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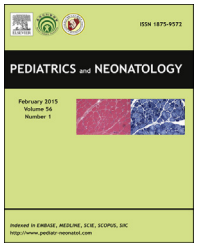

ORIGINAL ARTICLE

Rapid Increase in the Height and Width of the Upper Chest in Adolescents with Primary Spontaneous Pneumothorax

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Background: We determined the chest height in a cohort of patients with primary spontaneous pneumothorax (PSP) who had received chest radiographic examinations prior to the attack. The aim of this study was to determine when their chest height began to change and how this was related to the PSP.
Methods: From June 2009 to February 2012, the chest posteroanterior radiographs of 156 patients with PSP (Group 1) were reviewed. Among another 3134 patients with PSP, we identified 52 patients who had a chest posteroanterior radiograph prior to the attack (Group 2). We also recruited 196 controls for comparison (Group 3). The chest height and chest width at different levels were measured and analyzed.

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Results: Before 14 years of age, the chest height of patients in Group 2 was no different from that of patients in Group 3. By the age of 14 years, however, the chest height and upper chest width of patients with PSP was significantly higher than that of the normal controls. The difference from normal chest height did not increase at adulthood.
Conclusion: The rapid increase in chest height and upper chest width is a unique finding in patients with PSP. It might be attributable to the occurrence of PSP. This finding may also help to identify patients who are at risk of PSP.

1. Introduction

Patients with primary spontaneous pneumothorax (PSP) are characteristically thin with a low basal metabolic index and male adolescents are the most frequently affected.[1–3] As early as 11—14 years of age, the body height (BH) of patients with PSP is higher than that of normal individuals.[4] Several studies have provided dimensions on chest wall (CW) development in adolescents in addition to their BH growth. The chest height (CH) of adolescents with PSP has been reported to be significantly higher than that of age-matched controls.[5,6] The aim of our study was to compare the CH on chest radiographs of patients with PSP and those who had undergone chest radiographic examinations prior to their PSP to determine when CH begins to change and how it is related to the appearance of PSP.

2. Materials and methods

2.1. Patients and controls

From June 2009 to February 2012, the chest posteroanterior radiographs (chest PA) of 156 consecutive patients with PSP (Group 1) were collected. The control group comprised 392 age-matched pediatric patients who had undergone appendectomy or cleft lip surgery, or participants in school health examinations (Group 3) in the Chang Gung Children's Hospital, Taoyuan, Taiwan. Patients with asthma, cardiac disease, and other major congenital anomalies were excluded. We matched data using the one by two exact match method[7] in age for the three groups. All analyses were conducted using R statistical software, version 3.0.1 from the R Foundation for Statistical Computing (http://www.r-project.org/foundation/). These two groups were recruited and data on their CW dimensions were collected. To determine when CW growth begins to deviate from normal, we also enrolled patients with PSP who had undergone plain chest radiograph examinations prior to PSP for the purpose of comparing their pre- and post-PSP radiographs. We reviewed 3134 consecutive patients with PSP from five collaborating hospitals between June 2005 and August 2011. Fifty-five patients underwent chest PA prior to PSP and 52 had qualified radiographs for measurement and were assigned to the pre-PSP group (Group 2). These hospitals were tertiary referral centers in northern Taiwan. All chest PA radiographs were retrieved from the PACS system. The parameters on the radiographs in each group were measured and compared. There were no overlapping cases in Groups 1 and 2.

2.2. Selection of chest radiographs for measurement

The radiographs selected for measurement had to show complete re-expansion of the lung with clear costophrenic angles. These were usually the radiographs taken 1—2 weeks after the PSP episode. All PSP radiographs were reviewed and chosen for measurement by the first author.

2.3. Measurements

The PACS system digitizer was used by an independent radiology research assistant to measure the maximum transverse distance at the levels of the 2nd, 6th, and 9th rib pairs (R2, R6, and R9), representing the upper, middle, and

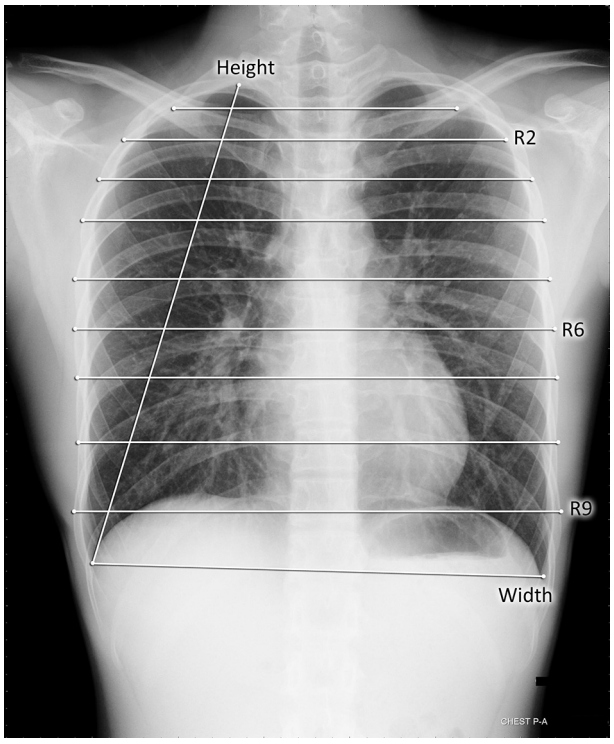

Figure 1 Radiographic measurement of chest wall dimensions.

