Eur Spine J (2003) 12 : 281–287
DOI 10.1007/s00586-002-0523-6

ORIGINAL ARTICLE

Gurkan Erkula
Paul D. Sponseller
A. Esat Kiter

Rib deformity in scoliosis

Received: 25 July 2002
Revised: 6 October 2002
Accepted: 27 November 2002
Published online: 14 March 2003

This study was presented orally (O76) at the 2001 Annual Meeting of the European Pediatric Orthopedic Society (EPOS), held at Montpellier, France. One of the researchers in this study (G.E.) was awarded a grant in scope of the NATO Science Fellowship Programme by the Scientific and Technical Research Council of Turkey (TUBITAK)

G. Erkula (✉) · A. E. Kiter
Department of Orthopedics
and Traumatology, Faculty of Medicine,
Pamukkale University, Denizli, Turkey
Tel.: +90-258-2410037/210,
Fax: +90-258-2410040,
e-mail: gerkula@ixir.com

G. Erkula
P.K. 295, 20104 Denizli, Turkey

P. D. Sponseller
Division of Pediatrics,
Department of Orthopedics,
Johns Hopkins University,
Baltimore, Maryland, USA

Abstract Rib deformity in scoliosis is of interest because it may help in the diagnosis, and also, in some pronounced cases, it may need correction by costoplasty. There are, however, debates about its use in diagnosis, because some authors think that rib deformity is not closely related to either the magnitude or the extent of rotation of the curve. In order to define the relation between rib deformity and scoliosis, 11 patients were recruited who were to undergo scoliosis surgery and thoracoplasty, and anteroposterior (AP) T1-S1 standing radiographs, computerized tomography (CT) scans, and three-dimensional (3D) reconstructions were obtained. From the radiographs, the most rotated vertebra, the Cobb angle, the apex and the type of the curve were determined. From the CT scans and 3D reconstructions, the exact level of the rib deformity measured was matched with the corresponding vertebral level. In this way, the most rotated vertebra and the most prominent part of the rib cage deformity were identified. The most rotated vertebra was found to be at the same level in both radiographs and CT scans in only five patients. In the rest of the patients, CT scans showed it either one level higher or lower than it appeared on the radiograph. The most prominent part of the rib cage deformity was at the same level as the most rotated vertebra in two patients, and in the rest of the patients it was one, two or three vertebral levels lower. There was no association between the Cobb angle, vertebral rotation and rib deformity. A CT scan is necessary preoperatively in patients who will undergo a costoplasty, to determine the exact levels of the prominence. However, a scanogram or a 3D reconstruction is required for exactly matching the most prominent part of the rib cage deformity to the corresponding vertebral level.

Keywords Rib hump · Scoliosis · Vertebral rotation

Introduction

Scoliosis is a three-dimensional deformity, affecting the shape of the back. It is a deformity mostly seen in females [38]. In the adolescent age group, after the diagnosis, both the parents and the child seek the best treatment for allowing the patient to return to their daily activities without any residual deformities.

Scoliosis can cause deformities in the coronal plane in different magnitudes correlated with the Cobb measurements, and it can also deform the vertebral column in the sagittal plane, presenting as typical loss of kyphosis in scoliosis or kyphotic curves. This is especially the case in those who are susceptible due to an underlying defect in the connective tissue like Marfan syndrome [29]. It also has a deforming feature in the transverse plane due to the rotation of the vertebral bodies, and it was thought that this rotation in the vertebral column causes the deformity in the upper back known as the rib hump [1, 9].

However, there are several studies questioning the role of vertebral rotation in the development of the rib hump.

Fig. 1 A scanogram is used to determine the level of the rib that corresponds to the exact vertebral level

Some researchers think that the development of the rib deformity in the back is not closely related to either the degree of vertebral rotation or the magnitude of the curve [11, 12, 16, 27, 35, 36, 37]. Some studies indicate that there are changes in the posterior elements of the vertebral column causing the rib deformity, which may be independent of the rotation in the vertebral column [11, 32, 33, 34].

The persisting deformity of the ribs after scoliosis surgery results, in some patients, in dissatisfaction with their self-image. Although most of the orthopedic surgeons are well aware of this deformity nowadays, it is a common occurrence that, after a combined successful thoracoplasty and scoliosis surgery, a deformity may remain in the upper back due to residual rib deformity.

