Dextrocardia and coronal alignment of thoracic curve: a population study

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Abstract The objective of this study was to evaluate the coronal alignment of the thoracic spine in persons with dextrocardia. Generally, the thoracic spine is slightly curved to the right. It has been suggested that the curve could be triggered by pulsation forces from the descending aorta. Since no population study has focused on the alignment of the thoracic spine in persons with situs inversus, dextrocardia, and right-sided descending aorta, we compared the radiographs of the thoracic spine in persons with dextrocardia to those having normal levocardia. Among 57,440 persons in a health survey, 11 cases of dextrocardia were identified through standard radiological screening. The miniature chest radiographs of eight persons were eligible for the present study. The study was carried out as a nested case–control study. Four individually matched (age, gender, and municipality) controls with levocardia were chosen for each case. Coronal alignment of the thoracic spine was analyzed without knowledge of whether the person had levo- or dextrocardia. A mild convexity to the left was found in all persons with dextrocardia and right-sided descending aorta (mean Cobb angle 6.6° to the left, SD 2.9). Of the 32 normal levocardia persons, 29 displayed a convexity to the right, and the

remaining three had a straight spine (mean Cobb angle 5.2° to the right, SD 2.3). The difference (mean 11.8°, SD 3.5) differed significantly from unity ($P = 0.00003$). In conclusion, it seems that a slight left convexity of the thoracic spine is frequent in dextrocardia. We assume that the effect of the repetitive pulsatile pressure of the descending thoracic aorta, and the mass effect of the heart may cause the direction of the convexity to develop opposite to the side of the aortic arch.

Keywords Situs inversus · Dextrocardia · Left thoracic curve · Aorta

Introduction

Although in normal individuals the spine is generally considered to be straight in the coronal plane, there is almost invariably a subtle lateral curvature in the thoracic spine. Even anatomists have observed the habitual lateral curve and regarded this a natural alignment (e.g., in the 37th edition of Gray's anatomy) [12]. However, the direction of the thoracic curvature is not randomly distributed between left and right. In the thoracic spine, this mild curvature is usually convex to the right [6, 8, 27].

There have been numerous speculations about associations of the left thoracic curve configuration with various conditions. Already in 1733, in *Osteographica*, Cheseldon [18] described the spine as “bent to the right side for better situation of the heart, which makes that side of the breast more convex and therefore stronger”. The combination of a left convex thoracic curve, dextrocardia, and right-sided aorta has been reported in a few selected cohort studies. Clinical experiences also suggest a possible association between a left thoracic curve and scoliosis, and certain

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pathologies such as some neurological conditions [5, 10, 21, 29] and congenital heart diseases [16, 20, 24]. In 1972, Jordan et al. [14] reported a strong association between the side of the heart and convexity of the thoracic curve to the opposite side. As dextrocardia and malposition of the aorta is rare, there are no extensive epidemiological data on the direction of the convexity of the thoracic spine in these patients.

To our knowledge, there are no matched studies that have investigated an association of the coronal alignment of the thoracic curve with dextrocardia in a random population. The objective of this nested case–control study was to determine the shape of the thoracic spine in the coronal plane in persons with dextrocardia, and to compare the direction of the curvature to that in persons with a normal levocardia.

Materials and methods

Subjects

The study subjects were gathered from a population-wide, multiphase health survey conducted in various parts of our country between 1966 and 1971. The survey consisted of 30,188 men and 27,252 women, aged 15–99 years, from both rural and urban areas. Details of the survey population, survey methods, and baseline results have been published earlier [1]. The position of the heart, in addition to several other parameters, was analyzed independently by two radiologists from the miniature standing chest radiographs (100 mm photofluorograms) of the participants. Eleven cases of dextrocardia were found. For nine of these, the original radiographs and medical records were available for re-evaluation from the archives. The two radiologists of the present study (K.T. and M.L.) confirmed dextrocardia in all cases, based on side marks and text on each image. In one case, the spine was overexposed on the radiograph and could therefore not be evaluated. Thus, the study group consisted of eight persons, six men and two women, with a mean age of 43 years (range 19–68 years).

For this study, four individually matched (age, sex, and municipality) controls per each dextrocardia case were enrolled from the same health survey. Exact matching was performed for sex and place of residence, whereas nearest available matching was used for age within the sex–place strata.

