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Title: The effect of concomitant rib deformity in congenital scoliosis on spinal curve correction after segmental pedicle screw instrumentation

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Abstract

Study Design Single-center, prospective study

Objective To investigate the effect of rib anomaly on surgical curve correction outcome in congenital scoliosis

Summary of Background Data The presence of rib anomalies may complicate surgical correction of congenital scoliosis. The outcome of surgical correction, however, has not been documented in scoliotic patients with and without rib deformity.

Methods Percent Cobb angle decrease (CAD) after operation was calculated in 94 patients with congenital scoliosis. Posterior segmental pedicle screw instrumentation (posterior approach) with or without previous anterior spinal release and fusion (anterior approach) was the method of correction. The impact of vertebral anomaly and rib deformity on CAD was examined.

Results Although the type of vertebral anomaly had no significant effect on the mean CAD, it was significantly lower in 56 patients with rib deformity compared to that in the remaining patients without rib deformity (35.14±15.83% vs. 51.54±17.82%; $p<0.001$); particularly in those with complex, unilateral rib abnormalities; and in those with same level vertebral and rib deformities. Patients' sex and age at the time of operation, rib number abnormality, and the type of operation (i.e. posterior only approach vs. anterior and posterior approach) did not contribute significantly to Cobb angle change after operation.

Conclusions Concomitant rib deformities, particularly of complex and unilateral types, significantly compromise operative curve correction outcome in congenital scoliosis.

Keyword: congenital scoliosis; vertebral anomaly; rib deformity; operative outcome

Introduction

Abnormal development of the vertebrae in the uterus at 4–6 weeks of gestation may cause curvature of the spine; a condition which is known as congenital scoliosis.[1] Although presence of defective vertebrae is the characteristic feature of scoliosis, rib deformities may coexist.[2, 3]

There are numerous surgical options for correcting spinal deformities in scoliotic patients.[4, 5] Severe and rigid curves usually require an anterior release and posterior instrumented fusion.[6]

Described for the first time by Flinchum in 1963,[7] concave rib osteotomy increases the flexibility of the scoliotic curve by allowing the deformed spine to be translated to the midline and could be valuable for esthetic reduction of rib abnormality. Due to existence of complex mechanisms of action during and after surgery in scoliotic patients with concomitant rib deformity, however, the usefulness and safety of mechanical rib correction is controversial in such cases.[8-10]

This study aimed to investigate the effect of rib anomaly on surgical curve correction outcome in congenital scoliosis.

Materials and Methods

A total of 94 patients with congenital scoliosis operated on from February 2008 to September 2013 were recruited from a university hospital.

Secondary/adult onset scoliosis and previous spinal and/or costal trauma/operation were exclusion criteria.

The ethics committee of a local university approved this study.

All operations were performed by a single skilled scoliosis surgeon with over 10 years of experience. The method of correction was posterior segmental pedicle screw instrumentation (posterior approach) with or without previous anterior spinal release and fusion (anterior approach).[11]

Essential information was collected from clinical and hospital chart, including imaging studies. Vertebral anomalies were classified as segmentation failure, formation failure, or a mixed form of both.[12]

Rib anomalies with variation in number (increased/missing) or structural changes were classified as either simple or complex.[13] Accordingly, simple rib deformities were reported when one of these abnormalities was present: (i) localized fusion or bifurcation of two or three ribs, (ii) small chest wall defect, and (iii) increased or decreased number of rib(s). A complex rib deformity was reported when multiple extensive rib fusions and/or bifurcations were present along with an adjacent chest wall defect due to absence or division of the ribs.

For localization purposes, the thoracic region was divided as upper-thoracic (T1-T4), middle-thoracic (T5-T8), and lower-thoracic (T9-T12).[14]

Vertebral and rib anomalies were considered at the same level when both were located in upper-thorax, middle-thorax, or lower-thorax.

The Cobb's method was used to measure the spinal curvature on anteroposterior radiographs.[15] The percent change of Cobb angle after operation compared to the preoperative amount (Cobb angle decrease, CAD) was designated as the outcome variable in the present study (Figure 1 and Figure 2).