There is some evidence to indicate that rib deformity may not be closely related to the Cobb measurements or the amount of rotation in the vertebral column. This study

Fig. 2 Three-dimensional (3D) computed tomography (CT) reconstructions of the spine of the same patient as in Fig. 1 is used for checking to see whether the level of the rib measured in the scanogram matches the measured vertebral level

is designed to see whether this assumption is true, and to show the relation between scoliosis and rib hump.

Materials and methods

Patients with scoliometer measurements of over 10° [14], who were candidates for scoliosis surgery and also needed thoracoplasty for correction of the deformity in the back, were recruited for the study. There were eight female, and three male recruits, with an average age of 15 years.

All of the patients were properly informed about the radiation exposure and gave their consent, and standing anteroposterior (AP) T1–S1 radiographs were obtained. From the AP radiographs, the type of curve according to King [15] and the apical vertebra was defined, and the Cobb angle for the major curve was measured, with the most rotated vertebra being defined according to Nash and Moe's method [23].

Computerized tomography (CT) scans of the vertebral column from each patient were obtained with the recruits lying supine on the table. Determination of the exact level of the rib that corresponds to a certain vertebral level is difficult from transverse CT slices alone, due to the downwards sloping of the ribs. Two techniques were therefore used to determine the exact level of the vertebra that corresponds to the measured rib deformity.

First, from each CT scan, a scanogram was taken, and from these scanograms, the level of the rib that was going to be measured for the rib deformity was matched with the exact corresponding vertebral level (Fig. 1).

In addition, three-dimensional (3D) reconstructions were done to detect and check to see whether the level of the rib deformity corresponded exactly to the level of the vertebra obtained from the scanograms (Fig. 2, Fig. 3).

The rib deformity was then measured at the pre-defined level of the corresponding vertebra on the transverse plane slices of CT scans, by the angle formed between a horizontal line drawn parallel to the table, and the line drawn tangential to the rib deformity. This angle, which shows the magnitude of the rib deformity at

