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EVALUATING THE EFFECTIVENESS OF NEW RADIOLOGICAL INDEX FOR THE DIAGNOSIS OF THE PECTUS DEFORMITIES USING COMPUTED TOMOGRAPHY IMAGING

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Abstract

BACKGROUND: Chest deformities have an incidence of 1:1000 live births and with the wide spectrum of congenital chest wall deformities seen, pectus deformities are by far the most common anterior chest wall deformities. Many international indices have been utilized for the evaluation of pectus deformities which aid in categorizing the chest as normal or deformed. With every index presenting its own limitations and drawbacks, precise radiological assessment parameters delineating the limits of normal and pathological have not yet been defined. The present study has attempted to bring forth a new radiological index for the overall quantitative assessment of pectus deformities, by the inclusion of manubriosternal joint (MSJT) angulation or position alongside international radiological indices. The influence of MSJT alteration on mediastinal/intra-thoracic space has been assessed by correlating with Sterno-vertebral distance and transverse diameter of the chest.

AIM: Therefore, this study was aimed at evaluating the effectiveness of a new radiological index for the diagnosis of pectus deformities using computed tomography imaging.

MATERIAL AND METHOD: his Case-Control study has been conducted in the Department of Radiology.30 subjects with mild to moderate pectus deformities and 50 controls, with the age group of 1- 40 years were evaluated for the study. Non-contrast computed tomography images with sagittal, axial sections were utilized for the measurement of the manubriosternal joint (MSJT) angle, Vertebral index, Haller's Index, sterno-vertebral distance (SV), and the transverse diameter of the chest (a). The purpose of the study was explained to patients. Informed written consent was taken prior to the actual participation of the patient in the study. Data were tabulated and statistical analysis was performed using ANOVA and unpaired student's t-test.

RESULTS: The Sterno-vertebral distance was increased in the pectus carinatum and reduced in pectus excavatum in comparison with controls, which were found statistically significant, whereas the transverse diameter of the chest showed higher distance in pectus excavatum and lower distance in the pectus carinatum when compared with controls. Therefore, the sterno-vertebral distance had a positive correlation with MSJT angulation, whereas the transverse diameter of the chest showed a weak negative correlation. A comparison of international radiological indices in controls and cases was documented. In pectus carinatum, the vertebral index showed a lower mean of 18% and Haller index with a ratio of 2.08, whereas in pectus excavatum the vertebral index had a higher mean of 24% and Haller index with a 3.2 ratio, which was significantly higher in comparison with controls.

CONCLUSION: Only a better knowledge of normal anatomical parameters enables a better understanding of both normal and abnormal. Therefore, it was necessary to estimate the normal range of MSJT angulation so as to identify the extent of changes in MSJT angulation in pectus deformities. Our study has been the first of its kind where in the MSJT is being taken into consideration for measuring the severity of chest wall deformation. The knowledge about MSJT angulation can be used as an objective method for the assessment of patients with pectus deformities.

KEYWORDS: Pectus deformities; Manubriosternal angulation; Radiological index; Chest wall, Posterior depression, Configuration index, Vertebral index

Introduction

Congenital chest wall anomalies are grouped under two categories: those with overgrowth of the rib cartilage causing depression or protrusion, and those with varying degrees of either dysplasia or aplasia of skeletal components of the thorax.[1] Chest deformities have an incidence of 1:1000 live births[2] and with a wide variety of congenital chest wall deformities seen; pectus deformities are by far the most common anterior chest wall deformities. PE is the posterior depression of the sternum and costal cartilage, accounting for about 87% of anterior chest wall deformities. It can be easily detected during birth and progresses with growth, especially during puberty. [,3, 4] It occurs in 1 per 400 live births, more common in males at a male-to-female ratio of 4:1, with a strong genetic predisposition of 40-45%.[5] PC (pouter pigeon deformity and chicken breast) is an anterior protrusion of the sternum, that occurs less frequently than PE. It is rarely distinguished at birth and exaggerates during the pubertal growth spurt. It occurs approximately 1 per 1500 live births, more common in males. It constitutes 5-15% of chest wall deformities, with a family history of 26%.[6,7]Many thoracic surgeons and radiologists have done extensive work on radio-diagnosis of pectus deformities and have given many internationally accepted radiological indices for evaluating and categorizing chest wall. Among those indices, Haller's index (HI), classical vertebral index (VI), configuration index (CI), and cardiac deformity index, have proved to be beneficial for the objective evaluation of pectus deformities and also in quantitative assessment of internal thoracic volume.[8-9] With every index presenting its own constraints and drawbacks, precise radiological assessment parameters depicting the limits of normal and pathological, have not yet been defined.[10]

