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ORIGINAL PAPER

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# Scoliosis curve correction, thoracic volume changes, and thoracic diameters in scoliotic patients after anterior and after posterior instrumentation

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**Abstract** Thoracic volume was calculated in 50 adolescent patients operated on for severe idiopathic thoracic scoliosis. In 25, anterior instrumentation was used (group 1), and posterior instrumentation in the other 25 patients (group 2). Calculation of thoracic volume was made from measurements of pre-operative and post-operative radiographs. The mean spinal curvature in group 1 was 73±12.4° before the operation, and 19±15° after the operation, and in group 2 the curvature was 75±13° before the operation and 37±10° after the operation. The calculated thoracic volume in the group with anterior instrumentation increased from 5234 ml pre-operatively to 6043 ml post-operatively, while with posterior instrumentation it increased from 5155 ml to 5489 ml. The correlation between the change in the Cobb angle and the thoracic volume change was poor for both groups. To determine the role in the thoracic volume increase of the frontal, sagittal and vertical thoracic diameters, further correlation tests were made between these and the thoracic volume increase in each diameter. The best correlation was found between the frontal and vertical increase of diameters in group 1, whereas in group 2 the best correlation was found between the volume increase and the sagittal parameters.

**Résumé** Le volume thoracique a été calculé chez 50 patients adolescents opérés pour une scoliose grave. Chez 25 patients une instrumentation antérieure a été utilisée (groupe 1), et chez 25 patients une instrumentation postérieure (groupe 2). La déviation moyenne de la colonne vertébrale dans le groupe 1 a été 73±12.4° avant l'opération et 19±15° après l'opération. Dans le groupe 2 la déviation a été 75±13° avant et 37±10° après l'opération. Dans le groupe 1 le volume thoracique calculé a augmenté de 5234 ml avant l'opération á 6043 ml après l'opération et dans le groupe 2 de 5155 ml á 5489 ml. La corrélation entre le changement d'angle de Cobb et le changement du volume thoracique a été faible dans les deux groupes. Afin de déterminer le rôle du diamètre thoracique frontal, sagittal et vertical dans l'augmentation du volume thoracique, des essais supplémentaires de corrélation ont été faits. Dans groupe 1 la meilleure corrélation a été trouvée entre l'augmentation des diamétres frontaux et verticaux, alors que dans groupe 2 la meilleure corrélation a été trouvée avec les paramètres sagittaux.

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## Introduction

Severe scoliosis is not only a three-dimensional spinal deformity but also a three-dimensional trunk deformity. It has been suggested that the trunk deformity is responsible for the severe cardiopulmonary difficulties that can occur in severe spinal deformities. Numerous authors report controversial results about the influence of severe scoliotic deformity on cardiorespiratory function [2, 3, 6, 8, 11, 12], and a number of investigations have been made in order to present scoliosis objectively as a three-dimensional spinal deformity [1, 5, 14]. However, very little is known about the relationship between scoliosis and thoracic volume (TV) [9, 10, 15], especially in relation to changes in thoracic volume after an anterior surgical correction. The purpose of this study was to compare the changes which occur in thoracic volume after posterior and after anterior instrumentation in severe thoracic idiopathic scoliosis. In order to assess the influence of frontal, sagittal and vertical thoracic diameters in thoracic volume change, a correlation analysis was performed between these parameters.

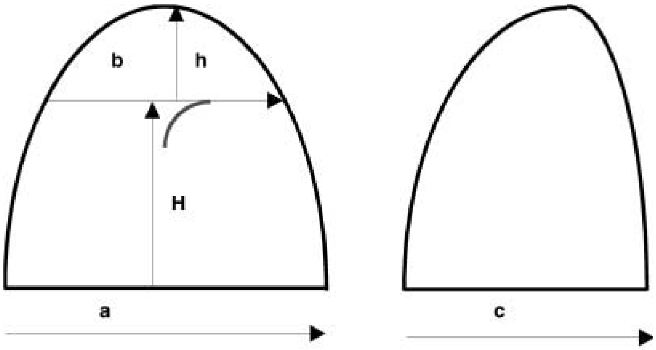


**Fig. 1** Schematic presentation of thoracic diameter measurements from plain X-rays (*a* thoracic width at the thoracic base, *b* thoracic width at the level of aortic arch, *c* sagittal diameter at the thoracic base, *H* thoracic length from the base to the aortic arch, *h* thoracic length from the aortic arch to the top of the thorax)

## Patients and methods

We studied 50 adolescent patients who underwent surgical correction of severe thoracic idiopathic scoliosis between 1995 and 1998. The groups included only major thoracic/minor lumbar and single thoracic curves (King II and King III types) as only thoracic changes were measured. Group 1 contained 4 boys and 21 girls (15.8±2.9 years) with anterior instrumentation. Group 2 had 5 boys and 20 girls (14.5±2.5 years) who underwent surgery with posterior instrumentation. The scoliotic curves in group 1 were 73±12.4° pre-operatively and 19±15° post-operatively. In group 2 the curves were 75±13° pre-operatively and 37±10° post-operatively. All the patients were operated on by the same surgeon and the same anterior instrumentation was used. Patients with posterior instrumentation were fused either by sublaminar wiring or by means of a multiple hook-rod system. The results between these two methods of posterior fixation did not differ significantly. No thoracoplasties were performed.