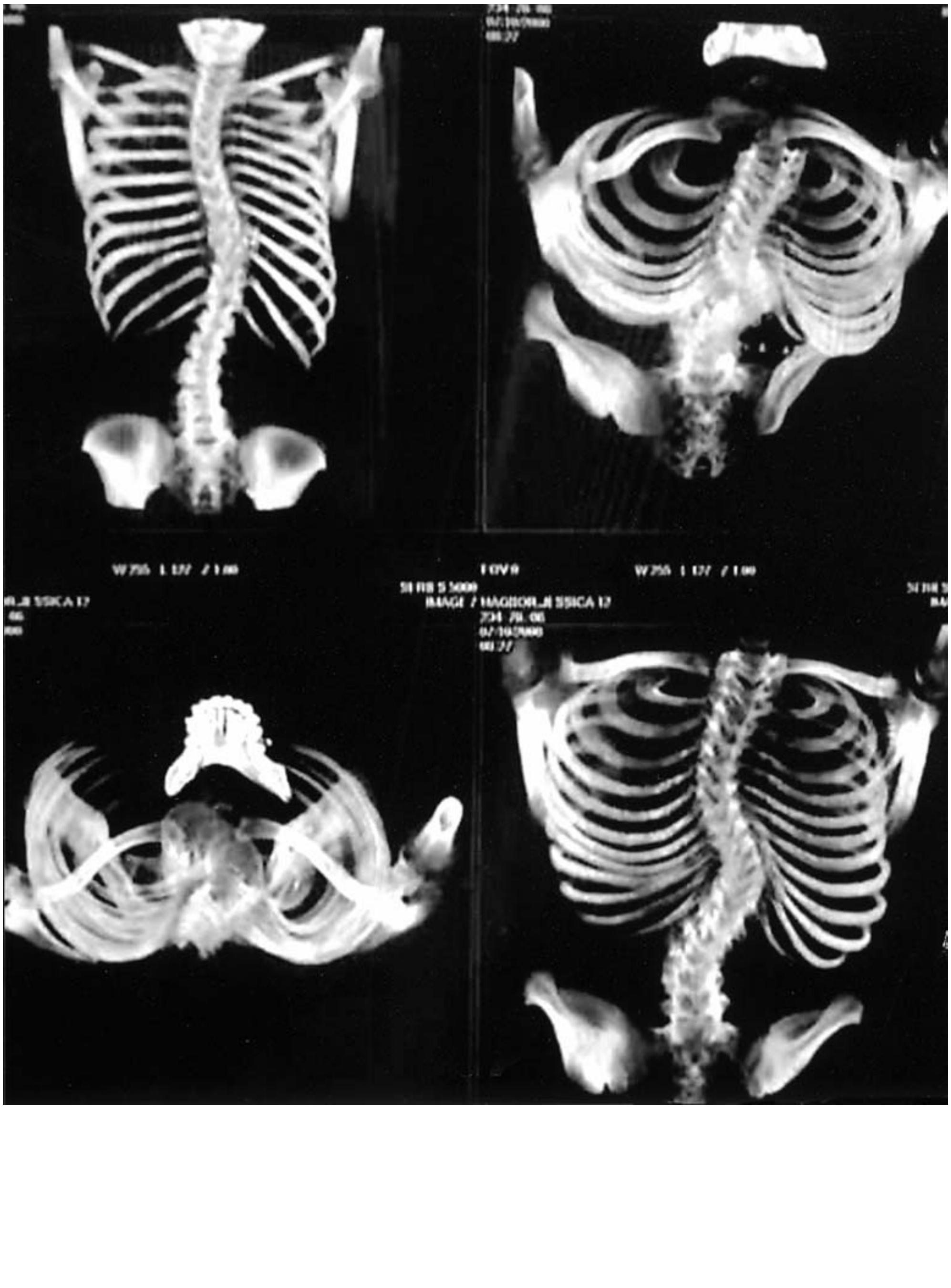

Fig. 3 Different views of 3D reconstructions are used to confirm that the predetermined level of the rib exactly matches the measured vertebral level in the same patient

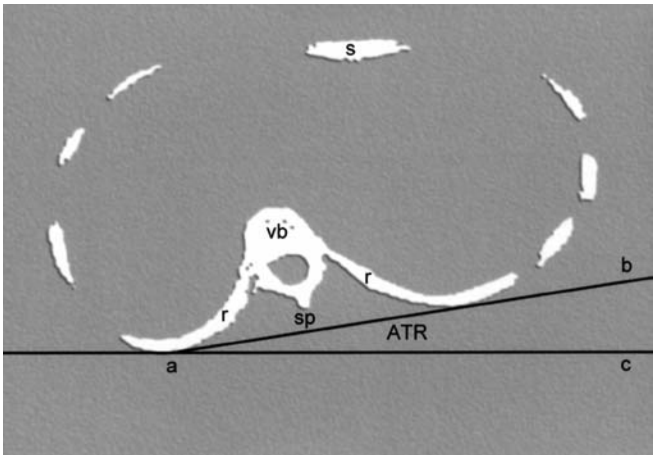

Fig. 4 Measurement of the angle of trunk rotation (ATR) on CT scan. On transverse CT slices, the ATR is given by the angle formed between a horizontal line drawn parallel to the table (a–c), and the tangential line drawn to the rib deformity (a–b) (*s* sternum, *vb* vertebral body, *sp* spinous process, *r* ribs)

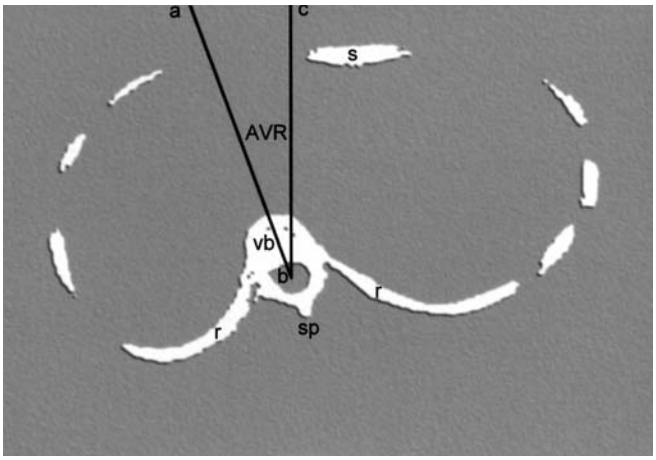

Fig. 5 Measurement of the angle of vertebral rotation (AVR). On transverse CT scan slices, a perpendicular line starting from the posterior central aspect of the vertebral foramen is drawn to the horizontal (b–c) and the angle formed between this line and the line drawn starting from the posterior central aspect of the vertebral foramen, crossing the middle part of the vertebral body (b–a) gives the AVR (*s* sternum, *vb* vertebral body, *sp* spinous process, *r* ribs)