The manubrium and the body of the sternum along with ribs and vertebral column are among the key components providing a normal contour/shape to the chest. It is the alteration of these components, which changes the shape of the chest from being round or oval during infancy to a reniform shape in adults and even pigeon or funnel-shaped chest as seen in pectus deformities. Furthermore, in the development of pectus anomalies, the sternum is usually regarded as the culprit. The advocates of this hypothesis believe that displacement of the sternum occurs first, followed by changes in the costal cartilages, which have no option but to follow the sternum in its displaced position. In pectus deformities, sternal depression/protrusion usually begins at the 3 junctions of the manubrium and body (gladiolus) and becomes progressively deeper toward the xiphoid process.[11]

Intra-thoracic space has a limited area to accommodate numerous structures including the heart and lungs. Openshaw and Haller et al explained the alteration in the intra-thoracic space and its dimensions, which may be seen due to positional change of sternum in front, ribs on either side or vertebral column behind. These changes are seen as a part of aging the process from early infancy to adulthood or in the cases of the anterior chest wall and spine deformities.[12,13] The contribution of ribs and vertebral column in providing the shape to the thoracic cage and its alterations in the chest wall and spine deformities are well understood as extensive literature is available, but the involvement of the sternum and its contribution to the shape of the thorax is not clearly understood.

Our study has been an initial step toward exploring the different presentations of chest deformities in the Indian population. The study has attempted to bring forth a new radiological index for the overall quantitative assessment of pectus deformity, by the inclusion of MSJT angulation or position alongside international radiological indices. The influence of MSJT alteration on mediastinal/intra-thoracic space has been assessed by correlating with Sterno-vertebral distance and transverse diameter of the chest. Therefore, MSJT angulation can be considered an indicator of a normal and deformed chest.

MATERIAL AND METHODS

This Case-Control study has been conducted in the Department of Radiology. Controls – Individuals with normal chest contour of age group 1 – 40 years (N=50). Cases – Patients with pectus excavatum and carinatum of age group 1 - 40 years(N=30). The purpose of the study was explained to patients. Informed written consent was taken prior to the actual participation of the patient in the study. Patients were then explained about their disease process and the possible line of management. Informed written consent was taken from the patients or their guardians willing to participate in the study.

Inclusion criteria for controls:

The criteria for the inclusion of normal subjects were as follows:

1. Chest wall with the absence of depression or protrusion of the central portion of the anterior thoracic wall in relation to the adjacent costal cartilage, during physical examination.
2. Age ranges from 1 to 40 years; 2.4

Inclusion criteria for cases:

The criteria for inclusion of patients with PE and PC were as follows:

- ✓ Presence of the depression or protrusion of the anterior thoracic wall in relation to the adjacent costal cartilage.
- ✓ Age ranges from 1 to 40 years

Exclusion criteria for controls

Subjects whose chest walls were found to be deformed on physical examination were excluded.

Exclusion criteria for cases

- ✓ Sternal fractures or rib fractures may sometimes give a false appearance of a deformed chest.
- ✓ Surgically subjected chest wall (overcorrected chest wall during pectus deformity).

Measurement of Radiological Indices

Sagittal and axial images and plain CT images of the thorax have been utilized for the measurement of angulation and diameters.

Manubriosternal joint (MSJT) position/ angulation measurement

Measurement of MSJT angulation was performed by marking points on the different areas of the sternum on the sagittal CT image of the thorax. The first point was marked on the upper-end posterior border of the manubrium, the second point on the posterior end of MSJT, and the third point was marked along the posterior border of the body of the sternum at the level of the fourth costal notch. The angulation at the posterior end of MSJT was determined by drawing a line joining the first point with the second and another line joining the third point with the second, creating an angle at the posterior end of MSJT, which was measured by the "Java 8" inbuilt software.