Radiological method

All miniature chest radiographs were obtained in the standing position. Using a video camera, the radiographs

were magnified on a monitor screen and adjusted for brightness and contrast. The original marks on the films indicating the left and right sides were covered during the analysis. For the analysis, the images of the eight persons with dextrocardia were mixed with the images of 32 controls. When performing the measurements all images were viewed with the heart on the left side. The direction and magnitude of thoracic convexity and the side of the thoracic aorta were analyzed without knowledge of the real position of the heart. In all cases with a visible gastric air bubble, it was located on the same side as the heart, both in the persons with levocardia and those with complete situs inversus. The magnitude of the curvature was assessed by the Cobb method [3] using an angle measurer (Plurimeter, Dr. Rippstein, La Conversion, Switzerland). An approximately 8× magnification was used, making angle measurements along vertebrae endplates easy. Only after all the measurements were completed the real position of the heart and the descending aorta, and the convexity of the thoracic curvature was revealed. In six cases a total situs inversus was confirmed, with the heart, the aorta and gastric air bubble situated on the right side. In the remaining two cases it was not possible to determine whether the findings were compatible with dextrocardia or a total situs inversus.

Statistical analysis

The statistical significance of differences in the direction and degree of thoracic curvature between persons with dextrocardia and controls was tested using the paired *t* test. Statistical analysis system (SAS) software (Version 9.1.2, SAS Institute, Gary, NC, USA) was used for statistical analysis.

Results

Each of the eight persons with a previously established, and by us reconfirmed dextrocardia had a right-sided descending aorta. A left convex thoracic convexity was found in all persons with dextrocardia and right-sided descending aorta (mean Cobb angle 6.6° to the left, SD 2.9). In contradiction, none of the normal levocardiac persons showed a convexity to the left (mean Cobb angle 5.2° to the right, SD 2.3). This difference in the direction of the curve was statistically significant ($P = 0.00003$). Otherwise the distributions of cases and controls seemed mirror reflections (Table 1). Two of the spines of the dextrocardia cases, and four of the controls had curves of 10° or more, meeting the radiologic criteria for true scoliosis.

Table 1 Convexity (Cobb angle, degrees) of the thoracic spine in eight cases with dextrocardia and the set of individually matched control radiographs

Distribution	Dextrocardia degrees to left	Control sets degrees to right	Difference
Mean	6.6	5.2	11.8
Standard deviation	2.9	2.3	3.5
Smallest value	2.0	2.5	4.5
Lower quartile	4.5	3.6	10.4
Median	7.0	5.1	12.6
Upper quartile	9.0	5.8	14.5
Largest value	10.0	10.0	15.0
<i>P</i> value*			0.00003

* Paired *t* test; convexity to the left was considered negative

Discussion

In this population-based study comprising chest radiographs of 57,440 persons, eight persons with a dextrocardia, a right-sided aortic knob and a well visible and measurable thoracic spine were found. All of them showed a slight left convexity of the thoracic spine. None of the 32 controls matched for age and gender had a convexity to the left; 29 displayed a convexity to the right, and the remaining three had a straight spine.

The term dextrocardia refers to a condition in which the cardiac apex is on the right side. In most individuals, the aortic knob and the thoracic aorta are located on the same side as the heart. The incidence of dextrocardia in a study reported from Australia by Kidd et al. [15] is 0.40 per 10,000 live births. An almost similar incidence, 0.53 per 10,000 live births, was estimated by Ferencz et al. [7] in an infant study spanning an 8-year period from 1981 to 1989 in Baltimore, Washington, USA. These as well as other studies confirm that dextrocardia is a rare congenital anomaly. In our population-based sample, the prevalence of dextrocardia was higher, 1.9 per 10,000 adult persons. Apart from genetic factors, no definite explanation for this difference can be offered. However, it is important to note that case identification from chest radiographs, as performed in our study is more sensitive than a clinical examination of infants.

In a review of radiographs of 550 patients with idiopathic scoliosis, McCarver et al. [17] found that 1.3% had a left thoracic curve. More recently, Coonrad et al. [4] reviewed the radiographs of 2,000 cases of idiopathic scoliosis, covering a period of 30 years, and noted in 2.2% a left thoracic curve pattern. Some authors have attributed the left thoracic curve to the bending effect of the heart and aorta [19, 22, 27]. The fact that the aortic arch is frequently contralateral to the convexity of the spinal curve has led to speculations that the spine deviates laterally, away from the vigorous pulsations of the aorta [14, 22]. Taylor [27] has propounded the hypothesis that the aorta in its position exerts an asymmetrical rotational force on the vertebral

bodies. In adolescents, he found a flattening of the vertebral bodies on the side of the aorta. Taylor concluded that the direction of the spinal curvature may be explained by the normal vascular asymmetry seen in almost all humans.

