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Relationship between the Degree of Thoracic Deformity and the Angle Formed by a Line Connecting the Sternum and the Spinous Process of the Vertebrae in Individuals with Severe Motor and Intellectual Disorders

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Abstract. [Purpose] The purpose of this study was to examine the relationship between the degree of thoracic deformity (TD) and the angle formed by a line drawn on transverse plane computed tomography (CT) images, connecting the sternum and the spinous process of the vertebrae at the level of the xiphisternum, and the perpendicular line from the floor (ANGLE), in individuals with severe motor and intellectual disorders (SMID). [Subjects] Twenty seven individuals with SMID were examined. [Methods] CT transverse images were acquired at the level of the xiphisternum of each patient. Two protocols were used to measure the anteroposterior (AP) and laterolateral (LL) diameters. The largest AP diameters were measured along a perpendicular line from the floor (protocol 1) and the line from the midline of the sternum to the spinous process of the vertebrae (protocol 2). The largest LL diameters were measured along the lines perpendicular to the AP diameters in each protocol. The ratios of the AP to LL diameters and the difference between the ratios of protocols 1 and 2 (DIFFERENCE) were calculated. [Results] Moderate to good correlation between DIFFERENCE and ANGLE was observed, and DIFFERENCE became larger with increasing ANGLE. [Conclusions] These results show that ANGLE indicates the degree of TD.
Key words: Severe motor and intellectual disorders, Thorax, Deformity

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INTRODUCTION

Individuals with severe motor and intellectual disorders (SMID) are defined as those who are bedridden or able to sit, and have an intelligence quotient (IQ) lower than 35[1)]. Almost all such subjects have cerebral palsy. Thoracic deformity (TD) secondary to severe kyphoscoliosis occurs frequently in individuals with SMID. This deformity restricts lung function by reducing both chest wall compliance and the mechanical advantage of the respiratory muscles, eventually resulting in pneumonia[2)]. We recently developed 2 protocols for the measurement of TD in individuals with SMID, and these protocols were demonstrated to be highly reliable[3)]. In addition, the degree of TD was shown to be indicated by the differences in the ratios of the anteroposterior (AP) to laterolateral (LL) diameters obtained using our protocols[4)].

Individuals are exposed to X-rays when these protocols are used to evaluate TD. Further evaluations of degree of TD are needed to determine methods that can minimize or avoid exposure to X-rays. In this study, we examined the relationship between the degree of TD and the angle formed in transverse plane computed tomography (CT) images by a line connecting the sternum and the spinous process of the vertebrae at the level of the xiphisternum and a perpendicular line from the floor.

SUBJECTS AND METHODS

Twenty seven individuals with SMID (15 males and 12 females), who were treated at Nishiotaru Hospital, were the subjects of this study. Patients were included if they had previously undergone chest CT (Asteion TSX-021B, Toshiba, Japan) for the diagnosis of pneumonia. The mean age of the patients was 32.3 years (SD = 21.0 years; range, 4–81 years). Ethical approval was granted by Nishiotaru Hospital, and informed consent was obtained from the parents or guardians of all the subjects.

CT images of the thorax in the transverse plane at the level of the xiphisternum were saved as digital images of each patient on a personal computer. Two protocols were

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used to measure both the AP and LL diameters.

In protocol 1, Microsoft PowerPoint 2007® (PP; Microsoft Corp., Redmond, WA, USAPP) was used to display a digital image of the thorax in the transverse plane, and a rectangle was drawn on the image. The rectangular length was matched to the largest AP diameter, and the width was matched to the largest LL diameter (Fig. 1-right). The digital image and rectangle were grouped and saved as a picture in the JPEG image file format. The public domain image processing program, ImageJ®, was used to measure the rectangular length and width of the AP and LL diameters.

In protocol 2, PP was used to display a digital image of the thorax in the transverse plane. After a grid was superimposed on the slide, vertical and horizontal lines were drawn along the grid lines. These lines were grouped as the perpendicular bisector, which was matched to the inclination and size of the sternum to indicate its midpoint (Fig. 2-left). A line was drawn connecting the midpoint of the sternum with the tip of the spinous process of the vertebrae at the level of the xiphisternum in the transverse image (Fig. 2-right). After drawing two rectangles, the right side of one rectangle length and the left side of the other were matched to the connecting line. The rectangular length of each side was determined as the largest AP diameter of the side, and the rectangular width of each side was determined as the largest LL diameter of the side (Fig. 1-left). The digital image, perpendicular bisector, and rectangles were grouped and saved in the JPEG format. ImageJ® was used to measure the AP and LL diameters. The length between A and B in Fig. 1-right was measured as the AP diameter. The length obtained by adding the right rectangular side (the length between A and D in Fig. 1-right) to the left side (the length between B and C in Fig. 1-right) was measured as the LL diameter (Fig. 1-right).

The ratio of AP to LL in each protocol was subsequently calculated. In addition, the difference between the ratios of protocols 1 and 2 (DIFFERENCE) was calculated as: the difference

DIFFERENCE = ratio of protocol 2 − ratio of protocol 1.