each corresponding vertebral level, is called the angle of trunk rotation (ATR). In this way, the maximum ATR and the corresponding vertebral level was found for the scoliotic curve (Fig. 4).

The amount of vertebral rotation about the longitudinal axis relative to the sagittal plane was measured at each vertebral level using the technique described by Aaro and Dahlborn [2]. A perpendicular line starting from the posterior central aspect of the vertebral foramen is drawn to the horizontal, and the angle formed between this line and the line drawn starting from the posterior central aspect of the vertebral foramen, crossing the middle part of the vertebral body, gives the angle of vertebral rotation at each vertebral level about the longitudinal axis relative to the sagittal plane (AVR) (Fig. 5). This information allowed us to establish which was the most rotated vertebra on CT scan.

Statistical analysis, using the Mann-Whitney-U test in the SPSS 9.0.0 (Statistical Programs for Social Sciences) statistical package, was performed to see whether the AVR correlates with Cobb angle measurements, and the whether the ATR correlates with either the Cobb angle or the AVR.

Results

There were three King type I, six type II, and two type III curves, with an average Cobb angle of the major curve of 54.6°. The most rotated vertebra coincided with the apex of the curve in all but one King type I and one type II curve; in both these exceptions, the curve apex was located at the disc space below the most rotated vertebra (Table 1).

The average ATR for the whole group was 11.9°, and the average AVR was 18.6°. When the levels of the most rotated vertebra on the AP radiographs were compared to those identified on the CT scans, they were found to be at the same level on both imaging techniques in five patients. However, in four patients the most rotated vertebra measured on CT scan was found to be located one level lower, and in two patients one level higher than on the radiographs (Table 1).

The corresponding vertebral level of the maximum ATR measured on CT scan was compared with the level of the maximum rotated vertebra as measured on CT scan. They were found to be at the same level in two recruits, while the maximum ATR was found to be one vertebral level lower in five, two levels lower in three patients, and three levels lower in one patient (Table 1).

The results showed that the AVR has a significant relation with the magnitude of the Cobb angle measurements ($P<0.05$). However, the ATR has no significant relation to either Cobb angle measurements or the AVR ($P>0.05$).

The results obtained from the whole study group can be seen in Table 1.

Discussion

Scoliosis is a three-dimensional plane deformity, causing changes in the transverse, sagittal and coronal planes. Since it is a deformity mostly affecting the shape of the body, and, after progression of the deformity, affecting other parts of the body like pulmonary function, it has to be treated. There are several methods of treatment, including observation, bracing, casting, and eventually surgical correction [22, 24, 26, 28, 38].

Surgical correction of the deformity is being continually improved, as newer and better instrumentation systems are manufactured for surgery. Although these newer systems and better surgical techniques can correct the sagittal, coronal and rotational deformities, there are still some decompensational problems, residual deformities and persistence of the rib hump in the upper back [5, 6, 17, 18, 19, 20].

Table 1 Results of the study group(*AVR* angle of vertebral rotation, *ATR* angle of trunk rotation)

Patient	King type	Cobb angle	Most rotated vertebra[a]	Apex	Max AVR and level[b]	Max ATR and level[b]
1	II	50°	T8	T7-8	17° (T8)	12.5° (T9)
2	I	58°	T7	T7	23° (T7)	11° (T8)
3	II	44°	T8	T8	15° (T9)	16° (T10)
4	II	54°	T8	T8	14° (T7)	9° (T8)
5	II	46°	T9	T9	22° (T9)	13° (T10)
6	III	56°	T10	T10	13° (T9)	10° (T12)
7	III	68°	T9	T9	25° (T9)	15° (T11)
8	II	56°	T9	T9	20° (T10)	7° (T12)
9	II	57°	T8	T8	19°(T9)	14.5° (T9)
10	I	57°	T7	T7-8	22° (T7)	10° (T9)
11	I	54°	T7	T7	15°(T8)	13° (T8)

[a] Measured on anteroposterior radiographs according the technique of Nash and Moe
[b] Measured on CT scan

The deformity of the ribs in scoliosis has attracted the attention of researchers because it is a deformity that can aid in the diagnosis of the disease [7, 9]. Forward bending in either standing or sitting position can amplify the rib deformity, which can help the diagnosis to be made. The scoliometer was invented in order to detect the deformity, and it can also give an idea about the magnitude of the deformity [7].