There are several methods to calculate thoracic volume using routine chest X-rays [4, 7, 9, 10, 13], and we used the formula proposed by Stolle at al. in 1985 [13]:

$$VT=3.14/3\times cH(a+b+b3/a)+2b2h/a \qquad (1)$$

where *a* is thoracic width at the thoracic base, *b* thoracic width at the level of the aortic arch, *c* sagittal diameter at the thoracic base, *H* thoracic length from the base to the aortic arch, and *h* thoracic length from the aortic arch to the top of the thorax (Fig. 1).

## Results

The calculated thoracic volume in group 1 increased from 5234 ml (range: 2976–8211 ml) pre-operatively to 6043 ml (range: 3969–8513 ml) post-operatively. In group 2 this increased from 5155 ml (range: 2327–8666 ml) to 5489 ml (range: 2559–9826 ml; Table 1). The results of the thoracic diameter changes (and percentage changes) are presented in Tables 2, 3, and 4. The correlation tests between the Cobb angle change and the thoracic volume change (Figs. 2, 3) showed a poor correlation rate (+0.19 for group 1 and –0.38 for group 2). A correlation analysis performed between the TV change and different thoracic diameter changes is presented in Figs. 2 and 3. Frontal parameters (*a* and *b*) played a significant role in group 1 (especially parameter *a*), whereas sagittal parameters were more important in posteriorly instrumented patients (Figs. 2, 3).

**Table 1** Average curve magnitude before operation (*Cobb 1*) and after operation (*Cobb 2*). Thoracic volume before operation (*TV1*) and after operation (*TV2*) expressed in ml. Increase of thoracic volume after operation expressed in percentage (*V%*)

| | Cobb1 | Cobb2 | TV1 | TV2 | V% |
|---|---|---|---|---|---|
| Group 1 | 73 | 19 | 5234 | 6043 | 17 |
| Group 2 | 72 | 37 | 5155 | 5489 | 6 |

**Table 2** The mean value of pre-operative and post-operative transverse diameters at the thoracic base (*a1* and *a2*, respectively), diameters at the level of the aortic arch (*b1* and *b2*), and sagittal diameters at the thoracic base (*c1* and *c2*) in cm

| | a1 | a2 | b1 | b2 | c1 | c2 |
|---|---|---|---|---|---|---|
| Group 1 | 11.98 | 12.58 | 10.46 | 11.02 | 7.99 | 8.07 |
| Group 2 | 11.62 | 11.77 | 10.34 | 10.44 | 7.85 | 7.87 |

**Table 3** The mean values of pre-operative and post-operative vertical diameters from the thoracic base to the aortic arch (*H1* and *H2*) and of the diameters from the aortic arch to the top of the thorax (*h1* and *h2*) in cm

| | H1 | H2 | h1 | h2 |
|---|---|---|---|---|
| Group 1 | 15.96 | 17.48 | 6.30 | 6.74 |
| Group 2 | 15.68 | 16.63 | 6.26 | 6.42 |

**Table 4** Postoperative increase in thoracic diameters expressed as percentage. Transverse diameters at thoracic base (*a*) and at the level of the aortic arch (*b*). Sagittal diameter change at the thoracic base (*c*). Vertical diameters from the thoracic base (*H*) and from the aortic arch (*h*)

| | a | b | c | H | h |
|---|---|---|---|---|---|
| Group 1 | 5.44 | 5.81 | 1.09 | 10.86 | 7.61 |
| Group 2 | 1.43 | 0.9 | 0.28 | 6.03 | 3.15 |

## Discussion

The thoracic volume was calculated from the thoracic diameters. These diameters are influenced by sex and age, but as we analysed the relationship between the diameters and the thoracic volume we were not particularly interested in the age and sex of the adolescents. The group of male patients was very small and the results are not relevant. The average ages of both groups were almost identical and they were also comparable in respect to sex and age. The calculation of the thoracic volume showed a significantly increased post-operative thoracic volume of 17% in the anteriorly operated group, whereas there was only a 6% post-operative increase in the posteriorly operated group.