Statistical analysis

The SPSS software version 16.0 (SPSS Inc., Chicago, IL) was used for statistical analysis. Independent samples *t* test and one-way ANOVA with Tukey *post hoc* analysis were used for comparisons. Pearson's coefficient (r) was calculated to study correlation. Differences with a p-value ≤ 0.05 were considered as statistically significant.

Results

Patients were 48 males (51.1%) and 46 females (48.9%) with a mean age of 15.6±4.7 years (range: 12-38) at the time of operation.

Posterior approach was used for operation in 64 patients (68.1%) and both anterior and posterior approaches were used in 30 patients (31.9%).

The mean preoperative and postoperative Cobb angles were 71.2±24.9 degrees (range: 30-140) and 42.2±20.1 degrees (range: 8-90), respectively. The mean CAD was 41.8±18.4% (range: 3.9-82.2).

Failure in segmentation, failure in formation, and a mixed type were observed in 30 (31.9%), 50 (53.2%) and 14 (14.9%) patients, respectively.

Hemivertebra, unilateral unsegmented bar and wedge vertebra were present in 46 (48.9%), 44 (46.8%), and 18 (19.1%) patients, respectively.

Vertebral anomalies were located in the upper thorax in 12 patients (12.8%), in the middle thorax in 28 patients (29.8%), in the lower thorax in 22 patients (23.4%), in the middle-lower thorax in 16 patients (17%), and in the lumbar region in 16 patients (17%).

Rib anomalies were present in 56 patients (59.6%), including simple deformities in 36 cases (64.3%) and complex deformities in 20 cases (35.7%).

Fused ribs, bifid ribs, and widened/irregular ribs were present in 32 (57.1%), 18 (32.1%), and 28 (50%) patients, respectively.

Rib anomalies were located on the convex side of scoliosis in 12 patients (21.4%), on the concave side of scoliosis in 20 patients (35.7%), and bilaterally in 24 patients (42.9%).

They were in the upper thorax in 12 patients (21.4%), in the middle thorax in 14 patients (25%), in the lower thorax in 8 patients (14.3%), and in the middle-lower thorax in 22 patients (39.3%).

Vertebral and rib anomalies were located at similar levels in 18 cases (32.1%).

The number of ribs was normal in 54 patients (57.4%), increased in 12 cases (12.8%), and decreased in 28 cases (29.8%).

No significant correlation was present between CAD and patients' age (Pearson $r=-0.12$, $p=0.26$). Associations between CAD and other study variables are examined in Table 1.

CAD was not significantly associated with patients' sex (independent samples *t* test $p=0.25$), the type of vertebral anomaly (one-way ANOVA $p=0.26$), rib number (one-way ANOVA $p=0.43$), or the type of operation (independent samples *t* test $p=0.57$).

Compared to those with rib anomalies, however, the mean CAD was significantly higher in patients without rib anomaly (independent samples *t* test $p<0.001$).

It was also significantly higher in patients with simple than those with complex rib deformities (independent samples *t* test $p=0.002$); in patients with bilateral rib involvement compared to those with unilateral deformity (Tukey *post hoc* analysis p=0.01 for both); and in those with different levels of vertebral and rib deformities compared to those with vertebral and rib deformities at similar levels (independent samples *t* test p=0.03).

Discussion

In the current work the presence of rib anomalies, particularly of complex and unilateral types, was significantly along with worse postoperative correction (Cobb angle decrease). Type of vertebral anomaly, variation in rib number, and the type of operation, however, did not paly a significant role in this regard.

It is widely accepted that any corrective surgery on a deformed spine should provide a balanced, well-corrected, cosmetically satisfactory result.[16, 17]

Correction of scoliotic curves becomes more complex in the presence of rib anomalies. In such patients the ribs are crowded together on one side and widely separated on the other side. With curve progression, a rib hump could develop on the convex side and a rib depression develops on the concave side.[18] This abnormality may cause extra pain, functional compromise, cosmetic concerns, low self-esteem, and psychological problems.[19, 20]

Despite dramatic improvements in surgical correction of rib deformities in scoliotic cases after introduction of more efficient techniques and better instrumentation systems in recent years,[2, 21-24] the efficacy and safety of rib resection is still a controversial topic.[5, 8, 10, 23, 25-32]

In a study on 34 patients with rigid thoracic curves, Pereira *et al*[33] showed that posterior thoracic instrumented fusion accompanied with concave ribs osteotomies reduced Cobb angle by 58%.