This feature of the disease has made it possible to introduce school screening programmes for early diagnosis, either using forward bending alone, or using the Bunnell scoliometer for exact measurement of the rib deformity [8, 21].

However, there are debates about the rib deformity and its use in screening, since it can change according to the position of the patient [10, 25, 31, 36]. Some researchers think that the forward bending test should be done in the standing position, while others think that it should be done sitting, and a third group think that there is no difference in the measurements according to the posture of the child. Although there are debates about the position of the patient during the Adam's forward bending test, scoliometers are used to diagnose scoliosis using the rib deformity in the back. However, after these screening efforts, it is apparent that some patients with a high degree of rib deformity may have a very small Cobb measurement, and vice versa [13, 35, 36]. In fact, some patients with a severe deformity in the ribs may not even have a scoliotic curve. So these findings have resulted in questions being raised about the effectiveness of school screening programs in diagnosing scoliosis.

Some researchers have also started looking at the rib deformity, and questioning its correlation with Cobb measurements. Some think that scoliometer measurements are directly correlated with the magnitude of the curve, whereas others think that they are not [1, 7, 9, 13, 16, 35, 36]. There are some studies showing that rib deformity is a feature independent of both the Cobb measurements and vertebral rotation [11, 12, 35].

Since the rib deformity is not well understood, there are also problems in correcting the hump during scoliosis surgery. Costoplasty was invented for this purpose: to correct the rib deformity by extracting the ribs causing the deformity [4, 14, 27, 30]. Most surgeons extract the ribs at the apex of the scoliotic curve, hoping to correct the rib hump. However, in some cases there will be a persistent rib deformity, causing dissatisfaction with the result of the surgery.

As ribs slope obliquely downwards, it is difficult to predict which vertebral levels one is making measurements for. The complex technique of obtaining scanograms followed by 3D-CT reconstructions is used in an effort to address this difficulty. First a scanogram is obtained, then, using the scanogram, the rib and the corresponding vertebral level are identified, and this is followed by a second check using the 3D reconstructions. Only once the level of the rib for a certain vertebra has been identified by this technique is the ATR measured for that vertebral level.

Although the number of recruits in this study was small, the results clearly show that, in many patients, the most rotated vertebra as identified on CT scan is not the same as that identified on AP radiographs. Hence, it is also found that the level of maximum ATR measurements, reflecting the peak of the rib deformity, does not always coincide with the level of the most rotated vertebra. This feature of the rib deformity revealed in this study may help to clarify why there are failures in some patients after thoracoplasty. The fact that the study was conducted with the recruits lying in a supine position for the CT scans could be argued to be limitation, because the maximum ATR can change in accordance with the position of the patient. However, vertebral rotation can also change, as shown by a study conducted by Acaroglu et al. [3]. It can therefore be postulated that, while there may be changes in the measurements made due to the patients' supine lying position, this study is able to give an idea about rib deformity and whether it matches up with Cobb angles and the amount of vertebral rotation. Consequently, in this study it is shown that there is no relation between the ATR and either Cobb angle measurements or the AVR. It should also be noted that the most rotated vertebra differs between standing radiographs and CT scans, and this might be due to the fact that CT scans are taken with the patient lying down. However, since both of the parameters (ATR and AVR) may change due to the lying position of the patient in CT scan, we think that a standardization is obtained within the group, which enables a statistical analysis.