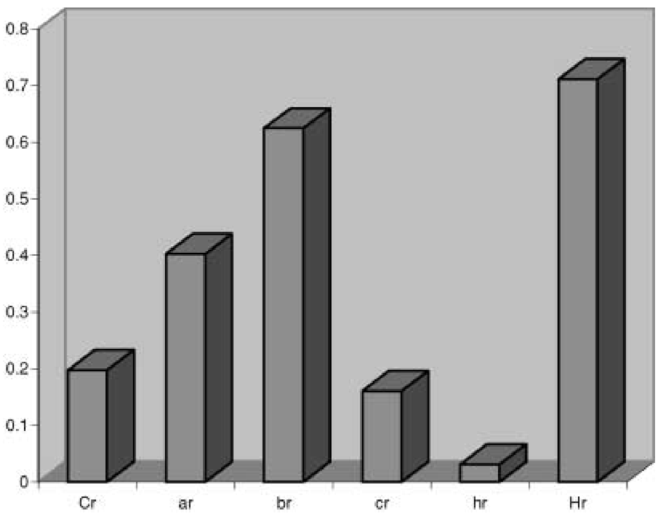


**Fig. 2** Correlation coefficients (*r*) in anteriorly instrumented patients (group 1) between the increase in thoracic volume and Cobb angle (*Cr*), transverse thoracic diameter "a" (*ar*), transverse thoracic diameter "b" (*br*), sagittal diameter "c" (*cr*), vertical diameter "h" (*hr*), and vertical diameter "H" (*Hr*)

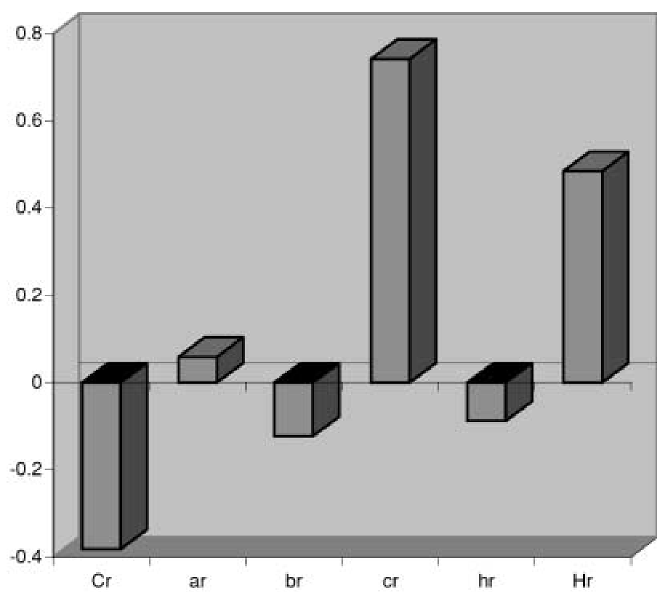


**Fig. 3** Correlation coefficients (*r*) in posteriorly instrumented patients (group 2) between the increase in thoracic volume and Cobb angle (*Cr*), transverse thoracic diameter "a" (*ar*), transverse thoracic diameter "b" (*br*), sagittal diameter "c" (*cr*), vertical diameter "h" (*hr*), and vertical diameter "H" (*Hr*)

When considering the better percentage of correction in group 1 it is possible that correction of the Cobb angle influenced the thoracic volume change. However, a correlation test did not confirm this hypothesis. In fact there was even negative correlation in group 2, and a poor correlation in group 1. It suggested that a change of Cobb angle had very little influence on the thoracic volume.

Frontal parameters (*a* and *b*) played a significant role in group 1 (especially parameter *a*), while sagittal parameters were more important in group 2. It was surprising that vertical parameters (*H* and *h*) played a greater role in group 1, despite the fact that a greater overall height increase is expected in posteriorly instrumented patients.

The height increase in posteriorly instrumented patients is probably due to distraction in the lumbar region rather than in a segment of the thoracic spine, so that any elongation in group 2 did not enter into the calculation. Sagittal parameters (*c*) played a crucial role in the posteriorly instrumented group, and this corresponds to a more pronounced 'kyphosing' effect in posteriorly instrumented patients.

We found a significantly lower volume increase (6%) in group 2, despite the 49% of frontal correction and the restoration of the normal thoracic kyphosis, than the 16% increase reported by Ogilvie and Schendel [10]. The relationship between thoracic volume and the increased kyphosis was given by parameter *c* which represents the sagittal width of the thorax and thus indirectly also the amount of kyphosis. We preferred this type of analysis as it gave us more relevant information. The level of the apex of the kyphosis varies in curves, which means that measurements may not be accurate. Our results showing an increased post-operative thoracic volume in group1 do not support the observation of Wong et al. [15] who found impairment of post-operative lung capacity after anterior procedures. However, in our study it was intended only to give an idea of the morphologic changes of the thoracic cage during the operative correction of scoliosis.

In conclusion, anterior instrumentation of the spine results in a significantly greater thoracic volume than occurs with posterior instrumentation. Changes in the Cobb angle have only a poor or even a negative correlation with thoracic volume changes. The frontal parameters (*a* and *b*) and the vertical parameter (*H*) influenced the thoracic volume increase more significantly in anterior instrumentation, whereas the sagittal parameter (*c*) and the frontal parameter (*b*) played the most important role in posteriorly instrumented patients.

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