Measurement of the vertebral index (VI)

It is defined as "the quotient of the sagittal diameter of the vertebral body and the sagittal diameter of the chest, which measures from the anterior portion of the vertebral body to the posterior portion of the sternum". These diameters are measured at the point of maximum concavity of the sternum, which is the deepest part of the deformity, or at the xiphisternal joint for normal subjects 15.

Measurement of Haller's index

It is the ratio between the horizontal distance of the inside of the rib cage at the widest point by the minimum anteroposterior distance from the midpoint of the anterior surface vertebral body and the posterior surface of the sternum 16. In case of asymmetrical pectus deformities, it is necessary to measure from the deepest coastal cartilaginous which shows maximum depression to a line tangential to the anterior cortex of the subjacent vertebra

To analyze the influence of manubriosternal angulation on internal thoracic volume. Two important thoracic dimensions were taken into consideration

- Sterno-vertebral distance (c)
- Transverse diameter of the chest (a)

Both the dimensions were components of two internationally accepted radiological indices; Haller's index and vertebral index

STATISTICAL ANALYSIS

Data assessment was done using Excel and SPSS software. Significance between controls and cases has been calculated using ANOVA' and unpaired student 't-test for unequal sample size at 95% confidence interval. The correlation between MSJT angulation and sterno-vertebral distance, as well as the correlation between MSJT angulation and transverse diameter, was analyzed using the Karl Pearson correlation.

RESULT:

Table 1: Comparison of MSJT angulation between controls and cases

	Age group	Gender	Groups		
			Controls	**PC**	**PE**
MSJT (0)	>12years	Males	154.30±3.26	163.01±1.79	148.40±4.86
		Females	155.05±2.15	158.50±4.39	156.20±5.71
	12-20 years	Males	157.18±2.37	158.22±4.78	157.00±09.00
		Females	155.73±2.23	175.69±1.62	150.62±5.10
	20-40 years	Males	157.45±4.56	159.80±3.20	144.83±6.76
		Females	155.25±3.33	--------------	153.35±4.09

Males in the age group of 20 years showed a significant change in the MSJT angulation in pectus deformities when compared with controls. No significant variation was seen in males in the age group of 12-20 years. Whereas females in the age group between 12-20 years showed a significant alteration in the MSJT angulation in pectus deformities when compared with controls. However, no significant change was seen in the age group of < 12 years and > 20 years. Significance in female subjects with pectus carinatum, in the age group of >20 could not be analyzed, as no subjects were found. Results suggest that MSJT angulation significantly alters pectus deformities when compared with controls

Table 2: Comparison of Vertebral (VI) index between controls and cases

	Age group	Gender	Groups		
			Controls	**PC**	**PE**
VI (%)	>12years	Males	14.52±1.16	16.77±1.50	19.01±2.43
		Females	15.02±1.36	14.76±1.43	24.10±3.72
	12-20 years	Males	13.00±3.15	15.9±2.18	19.10±1.32
		Females	17.40±1.73	14.82±0.68	21.64±1.34
	20-40 years	Males	15.21±1.83	16.03±1.11	20.65±2.08
		Females	17.00±1.78	------------	21.82±1.14

Alteration of the vertebral index is an important indicator for changes occurring in pectus deformities Comparison of the vertebral index within the study group showed significant change in pectus deformities when compared with controls. Both the sexes in different age groups showed a significant alteration in the vertebral index, except for males in the age group of 12-20 years were found statistically insignificant.

Table 3: Comparison of Haller's index (HI) between controls and cases

	Age group	Gender	Groups		
			Controls	PC	PE
HI (ratio)	>12years	Males	1.21±0.34	1.02±0.10	2.11±0.35
		Females	1.20±0.23	1.04±0.17	3.20±1.30
	12-20 years	Males	1.28±0.35	1.29±0.23	2.02±0.20
		Females	1.26±0.23	1.02±0.19	1.16±0.26
	20-40 years	Males	1.32±0.24	1.88±0.26	1.76±0.27
		Females	1.34±0.36	----------	2.10±0.15

In comparison with controls, pectus deformities showed significant alteration in the Haller's ratio in both the sexes and in every age group, No significant change was observed in males in the age group of 12-20 years. The results confirm that Haller's index is a vital index for measuring the severity of chest deformities

DISCUSSION

Sternum along with ribs and the vertebral column is the key skeletal structure providing shape and contour to the chest wall. They also provide protection to vital mediastinal structures, especially the aorta and its branches, brachiocephalic vein, superior vena cava, heart, and lungs.