This rate was 35% in our patients with concomitant rib abnormalities and 52% in those without rib anomalies.

It is believed that the ribs are involved in transmission of loads from the sternum to the spine. In this concept, the ribs support maintenance of the thoracic spine from both sides in normal condition.[34] Acting as a buttress, concave ribs in scoliotic patients prevent reduction of the spine towards the midline and diminish curve flexibility.[33] This could explain why the amount of correction was significantly lower in our patients with unilateral rib deformities compared to those with bilateral involvement.

As mentioned before, the rate of correction was significantly less in cases with vertebral and rib anomalies at the same level than that in patients with abnormalities at discordant levels. We assume that such rib abnormalities may prevent surgeons from acting optimally, compromising final outcome of surgery. This assumption, however, needs to be verified in future clinical studies.

Abnormal rib count is not an uncommon finding in patients with scoliosis. Its effect, however, on surgical treatment has not been well described in the literature.[35, 36] We also found no contributing role for this variable in the present study.

It has been reported that a posterior-only fusion yields comparable rate of correction with an anterior-posterior approach in patients with adolescent scoliosis.[37] Detecting no significant role for the type of operation in determining the rate of postoperative correction in our work is a finding in line with this report.

This study bears some limitations. We used Cob angle change as the only outcome variable in this study, while corrections in other planes and flexibility rate could also affect drawing a solid conclusion. The main reason for this approach was that we sought to examine the influence of rib deformities on scoliosis correction outcome and Cobb angle has been proposed as on of the best indicators in this regard.[38] Although novel in nature in the current literature, findings of the present study need to be validated in clinical settings.

In conclusion, this study showed that the outcome of surgical correction of congenital scoliosis might be affected by the presence of rib deformities, especially complex and unilateral ones at the same level of vertebral abnormalities. The type of vertebral anomaly and variations in rib number did not play a significant role in this regard.

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Figure legends

Figure 1 Anteroposterior (upper row) and lateral (lower row) radiographs of the spine in a 14-year-old female with congenital scoliosis and no rib deformity before (A and C, Cobb angle=40^o) and after (B and D, Cobb angle=15^o) surgical correction

Figure 2 Anteroposterior (upper row) and lateral (lower row) radiographs of the spine in an 18-year-old female with congenital scoliosis and rib deformity on the concave side before (A and C, Cobb angle=85^o) and after (B and D, Cobb angle=56^o) surgical correction

Table 1 Association between percent postoperative Cobb angle decrease (CAD) and study variables

Variable			N	CAD (%) (Mean±standard deviation)	*p-value*
Sex		Male	48	43.93±19.05	0.25
		Female	46	43.93±19.05	
Type of vertebral anomaly		Segmentation failure	30	45.74±17.57	0.26
		Formation failure	50	40.89±19.14	
		Mixed failure	14	36.40±17.07	
Rib anomaly		Present	56	35.14±15.83	<0.001*
		Absent	38	51.54±17.82	
	Type	Simple	36	39.81±14.79	0.002*
		Complex	20	26.73±14.37	
	Side	Convex	12	35.66±10.61	0.02*
		Concave	20	42.30±18.09	

	Bilateral	24	28.90±13.77	
Level of rib-vertebral anomaly	Similar	18	22.17±19.33	0.03*
	Different	38	36.69±14.83	
Rib number	Increased	12	37.69±10.61	0.43
	Decreased	28	39.49±17.30	
	Normal	54	43.85±20.24	
Type of operation	Posterior	64	41.02±16.90	0.57
	Anterior and posterior	30	43.36±21.60	

*p-value<0.05 is statistically significant.

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