In extensive population studies on scoliosis, spine curvatures have been identified and classified based on radiographs according to their coronal patterns, direction, magnitude and whether they are single or double, or primary or secondary [4, 6, 9, 11, 13, 24, 25, 28]. However, besides the type of scoliosis, no notice has been taken of levo- versus dextrocardia, although this would have been easy to identify. Neither has the opposite, i.e. the occurrence of left thoracic curves in explicitly and solely levocardiac persons been investigated and reported. On the other hand, occurrence of left thoracic curvature has been noted in some levocardiac persons in association with some cardiac and neurological disorders.

Spinal curvatures occur much more frequently in patients with congenital heart diseases than in the general population, but the reason for this is debated. In a study on patients with various congenital heart diseases, Jordan et al. [14] noted that the cumulative incidence of scoliosis was much higher, from 19 up to 44%, depending on what magnitude of curve was considered significant. They found a strong association between the direction of the convexity and the aortic arch—usually the convexity was opposite to the side of the aortic arch. Their conclusion was that the spine is bowed away by the pulsations of the aortic arch and the descending aorta. In the following year, Roth et al. [22] published a study of 500 consecutive patients with congenital heart disease and a scoliosis greater than 10°. In their study, one-third of the 33 dextrocardia patients had scoliosis, probably attributable to the high percentage of cyanotic individuals. The conclusion was that the side of the aortic arch did not seem to have a significant influence on the direction of the scoliotic curve. Roth's material consisted of patients with heart pathology, while ours comprised individuals without other abnormality than a 'mirror image' of the thoracic organs. Furthermore, only two of the eight cases

with dextrocardia in our study exhibited curvatures of 10° or more, meeting the criteria for scoliosis according to the Scoliosis Research Society.

Analyses of tuberculosis screenings using miniature chest radiographs have been used earlier to estimate the prevalence of thoracic scoliosis [2, 6, 24, 25]. Although these images are usually adequate for evaluating the thoracic curve, their quality does not always allow diagnosis of structural changes of the vertebrae or classification of scoliosis. The reason for this is that the films are optimally exposed for soft tissues and not for bony details. Due to poor definition of the vertebral bodies, one of the dextrocardia cases was excluded from the present study. Furthermore, the small size of the vertebral bodies in the miniature radiographs occasionally made accurate angle measurements difficult. To overcome this problem, we magnified the size of the vertebral bodies from 4–5 to 30–40 mm, resembling the magnification in a frontal radiograph of the spine, obtained at a distance of 2 m.

Similar to our study, most of left thoracic convexities have been shown to be minor, insignificant, and less likely to progress [23]. In a 5-year prospective study of the natural history of curves in 839 children, none of the 32 children with left thoracic curve showed progression in contrast with 22% among the 116 children with right thoracic curve [26]. On the other hand, left thoracic scoliosis is more likely to have an identifiable underlying pathology. Not only the literature but also clinical practice has been focused on asymmetrical organs and structures that in situ inversus are located abnormally. However, in our study, we found that at least the curvature in the thoracic spine follows the same pattern as the non-paired internal organs, i.e. the heart and the aorta, in the chest. Therefore, it is tempting to speculate whether the paired bony structures, such as ribs and shoulders, are also swapped, although this would not involve any consequences of practical significance.

The nested case–control design is actually effective in relation to the number of subjects analyzed. The results of our nested case–control study has a statistical power sufficient enough to show that the direction of a slight thoracic convexity differs significantly between persons with dextrocardia and levocardia. Although our study population material consisted of 57,440 persons, this was not large enough to identify numerous cases with both dextrocardia and scoliosis of substantial magnitude. In our study two of the dextrocardia subjects and four of the controls had a curvature classified as scoliosis, the remaining curvatures being less than 10° . Therefore, the data cannot be interpreted to automatically suggest full-blown structural scoliosis in the presence of dextrocardia. Our results support earlier hypotheses about the convexity of the thoracic curve being opposite to the side of the heart and aorta [14, 19, 22].

Conclusion

In this population-wide health survey including chest radiographs, eight persons with measurable thoracic spine had dextrocardia and a right-sided aortic knob. All of these dextrocardia patients had an obvious left convexity of the thoracic spine. To investigate the significance of this result, we compared the findings to 32 gender- and age-matched controls. None of these persons with ‘normal’ levocardia had a left thoracic curve, but 29 displayed a convexity to the right and the remaining three had a straight spine. Thus, we conclude that left convexity of the thoracic spine is frequently present with dextrocardia.

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