Aortic Location and Flat Chest in Scoliosis : A Prospective Study

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Aortic Location and Flat Chest in Scoliosis: A Prospective Study

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Abstract

Background : Adolescent Idiopathic Scoliosis tends to be complicated with spine and ribcage deformities. In addition to the coronal curvature, among the features of right thoracic scoliosis, flat chest, ribcage rotation, cardiac compression and an aortic left shift are also observed. Aorta is known to shift in a leftward direction, especially at the mid-thoracic level. The cause of aortic left shift in scoliosis is not known. To clarify the features of a scoliosis deformity, especially the relationship of the aortic left shift and the flat chest in scoliosis, we investigated the CT scan images of scoliosis patients.
Methods : For the measurement of scoliosis patients, the pre-operative CT scans of 22 patients with non-congenital right thoracic scoliosis were recruited. For controls, 25 age-matched non-scoliosis patients were recruited. The aortic location, the ribcage rotation angle and chest depth were measured by CT scan. The chest depth was defined as the smallest inner chest cavity depth between the anterior vertebral body and the anterior inner chest wall.
Results : Chest depth in scoliosis patients was found to be significantly narrower than the control group at every thoracic level, from T6 to T11. The aortic left shift was significantly larger in scoliosis patients at all measured levels. The chest depth correlated with an aortic leftward shift ($r = 0.49$). The aortic location was found to be correlated with the ribcage rotation angle ($r = -0.52$), and the ribcage rotation angle correlated with the thoracic side curvature ($r = 0.61$)
Conclusions : In right thoracic scoliosis, an aortic left shift correlated with both flat chest and the ribcage rotation.

Key words : Scoliosis, Aorta, Flat Chest Rib Cage Deformity

Introduction

Adolescent Idiopathic Scoliosis (AIS) tends to be complicated with spinal and ribcage deformities[1]. Among the features of right thoracic scoliosis, flat chest, ribcage deformity and aortic left shift are often observed. The etiology of AIS is unknown, but it is important to clarify the cause of AIS for the development of fundamental treatments and preventive methods.

The aorta is known to shift leftward in AIS patients, especially at the mid thoracic levels[2)~4)]. The position of the aorta in scoliosis patients has been studied, as it is important to reduce risks of damaging aorta at the time of surgical procedures. However, it is not known why aortic left shift occurs and not known the relation to other coronal and axial deformities.

To clarify the features of AIS deformity, we investigated the flat chest, aortic position and rib cage rotation in each thoracic vertebral level using CT scan images of scoliosis, and analyzed the relationship between the aortic left shift and the other deformities.

Materials and Methods

For the measurement of scoliosis patients, from January 2008 to December 2009, pre-operative CT scans of 22 patients with non-congenital right thoracic scoliosis (7 male subjects, 15 female subjects, 16.0 years of age (range, 13-24), Cobb 63 : 43-90, height 160.3 ± 9.0 cm, body weight 47.4 ± 7.1 kg) were used. All scoliosis patients had a

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right thoracic curvature, with an upper end vertebra of T5.3 ± 0.6 (mean ± standard deviation), a lower end vertebra of T11.7 ± 1.0, and an apex of T8.5 ± 0.8 by average anatomical levels found in the patients. Age-matched control subjects (9 male subjects, 17 female subjects, 15.9 years of age (range, 13–21), height 158.3 ± 9.0 cm, body weight 50.8 ± 10.3 kg) who underwent a chest CT scan without obvious thoracic disease were recruited. There was no significant difference of body mass index between scoliosis patients and age-matched control. CT scans were performed in scoliosis patients to assess the spinal deformity and pedicle size for the spinal instrumentation. No new CT scan examination was ordered for the current study. The present project received approval from the Ethical Commission of Kyushu University Hospital.

All CT images were measured on the computer screen using a special measuring device (Fuji Synapse System, Fujifilm holdings, Tokyo, Japan). The chest depth (*d*), aortic location (*a*), and ribcage rotation angle (∠θ) were measured in each vertebral level from T6 to T11 (Fig. 1). Due to the fact that in scoliosis patients the vertebrae are tilted and the vertebral level is difficult to define, the level was therefore defined as the number of left-side vertebral rib heads. The chest depth was defined as the shortest distance between the vertebral body and the inner anterior chest wall (*d*). To measure the aortic location (*a*), we marked the center of the aorta on the neck of the rib, then determined the distance from the rib head (positive in value if found on the anterior-right side). The ribcage rotation angle (∠θ) was defined as the divergence from right angle between the line from the sternum to neural canal (basal line) and the line of the bilateral posterior inner chest wall. The rightward ribcage rotation was defined as positive.

