatively.

Again, patients who were at Risser grade 0 at one year showed a greater mean increase in vertebral rotation than those who were at Risser grade 1 or more ($3.5^\circ$ v $1.5^\circ$, not statistically significant).

Kyphosis. There was an increase in kyphosis of the fused area between $1^\circ$ and $10^\circ$ in 14 patients (47%). Eight (27%) showed a reduction in kyphosis and eight showed no change (Fig. 3). There was no significant difference in mean kyphosis between one year after surgery and final review (Table I).

Rib-vertebral-angle difference (RVAD). Seven patients (23%) showed a reduction in the RVAD of $1^\circ$ to $7^\circ$, and 11 (37%) showed an increase, of between $6^\circ$ and $16^\circ$, from one year postoperatively to final review (Fig. 3). The mean RVAD at one year was $25^\circ$ compared with $29^\circ$ at final review (Fig. 2; $p = 0.003$; Table I). In patients who were Risser grade 0 at one year, the RVAD increased by $5.5^\circ$ as against $4^\circ$ in those who were more mature. This difference was not statistically significant.

The changes in Cobb angle, vertebral rotation, kyphosis, RVAD and disc heights did not correlate nor
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![Graph showing Cobb angle and Rotation over time.](image)

**Fig. 4**

Change in mean values of Cobb angle and rotation with time.

**Table 1.** Comparison between mean (± SD) values one year postoperatively and at latest review

<table>
<thead>
<tr>
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<th>One year postop</th>
<th>Latest review</th>
<th>Difference in means</th>
<th>t value</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standing height (cm)</td>
<td>155.5 ± 6.3</td>
<td>160.5 ± 5.9</td>
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<td>% anterior disc height</td>
<td>20.3 ± 2.6</td>
<td>11.9 ± 1.8</td>
<td>8.4</td>
<td>13.4</td>
<td>&lt;0.001</td>
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<tr>
<td>% posterior disc height</td>
<td>18.1 ± 2.3</td>
<td>11.9 ± 1.8</td>
<td>6.2</td>
<td>12.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cobb angle (degrees)</td>
<td>31.8 ± 8.9</td>
<td>35.8 ± 9.9</td>
<td>4.0</td>
<td>5.8</td>
<td>&lt;0.001</td>
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<tr>
<td>Rotation (degrees)</td>
<td>18.4 ± 7.4</td>
<td>20.5 ± 7.1</td>
<td>2.1</td>
<td>3.0</td>
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<tr>
<td>Kyphosis (degrees)</td>
<td>8.8 ± 13.0</td>
<td>10.2 ± 12.6</td>
<td>1.4</td>
<td>1.3</td>
<td>0.212</td>
</tr>
<tr>
<td>RVAD† (degrees)</td>
<td>24.9 ± 16.5</td>
<td>29.2 ± 19.6</td>
<td>4.3</td>
<td>3.31</td>
<td>0.003</td>
</tr>
</tbody>
</table>

* Student's t-test for paired samples
† rib-vertebral-angle difference

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did they differ significantly with curve type and flexibility, onset of menarche, number of levels fused, Risser grade one year postoperatively, and increase in height (Pearson correlation coefficient; analysis of variance).

**DISCUSSION**

There is considerable controversy about the effect of posterior fusion on the growing spine. Vertebral growth occurs principally from the end-plates (Bick and Copel 1950; Roaf 1960) and is at its maximum between the ages of 10.5 and 13.5 years in girls and 12.5 to 15.5 years in boys (Tanner, Whitehouse and Takaishi 1966). Whether the fusion mass itself can grow in length has been a matter of some debate. Risser et al (1966) believed that the fusion mass could elongate due to ‘biological plasticity’, and this was also noted to occur after posterior spinal fusion for tuberculosis by Hallock, Francis and Jones (1957) but was not found by Johnson and Southwick (1960), or by Hefti and McMaster (1983) after posterior fusion for infantile and juvenile idiopathic scoliosis. It is now generally accepted that posterior growth ceases once successful fusion occurs.

It is of considerable interest to know whether differential anterior growth occurs, and its possible influence on a three-dimensionally deformed spine. We could find no other studies on both of these factors in immature adolescents with scoliosis. Progression of anterior growth can be detected by changes in the length of the fused segment, by changes in the relative height of the vertebral body to the disc, or by changes in the deformity in a scoliotic spine in which the posterior fusion mass may act as a tether.

We assessed anterior spinal growth in terms of changes in the ratio of disc/vertebral heights rather than absolute measurement of the length of the fused segments because these may vary not only with magnification (even with standardised radiography) but also with changes in the build of patients. The method used is a modification of that of Johnson and Southwick (1960); it eliminates the effect of continuing growth at the upper and lower end-plates of the end-vertebrae in the fused segment.
Serial radiographs of an 11-year-old girl at Risser grade 0, with a 70° right thoracic scoliosis, before operation (a). One year after Harrington instrumentation and posterior fusion, the Cobb angle was 34° (b,c) and seven years later it was 35° (d,e). The lateral radiographs (c and e) show the reduction in height of the disc spaces and also a change in the shape of the vertebral bodies: their height comes to exceed their anteroposterior diameter (e).

