Relationship between the Degree of Thoracic Deformity and the Angle Formed by a Line Connecting the Sternum and the Spinal 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

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 351). 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 pneumonia3). We recently developed 2 protocols for the measurement of TD in individuals with SMID, and these protocols were demonstrated to be highly reliable3). 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 protocols4).

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 on a personal computer. Two protocols were
used to measure both the AP and LL diameters.

In protocol 1, Microsoft PowerPoint 2007® (PP; Micro-
soft 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 super-
imposed 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 inclina-
tion 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 vertebræ
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 (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:

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\text{DIFFERENCE} = \frac{\text{ratio of protocol 2}}{-\text{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 vertebræ (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 exam-
ine 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 Founda-
tion 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 DIFFER-
ENCE and ANGLE was moderate to good \( (r_s=0.59, p<0.05) \). DIFFERENCE increased with ANGLE \( (R^2=0.53, p<0.05) \).

**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° | 0.12–33.1° | 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, \( r_s \): 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 correlation was found, and the degree of TD increased with increasing ANGLE.

Individuals with SMID develop TD secondary to severe kyphoscoliosis early in life. Both these conditions affect thoracic function and growth and have adverse effects on the function and growth of the lungs. TD restricts lung function by reducing both chest wall compliance and the mechanical advantage of respiratory muscles, and eventually resulting in pneumonia. The most common cause of death among Japanese with SMID is pneumonia/bronchitis, followed by respiratory diseases. TD restricts lung function by reducing both chest wall compliance and the mechanical advantage of respiratory muscles, and eventually resulting in pneumonia. 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. In addition, we demonstrated that DIFFERENCE is related to the degree of TD. Kyphoscoliosis and TD are not congenital deformities in individuals with SMID. These deformities develop with age, especially in individuals with SMID. 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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