The GraphPad Prism statistical software program (GraphPad Software, CA, USA) was used for the statistical analyses. The statistical methods included Pearson's correlation and Student's *t*-test. P-values of less than 0.05 were considered to be statistically significant.

Results

The chest depth was measured at levels from T6 to T11. The mean chest depth in AIS patients was significantly smaller than the control group for every thoracic level from T6 to T11 (Fig. 2). The difference compared to the control was the largest in the mid-thoracic level, around the T8 and T9 level.

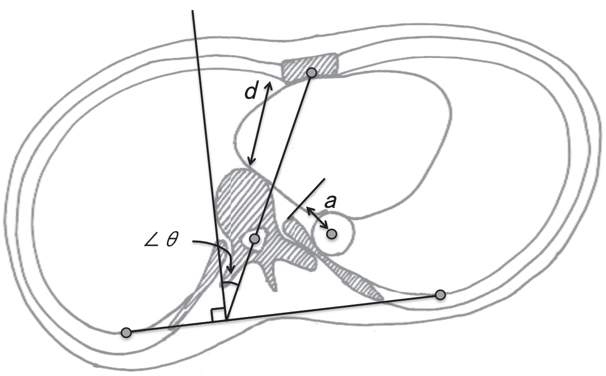

Fig. 1 CT image measurement
The chest depth (*d*), the aortic location, a positive value if found on the anterior-right side (*a*), and the ribcage rotation angle (∠θ) were measured on CT image. Rightward ribcage rotation was defined as a positive value.

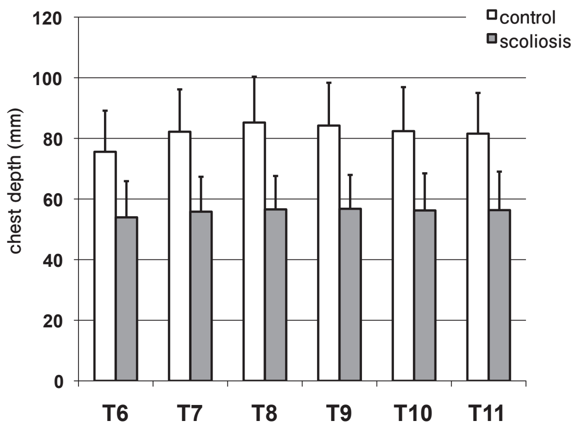

Fig. 2 Flat chest in AIS patients
The mean chest depth measured at each vertebral level is shown. The chest depth in AIS was significantly smaller than in normal spines at every thoracic level from T6 to T11. Bar shows the mean ± standard deviation.

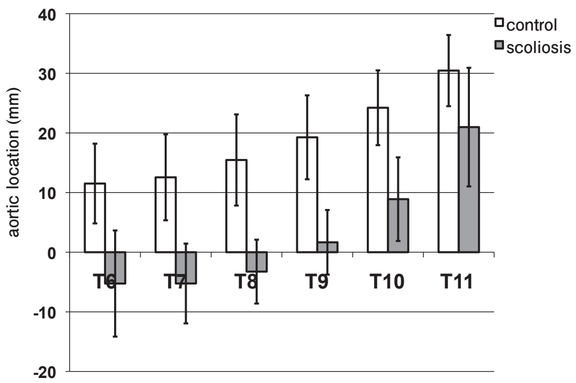

Fig. 3 The aortic leftward shift in AIS is prominent at the mid-thoracic level
The mean aortic location at each vertebral level is shown. The aorta shifted leftward in AIS patients at every measured vertebral level from T6 to T11. Bar shows the mean ± standard deviation.

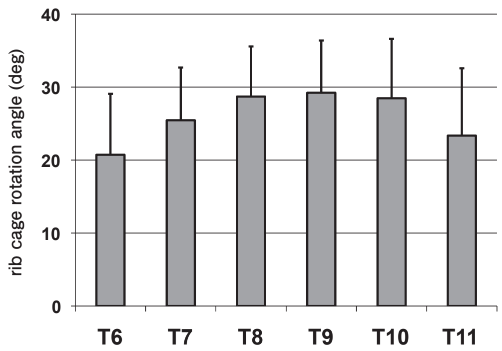

Fig. 4 Chest deformity in AIS patients is prominent at T8 and T9
The mean chest rotation angle is shown. Ribcage rotation was prominent at every vertebral level from T6 to T11, at T8 and T9 in particular, around the apical vertebrae. Bar shows the mean ± standard deviation.