We made our measurements on lateral radiographs rather than on anteroposterior radiographs to avoid difficulties caused by metal or the fusion mass and the obliquity of the plane of the disc. Our measurements may not be completely accurate, as noted by Johnson and Southwick (1960), but the reduction in disc spaces is obvious and striking (Fig. 5). Reduction in disc height has also been noted in infantile and juvenile patients after posterior fusion (Hefti and McMaster 1983) but has not been previously reported in adolescents.

The effect of anterior growth on changes in the sagittal spinal curvature has been evaluated in several studies. Continued anterior growth has been variously noted to result in decreased kyphosis (Ponseti and
Friedman 1950; Moe, Sundberg and Gustilo 1964; Hefti and McMaster 1983), increased kyphosis (Dubousset et al 1989), or to cause no change in the kyphotic angle (Letts and Bobechko 1974). An increase in lordosis after posterior spinal fusion in dogs was reported by Veliskakis and Levine (1966), but Coleman (1968) noted an initial increase in lordosis which ceased when the fusion mass became solid. Our finding of a minimal change in kyphosis agrees with the report of Letts and Bobechko (1974).

Changes in vertebral rotation that may accompany anterior growth have rarely been reported. Hefti and McMaster (1983) noted in infantile and juvenile scoliotic patients that there was a 6% progression of rotation when this was measured by the ratio of the distance from the pedicle to the border of the vertebral body on the convex side to the width of the vertebral body. Dubousset et al (1989) found an increase in rotation by as much as 15° in paralytic and idiopathic curves after posterior fusion. The two studies also found different progressions of the Cobb angle between one year postoperatively and final review: the mean Cobb angle was found to increase by 4.7° by Hefti and McMaster (1983) and 15° by Dubousset et al (1989).

Many of these reported observations are on patients with different spinal deformities (scoliosis and kyphosis), of mixed aetiologies (congenital, paralytic, idiopathic, and infective) and in different age groups (infantile, juvenile, and adolescent). Some earlier studies were after fusion alone, without instrumentation (Ponseti and Friedman 1950). Other studies have considered growth in relation to chronological age (Ponseti and Friedman 1950) rather than skeletal maturity and all patients have not always been followed to maturity (Dubousset et al 1989). These variations may account for some of the observed differences.

Scoliosis is three-dimensional; growth must affect all the components of the deformity. Hefti and McMaster (1983) measured rotation, kyphosis and the longitudinal growth, but only in infantile and juvenile curves. Dubousset et al (1989) measured both Cobb angle and rotation of idiopathic curves but only in three patients under 10 years of age and nine between 10 and 12 years.

We assessed the effect of growth on Cobb angle, vertebral rotation, kyphosis, and rib-vertebral-angle difference, using the Risser grade which correlates well with bone age (Dhar et al 1993). We found a small but significant increase in Cobb angle, rotation, and rib-vertebral-angle difference until skeletal maturity. Dubousset et al (1989) found a mean increase in Cobb angle (15°) and of rotation (15.5°) in their 12 patients with idiopathic scoliosis, and several patients had increased rib inclination. They recommended both anterior and posterior fusion in all immature patients. We found smaller, but statistically significant increases in these measurements, and little change in kyphosis.

There are several possible reasons for the differences between our findings and those of Dubousset et al (1989). The mean age of our patients was marginally higher; all but three of their 12 patients were at Risser grade 0 at one year compared with one-third in our study. All our patients had worn plaster jackets for at least six months while there is no mention of the postoperative treatment in their report. All our patients were followed until maturity, and finally there may be differences in spinal growth patterns between oriental and caucasian populations.

Our study has shown that in immature adolescents with idiopathic scoliosis, some spinal growth continues after posterior fusion until maturity. Patients and their parents should be warned that there may be some progression of spinal deformity, but that its magnitude is limited. Prophylactic anterior fusion may be considered to ensure that there is no possibility of deterioration, but our results show that such progression is seldom very marked. No routine decision to perform anterior fusion should be made, but the potential for growth in these patients means that they must be followed until growth has ceased. For most patients in this age group, posterior fusion alone is adequate and may be safely performed without fear of any dramatic increase in deformity.

Conclusions
1) Spinal growth occurs due to continued anterior vertebral growth after posterior fusion for idiopathic scoliosis in adolescents who are skeletally immature.
2) Anterior growth occurs in the fused segment by an increase in the height of vertebral bodies at the expense of the height of intervertebral discs.
3) There is some progression of scoliosis, vertebral rotation and RVAD after successful fusion, but little change in kyphosis.
4) The progression of deformity is rarely sufficient to warrant combined anterior and posterior fusion in this group of patients.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES
Cobb JR. Outline for the study of scoliosis. AAOS Instructional Course Lectures 1948; 5:261-75.