Although the rib deformity is mostly noticed by the parents while the child is bending forward for some reason, both parents and child are more concerned about the deformity in the back due to the deformity in the vertebral column. They are not aware of the fact that the rib deformity, when inefficiently corrected during surgery, may result in dissatisfaction with the results of the surgery. Though, the scoliotic deformity is well corrected, it is a common occurrence that the patient becomes aware of the uncorrected or partially corrected rib deformity, and complains about and questions the results of the scoliosis surgery. In light of the findings obtained in this study, we think that the scoliosis surgery and rib resection should be evaluated and planned separately. In patients who have a definite cosmetic deformity, and a rib deformity of >10º, we think that a preoperative CT evaluation with a scanogram may be performed. The sole indication for this should be to define the exact level of the ribs that are going to be resected in patients who are preoperatively planned for thoracoplasty, and it is not advisable for use in all preoperative scoliosis patients. The rib deformity can recur after a scoliosis surgery, and a second operation for rib resection may be needed [12, 14, 37]. Although there is an increased risk of radiation exposure, the cost of obtaining a preoperative CT evaluation is lower than a second operation for uncorrected or recurring rib deformity. Therefore, the patient and the parents should be informed about the rib deformity beforehand, and a CT scan should be taken to effectively detect the levels of the rib deformity, if a thoracoplasty is going to be performed.

Conclusions

Rib deformity seen in scoliosis is not related to either the magnitude of the Cobb angle of the curve or the amount of vertebral rotation. Since it is a deformity affecting the shape of the back, it has to be treated effectively. For this reason, a preoperative CT scan for determination of the exact levels of the maximum rib deformity in patients with a severe hump is necessary for effective planning of the operative extraction of the ribs. A scanogram or a 3D reconstruction of the spine and ribs will help define the exact level of the rib deformity that corresponds to a certain vertebral level.

References

1. Aaro S, Dahlborn M (1981) The longitudinal axis rotation of the apical vertebra, the vertebral, spinal, and rib cage deformity in idiopathic scoliosis studied by computer tomography. Spine 6: 567–572
2. Aaro S, Dahlborn M (1982) The effect of Harrington instrumentation on the longitudinal axis rotation of the apical vertebra and on the spinal and rib-cage deformity in idiopathic scoliosis studied by computer tomography. Spine 7: 456–462
3. Acaroglu E, Yazici M, Deviren V, Alanay A, Cila A, Surat A (2001) Does transverse apex coincide with coronal apex levels (regional or global) in adolescent idiopathic scoliosis? Spine 26: 1143–1146
4. Barrett DS, MacLean JGB, Bettany J, Ransford AO, Edgar MA (1993) Costoplasty in adolescent idiopathic scoliosis. Objective results in 55 patients. J Bone Joint Surg Br 75:881–885
5. Benli IT, Tüzüner M, Akalın S, Kis M, Aydın E, Tandogan R (1996) Spinal imbalance and decompensation problems in patients treated with Cotrel-Dubousset instrumentation. Eur Spine J 5:380–386
6. Bridwell KH, McAllister JW, Betz RR, Huss G, Clancy M, Schoenecker PL (1991) Coronal decompensation produced by Cotrel-Dubousset 'derotation' maneuver for idiopathic right thoracic scoliosis. Spine 16:769–777
7. Bunnell WP (1984) An objective criterion for scoliosis screening. J Bone Joint Surg Am 66:1381–1387
8. Bunnell WP (1993) Outcome of spinal screening. Spine 18:1572–1580
9. Burwell RG, James NJ, Johnson F, Webb JK, Wilson YG (1983) Standardised trunk asymmetry scores. A study of back contour in healthy school children. J Bone Joint Surg Br 65:452–463
10. Duval-Beaupere G (1992) Rib hump and supine angle as prognostic factors for mild scoliosis. Spine 17:103–107
11. Gaines RW, McKinley LM, Leatherman KD (1981) Effect of the Harrington compression system on the correction of the rib hump in spinal instrumentation for idiopathic scoliosis. Spine 6:489–493
12. Geissele AE, Ogilvie JW, Cohen M, Bradford DS (1994) Thoracoplasty for the treatment of rib prominence in thoracic scoliosis. Spine 19:1636–1642
13. Goldstein LA (1973) The surgical treatment of idiopathic scoliosis. Clin Orthop 93:131–157
14. Harvey Jr. CJ, Betz RR, Clements DH, Huss GK, Clancy M (1993) Are there indications for partial rib resection in patients with adolescent idiopathic scoliosis treated with Cotrel-Dubousset instrumentation? Spine 18:1593–1598
15. King HA, Moe JH, Bradford DS, Winter RB (1983) The selection of fusion levels in thoracic idiopathic scoliosis. J Bone Joint Surg Am 65:1302–1313
16. Korovessis PG, Stamatakis MV (1996) Prediction of scoliotic Cobb angle with the use of the scoliometer. Spine 21: 1661–1666
17. Lee GA, Betz RR, Clements III DH, Huss GK (1999) Proximal kyphosis after posterior spinal fusion in patients with idiopathic scoliosis. Spine 24: 795–799
18. Lenke LG, Bridwell KH, Baldus C, Blanke K (1992) Preventing decompensation in King type II curves treated with Cotrel-Dubousset instrumentation. Spine 17:S274–S281
19. Lowe TG, Kasten MD (1994) An analysis of sagittal curves and balance after Cotrel-Dubousset instrumentation for kyphosis secondary to Scheuermann's disease. Spine 19:1680–1685