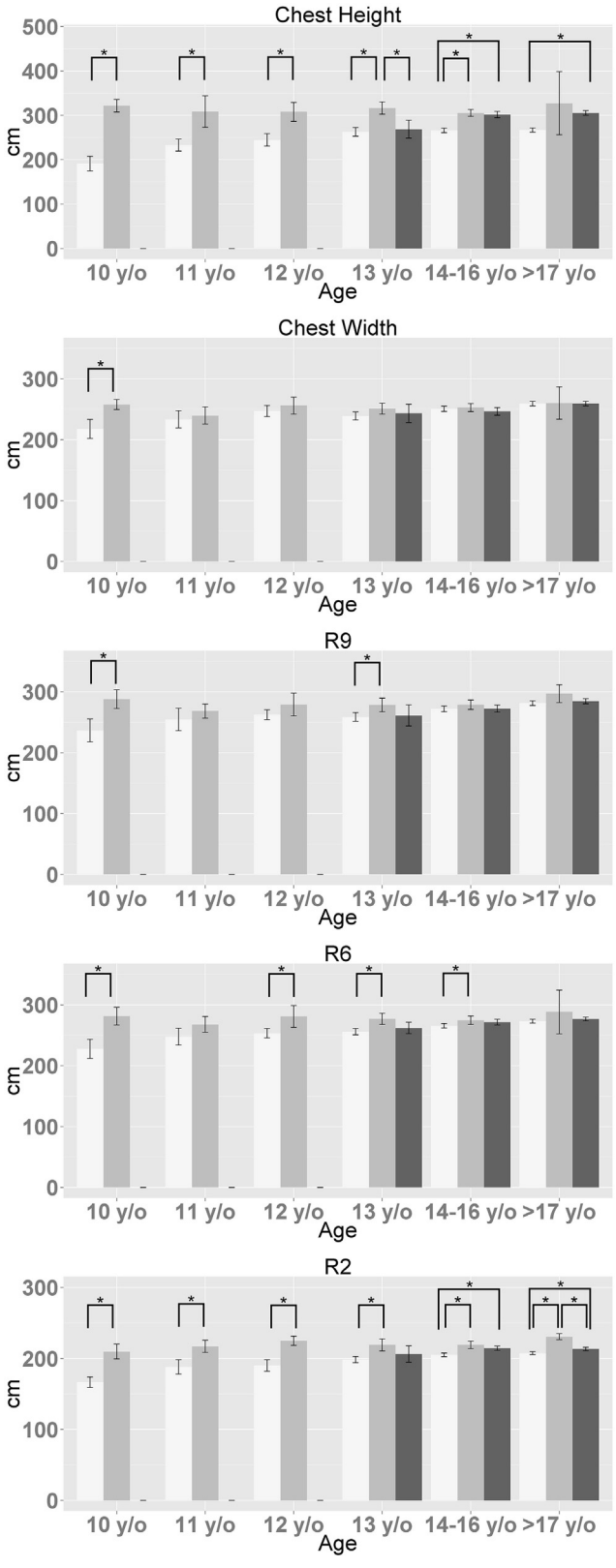

Figure 2 Comparison of chest wall dimensions of patients with primary spontaneous pneumothorax (PSP) and normal controls. *$p < 0.01$. Black bar = patients with PSP; grey bar = normal controls; white bar = patients prior to PSP.

lower CW, respectively. The CH and CW were also measured. The CH was defined as the distance between the lung apex and the costophrenic angle. Although the CH is an oblique line, it was chosen for measurement because the line can be easily identified. The CW was defined as the distance between the two costophrenic angles. The measurements are shown in Figure 1.

This study was approved by the ethics committees of our institutions (Institutional Review Board 100-3568C, 201103071RC, and 11MMHIS136).

3. Results

In Group 1, the median age was 18 years (range 13—35 years); most patients were aged between 15 years and 19 years (96 patients, 62%). Three patients experienced their PSP attack at the age of 13 years. The sex ratio was 8.18:1 (male to female 139:17). The correlation of the intrapersonal reliability of the measurement of the width of each rib pair, CH, and CW was 0.875—0.975.

After 14 years of age, the CH and R2 measurements were significantly larger than those of the age-matched control adolescents (Figure 2). No differences in CW, R6, or R9 were detected among all three of these populations at all ages. The mean right and left CH of Group 1 were 2.6 cm and 2.4 cm, respectively, greater than those in the control group. The mean BH of patients in Group 1 did not differ from that of a Taiwanese population after the age of 14 years.[8] The patients with PSP might have reached their final BH and CH after the age of 14 years.

Among the patients who underwent chest radiographic examination before and after the development of pneumothorax (Group 2), 25 patients were aged <14 years and 27 patients were 14—16 years old (Group 2). The CH was no different between Groups 1 and 2 in the 14- and 16-year-old populations (Figure 3). Comparison of the CH between the controls (Group 3) and pre-PSP patients (Group 2) at age <14 years showed no significant difference (Figure 3, Table 1).