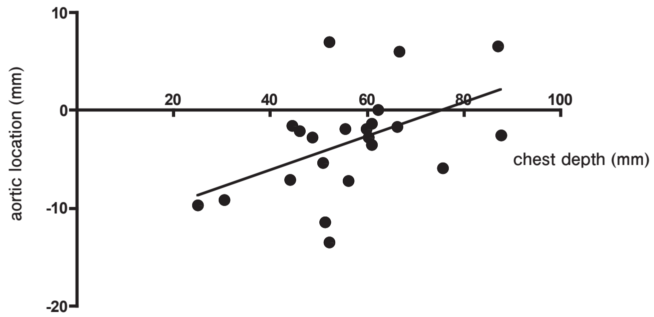

Fig. 5 Flat chest correlates with an aortic leftward shift.
Chest depth was correlated with the aortic location at the T8 level (r = 0.49, p = 0.020). In the individual who has a flat chest, the aorta is located more leftward in the thoracic cavity.

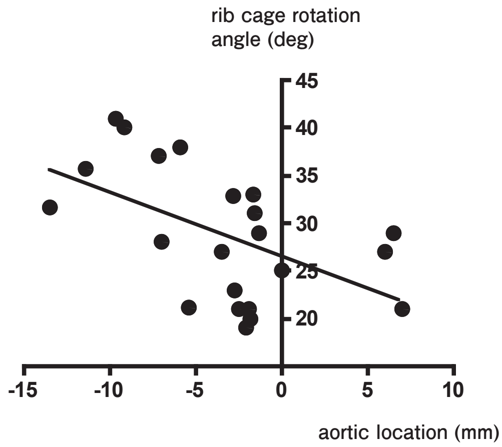

Fig. 6 Aortic location correlates with ribcage deformity.
The aortic location correlated with the ribcage rotation angle at the T8 level (r = −0.52, p = 0.012). In the individual with an aortic leftward shift, rightward ribcage rotation is prominent.

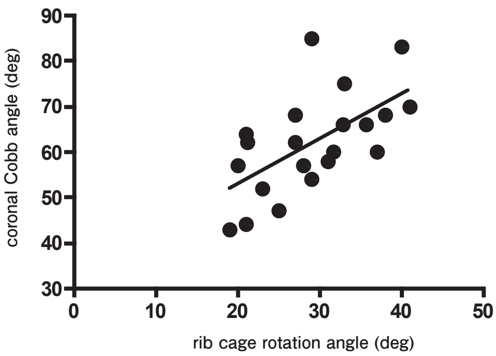

Fig. 7 Ribcage rotation correlates with the Cobb angle.
The ribcage rotation at the T8 level was correlated with the thoracic side curvature (r = 0.61, p = 0.003).

The aortic location was measured at levels form T6 to T11. The mean aortic leftward shift was significantly larger in AIS patients in all measured levels from T6 to T11 (Fig. 3). In particular, the difference was larger in the mid-thoracic region, around T8 and T9.

The chest deformity angle in AIS patients was observed at every thoracic level from T6 to T11. The mean chest deformity angle was the most prominent in the T8 to T10 levels (Fig. 4). Measuring the ribcage rotation angle, the sternum at the T11 level could not be identified in 3 patients. For those cases, the soft tissue just beneath the sternum was determined to be the anatomical point.

As the aortic left shift and chest deformity angle was prominent at the mid-thoracic level, the correlation of the deformities was analyzed at the T8 level. The chest depth correlated with the aortic location ($r = 0.49$, $p = 0.020$) (Fig. 5). The aortic location correlated with the ribcage rotation ($r = -0.52$, $p = 0.012$) (Fig. 6), and the ribcage rotation correlated with the thoracic side curvature ($r = 0.61$, $p = 0.003$) (Fig. 7). The chest depth was not well-correlated with the ribcage rotation angel ($r = -0.27$, $p = 0.229$) or with the coronal Cobb angle ($r = 0.36$, $p = 0.102$). In addition, the aortic location did not correlate closely with the coronal Cobb angle ($r = -0.14$, $p = 0.530$).

Discussion

Flat chest, aortic left shift and ribcage deformities all tend to be reported in patients with AIS[1]. We confirmed that these deformities were prominent compared to a normal spine, particularly at the middle thoracic level around T8 to T9.