20. McCance SE, Denis F, Lonstein JE, Winter RB (1998) Coronal and sagittal balance in surgically treated adolescent idiopathic scoliosis with the King II curve pattern. A review of 67 consecutive cases having selective thoracic arthrodesis. Spine 23:2063–2073
21. Morrissy RT (1999) School screening for scoliosis. Spine 24:2584–2591
22. Nachemson AL, Peterson LE (1995) Effectiveness of treatment with a brace in girls who have adolescent idiopathic scoliosis. J Bone Joint Surg Am 77: 815–822
23. Nash C, Moe JH (1969) A study of vertebral rotation. J Bone Joint Surg Am 51:223
24. Peterson LE, Nachemson AL (1995) Prediction of progression of the curve in girls who have adolescent idiopathic scoliosis of moderate severity. J Bone Joint Surg Am 77:823–827
25. Pun WK, Luk KD, Lee W, Leong JC (1987) A simple method to estimate the rib hump in scoliosis. Spine 12: 342–345
26. Rowe DE, Bernstein SM, Riddick MF, Adler F, Emans JB, Gardner-Bonneau D (1997) A meta-analysis of the efficacy of non-operative treatments for idiopathic scoliosis. J Bone Joint Surg Am 79:664–674
27. Shufflebarger HL, Smiley K, Roth HJ (1994) Internal thoracoplasty. A new procedure. Spine 19:840–842
28. Sponseller PD, Cohen MS, Nachemson AL, Hall JE, Wohl MEB (1987) Results of surgical treatment of adults with idiopathic scoliosis. J Bone Joint Surg Am 69:667–675
29. Sponseller PD, Hobbs W, Riley III LH, Pyeritz RE (1995) The thoracolumbar spine in Marfan syndrome. J Bone Joint Surg Am 77:867–875
30. Steel HH (1983) Rib resection and spine fusion in correction of convex deformity in scoliosis. J Bone Joint Surg Am 65:920–925
31. Stokes IAF, Moreland MS (1987) Measurement of the shape of the surface of the back in patients with scoliosis. J Bone Joint Surg Am 69:203–211
32. Taylor JR (1978) Genesis of scoliosis. J Anat 126:434–435
33. Taylor JR (1980) Vertebral growth and the genesis of idiopathic scolioses. J Bone Joint Surg Br 62:267
34. Taylor JR (1980) Vertebral genesis of scoliosis. J Anat 130:197–198
35. Thulbourne T, Gillespie R (1976) The rib hump in idiopathic scoliosis. Measurement, analysis and response to treatment. J Bone Joint Surg Br 58: 64–71
36. Upadhyay SS, Burwell RG, Webb JK (1988) Hump changes on forward flexion of the lumbar spine in patients with idiopathic scoliosis. A study using ISIS and the scoliometer in two standard positions. Spine 13:146–151
37. Weatherley CR, Draycott V, O'Brien JF, Benson DR, Gopalakrishnan KC, Evans JH, O'Brien JP (1987) The rib deformity in adolescent idiopathic scoliosis. A prospective study to evaluate changes after Harrington distraction and posterior fusion. J.Bone Joint Surg Br 69:179–182
38. Weinstein LS, Zavala DC, Ponseti IV (1981) Idiopathic scoliosis. J Bone Joint Surg Am 63:702–712