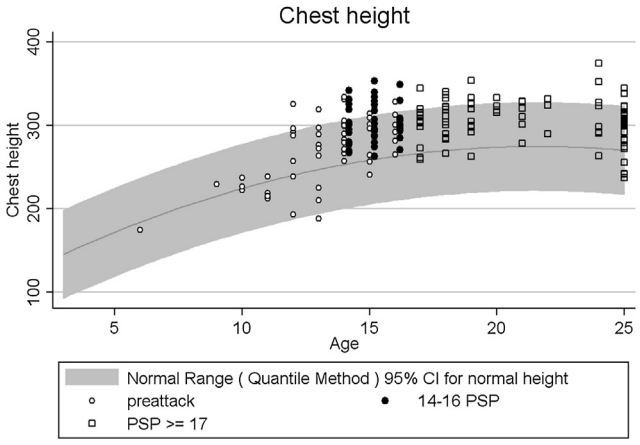

Figure 3 Chest height of patients. Open circle = Group 2 patients; closed circle = Group 1 patients aged between 14 and 16 years; open square = Group 1 patients aged >16 years; grey zone = 95% confidence interval of normal CH.

Table 1 Comparison of chest height of normal controls and patients prior to primary spontaneous pneumothorax at different ages.

Age (y)	Normal controls		Patients prior to primary spontaneous pneumothorax		*p*
	n	Mean ± SD chest height (mm)	*n*	Mean ± SD chest height (mm)	
14—16	130	265.94 ± 28.65	27	291.18 ± 24.11	<0.0001
13	36	262.85 ± 29.74	9	260.00 ± 43.23	0.8554
12	14	244.56 ± 26.56	7	269.95 ± 44.01	0.1967
11	10	232.89 ± 21.86	4	221.38 ± 11.82	0.2362

4. Discussion

In this study, we observed a significant increase in the vertical dimension of CH in patients with PSP from the age of 14 years. After the age of 14 years, the CH of the patients with PSP was already significantly higher than that of the control group, but the difference did not widen in adulthood. The rapid growth of the BH and CH of patients with PSP began earlier than in the normal population and soon plateaued at the age of 14—16 years. The age at which the rapid increase in the CH in patients with PSP coincided with the peak appearance of PSP was from the age of 14 years and upward. The upper CW also increased significantly after 14 years of age. The middle and lower CW were no different from those in patients with PSP, those with pre-PSP, or the normal controls at all ages. The difference in CW growth between the patients with PSP and the normal controls existed only for CH and upper CW, which matched the geographical distribution of the bullae that are usually located in the upper part of the lung.

The end of lung growth has been investigated extensively, but no definite conclusion has been reached. From 2 years of age to young adulthood, the pulmonary compartment grows in proportion to the lung volume,[9—13] and then successively until 8—11 years of age.[14,15] We postulated that the etiology of PSP might be related to the discrepancy between the static lung growth and the rapid increase in CH prior to adolescence. The bullae in lung parenchyma form because the lung tries to keep the visceral pleura in contact with the parietal pleura to compensate for the gap at the apical lung. With the continuous increase in the CH and widening of the upper CW (R2), even large bullae cannot compensate for the discrepancy; the bullae eventually burst and PSP develops. This hypothesis explains why the lung bullae exist at the peripheral surface of the apical region[15—17] and suggests that PSP is not a parenchymal lung disease.[18,19]

Spontaneous pneumothorax is now commonly treated with thoracoscopic surgery. However, the high recurrence rate reflects the imperfection of our present treatment.[20—23] Thoracoscopy with talc poudrage is effective in producing a pleurodesis.[24—26] This shows that the problem of PSP might relate to the detachment of the lung from its parietal pleura during the rapid growth of the CW in the teenage years. The stress distribution in the upper lung has been studied using a finite element model which showed that it does not have a major role in the development of spontaneous pneumothorax.[27]

Our study has several limitations. First, the measurements were linear; they did not necessarily reflect the true discrepancy between lung growth and the three-dimensional changes in the thoracic wall. Second, the patients who underwent pre-attack chest examinations were prone to selection bias. Third, the small number of patients aged <12 years may have affected the statistical significance. Fourth, our data just match the fact that the disorder has a sudden onset at 13 years of age and peaks at 17 years of age. It does not offer an explanation for adult onset. Finally, a more comprehensive and prospective long-term study is needed to confirm our postulate that a rapid increase in CH during early adolescence contributes to PSP, in addition to many other confounding factors.

5. Conclusion

In this study, we showed that a rapid increase in the vertical dimension of the thorax occurred in patients with PSP after the age of 12 years. Prior to adolescence, the CW dimensions of pre-attack patients with PSP did not differ from those of the normal age-matched population. The increased CH in adolescents becomes a characteristic feature of patients with PSP. The CH and upper CW measurements on frontal chest radiographs during adolescence may help to identify individuals who are at risk of PSP.

Conflicts of interest

All authors declare no conflicts of interest.

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