Earlier studies by **Selthofter et al2006**[14] who studied 55 male and 35 female sterna of the average age of 65 years, had measured the sternal angle by setting the sternum down and fixing it in the lateral position. Measurement was done using a protractor with a precision of 0.50. Here males showed an angle of 165.30 ± 7.19 and females an angle of 166.35±7.38. Studies by **Goodman et al1983**[15] on the sternum using computed tomography images, showed that manubrium formed a 20 - 400 angle with the horizontal plane, whereas the sternal body was nearly horizontal. **Chu et al2010**[16] explain that the inferior mediastinum is sandwiched between the body of the sternum in front and the vertebral column behind, the space between them is relatively fixed.

Robicsek et al1974[17] stated sternum was the culprit in producing the pectus deformity and it is the body of the sternum that alters first and the ribs have no other option rather than to follow it and these alterations in the chest wall begin at the manubrium-sternal joint. If the sternum is pulled in, it's PE and if the sternum protrudes, it is PC. This change in the angulation during pectus deformities was mainly attributed to the positional variation of the body of the sternum in relation to the relatively fixed manubrium. Some authors claim this alteration in the position of the body of the sternum may be due to the early fusion of sternal centers and some attribute it to the overgrowth of costal cartilages which is the widely accepted theory as of now. MSJT angulation showed a significant change in pectus deformities and can be conveniently used in diagnosing chest wall deformities and also would help in categorizing the chest wall as normal or deformed based on the findings.[18]

Brigato et al2008[19] studied the indices on 20 PE patients and 40 normal subjects and found the vertebral index to be 21% in normal subjects and 31% (median) in PE pre-operative and 23% in post-operative respectively.[19] Studies conducted by **Derveaux et al1989**[20] on 88 patients with pectus deformity, showed a mean lower vertebral index of 18% in controls (n=250) with a mean of 14 years, 29% in PE (n=54) and 16% in PC (n=13).[20]

Kilda et al2007[21], **khanna et al2010**[22], **Goresky et al2004**[1]mention, and most authors referred to 3.25 as the cut-off value. Haller's index might be unreliable since it varies with age, gender, and thoracic shape. Also, the results from controls and PE patients overlap with each other. Furthermore, it does not consider asymmetry, sternal and costal depression, and cardiac compression. On the other hand, while the vertebral index provides information regarding the position of the sternum, but only analyses the anteroposterior dimension of the thorax and does not provide any information regarding the transverse dimensions of the thorax and/or the asymmetry. With every index having certain constraints, there is a need for combinations of thoracic indices for a conclusive diagnosis of pectus deformities.

One of the primary objectives of surgical correction of pectus deformities is repositioning of sternum back to normal.[17] The extent of surgical elevation or depression of the sternum is based on the subjective analysis of the thoracic surgeon, which he performs by bringing the sternum to the plane of the costal cartilage. With evidence based on the current study, we propose that the objective method for analyzing the extent of repositioning of the sternum can be achieved by evaluating preoperative MSJT angulation and determining the degree of correction needed to bring back the sternum to its normal alignment.

Post-operative evaluation not only analyzes the improvement in the patient's respiratory functions and cardiovascular status but also measures the chest dimensions with radiological evidence. During the post-operative evaluation, the Haller index and the sterno-vertebral distance are recalculated to assess the extent of the prognosis. We propose that, as it was necessary to analyze radiological indices post-operatively, even the post-operative evaluation of MSJT angulation should be assessed to confirm the degree of correction

CONCLUSION:

Only a better knowledge of normal anatomical parameters enables a better understanding of both normal and abnormal. Therefore, it was necessary to estimate the normal range of MSJT angulation so as to identify the extent of changes in MSJT angulation in pectus deformities. Our study has been the first of its kind where in the MSJT is being taken into consideration for measuring the severity of chest wall deformation. The knowledge about MSJT angulation can be used as an objective method for the assessment of patients with pectus deformities. MSJT angulation can be used as an important guide for operative repositioning of the sternum.

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