In the normal spine, the thoracic ribcage is large at the T8 level to accomodate the heart. However, in AIS patients, a flat chest was observed, especially at the T8 and T9 levels compared to the control group. The aortic leftward shift was significantly greater at every measured thoracic level, from T6 to T11, especially from T8 to T9. The aortic leftward shift in AIS patients has been well studied to reduce the risk of damaging it during surgery[2)~4)].

Ribcage deformity, known as a rib hump, is prominent by the forward-bending test, and is used in school screenings. Because the ribcage deformity is easily detectable by CT scan, we measured the posterior ribcage rotation by the angle of bilateral posterior chest wall and the basal line (sternum and neural canal). The ribcage rotation angle was prominent, especially from T8 to T10.

In complicated scoliosis deformities, it is difficult to differentiate the primary changes in deformities from the secondary changes. Among the complicated axial deformity, the correlation of these changes is not well characterized. By our observations, the aortic left shift correlated with chest depth and ribcage rotation angle, but the flat chest did not correlate well with the ribcage rotation angle. Although the coronal Cobb angle correlated with the ribcage rotation angle, the coronal Cobb angle was not correlated with other deformities such as chest depth and aortic location. It is not known why the aortic left shift occurs, but based on the findings in the present study, we hypothesize that a flat chest and an aortic leftward shift are involved in the etiology or risk factors for scoliosis progression. In other words, in a flat chest, there is only a limited amount of space for the thoracic organs, and the heart and the aorta are compressed and pushed leftward and the vertebrae are pushed rightward, until finally these deformities induce ribcage rotation and a coronal scoliosis deformity. In fact, in the flat chest patients, for example in patients with a funnel chest, the tendency to develop scoliosis is considered to increase[5)~8)].

Recently, coronal and sagittal deformities were corrected by surgical procedures with spinal instrumentation. If scoliosis deformities occurred after a flat chest, and if scoliosis deformities are the result of maintaining space for the thoracic organs, the correlation of spinal alignment by a surgical procedure without a correlation of hypokyphosis might result in the heart and aorta being pushed harder into the flat chest, and heart dysfunctions may occur after the surgery. To maintain the space in the thoracic cavity for the chest organs, it may be important to gain thoracic space by the achievement of kyphosis during surgical correction in the thoracic spine.

The deformities in AIS patients are complicated. It is not even known whether each scoliosis deformity occurs in the early stages and whether they correlate with the AIS etiology or occur as a secondary deformity that is not involved with the AIS etiology. We found the presence of a flat chest to be correlated with an aortic leftward shift and the aortic leftward shift was correlated with ribcage rotation. It is not known whether these correlations are the causes or the result of AIS according to the current observations. To investigate the mechanism and etiology of the AIS, early-stage scoliosis observation or animal models of scoliosis must therefore be examined in the future.

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（和文抄録）

側弯症における大動脈位置と胸郭前後径の関係

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目的：思春期特発性側弯症における脊椎及び体幹の変形は，前額面での側弯のみでなく Flat chest や胸郭の回旋変形，そして大動脈の左方変位など複雑である．側弯の原因を考える意味でも大動脈の左方変位が起こるメカニズムを明らかにすることは重要と考え，特に胸郭回旋変形および胸郭前後径との関係について調べた．
方法：術前 CT を撮影した 22 例の思春期特発性側弯症患者および対象群として健常人（他疾患スクリーニング目的 CT 撮影者）25 例について計測を行った．計測項目は，大動脈の位置，胸郭回旋角度，胸郭前後径であり，それぞれ CT 画像上で T6 から T11 までの各レベルで計測し，それぞれの相関について調べた．
結果：側弯症患者では T6 から T11 全てのレベルにおいて有意に胸郭前後径が減少していた．大動脈の位置は T6 から T11 全てのレベルにおいて有意に後左方に変位していた．各変数の関係を見ると，胸郭前後径と大動脈左方変位に相関を認めた（r = 0.49）．また大動脈左方変位と胸郭回旋角度の間（r = 0.52）および胸郭回旋角度と側弯 Cobb 角の間（r = 0.61）に相関を認めた．
考察：胸郭前後径が小さい個体では，胸郭内臓器の収まるスペースが減少するため心臓及び大動脈は正中から左側に押し出され，椎体は逆に右側に押され，その結果として胸郭の回旋および側弯が起こっている可能性があると考えた．