ImageJ® was used to measure the angle between the line which connecting the midpoint of the sternum with the tip of the spinous process of the vertebrae (Fig. 2-right) and a perpendicular line from the floor (ANGLE).

The Shapiro -Wilk test was used to test the normality of the data. The data were not normally distributed, therefore, Spearman's rank correlation coefficient was used to examine whether DIFFERENCE and ANGLE were related. And linear regression analysis was performed.

Statistical significance was accepted for values of $p \leq 0.05$. The statistical program R, version 2.8.1 (R Foundation for Statistical Computing, http://www.r-project.org/), was used to perform all statistical analyses.

RESULTS

The results are shown in Table 1.

DIFFERENCE and ANGLE were not normally distributed, therefore, Spearman's rank correlation coefficient was used for the analysis. The correlation between DIFFERENCE and ANGLE was moderate to good[5] (r_s=0.59, $p<0.05$). DIFFERENCE increased with ANGLE (R^2=0.53, $p<0.05$).

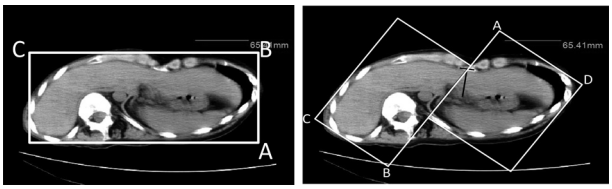

Fig. 1. Left: Protocol 1 for measuring anteroposterior (A–B) and laterolateral (B–C) diameter. Right: Protocol 2 for measuring anteroposterior (A–B) and laterolateral (A–D plus B–C) diameter

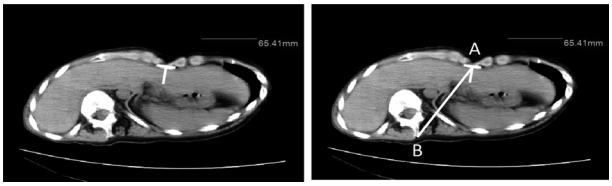

Fig. 2. Left: The perpendicular bisector was matched to inclination and the size of sternum to indicate the midpoint of the sternum. Right: A line connecting the midpoint of the sternum (A) with the spinous process of the vertebra (B) was drawn. Angle between A–B and perpendicular line to the floor was measured.

Table 1. The relationship between the difference of the two ratio protocols and the angle formed by the perpendicular and a line joining the sternum and the spinous process of the vertebrae at the level of the xiphisternum in the transverse image

DIFFERENCE		ANGLE		
average ± SD	range	average ± SD	range	r_s
0.115 ± 0.158	−0.073–0.500	10.3 ± 9.0°	0.12–33.1°	0.59*

DIFFERENCE: the difference = the ratio of protocol 2 − the ratio of protocol 1
ANGLE; between a line which was drawn connecting the midpoint of the sternum with the tip of the spinous process of the vertebrae at the level of the xiphisternum in the transverse image and perpendicular line to the floor
SD: Standard Deviation, rs: the Spearman rank coefficient of correlation. *: $p<0.05$

DISCUSSION

We examined the relationship between the degree of TD, determined by the difference in the ratios obtained using 2 measurement protocols, termed DIFFERENCE in this study, and the angle from the perpendicular formed by a line connecting the sternum and spinous process of the vertebrae at the level of the xiphisternum in the transverse plane CT images, termed ANGLE in this study. Moderate to good[5] correlation was found, and the degree of TD increased with increasing ANGLE.

Individuals with SMID develop TD secondary to severe kyphoscoliosis early in life[6]. Both these conditions affect thoracic function and growth and have adverse effects on the function and growth of the lungs[7]. TD restricts lung function by reducing both chest wall compliance and the mechanical advantage of respiratory muscles, and eventually resulting in pneumonia[1]. The most common cause of death among Japanese with SMID is pneumonia/bronchitis (25.9%), followed by respiratory diseases (16.0%)[1]. Therefore, measuring the degree of TD is clinically useful. We recently devised 2 protocols to measure TD in the transverse plane and demonstrated that they are highly reliable[3]. In addition, we demonstrated that DIFFERENCE is related to the degree of TD[4]. Kyphoscoliosis and TD are not congenital deformities in individuals with SMID. These deformities develop with age, especially in individuals with SMID[6]. They must be evaluated frequently, as they develop rapidly. However, individuals cannot be evaluated frequently because they would be exposed to excessive amounts of X-ray radiation when the 2 protocols are used to evaluate TD.

Considering this problem, we investigated a method for the evaluation of the degree of TD that would not require exposure to X-rays. The method was evaluated by investigating the relationship between ANGLE and the value of DIFFERENCE. Because the xiphisternum and the spinous process of the vertebrae can be palpated easily on the body surface, ANGLE can be measured by using direct anthropometric measurement, non-invasively. Our study showed that the correlation between DIFFERENCE and ANGLE was moderate to good and that DIFFERENCE increased with ANGLE. These results suggest that ANGLE can be used as an indicator of the degree of TD. To evaluate ANGLE without exposure to X-rays, the degree of TD should be evaluated frequently by our proposed alternative method to allow early detection. Further investigations to devise a method for direct anthropometric measurement of ANGLE are needed.

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