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Original Article

Application of multi-slice spiral CT in measuring airway remodeling of asthma in children

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Abstract: To investigate and discuss the application value of multi-slice spiral CT in measuring airway remodeling of asthma in children. A total of 70 children with moderate and severe asthma admitted and treated in our hospital from June 2016 to May 2017 were enrolled into observation group, and 70 healthy children in the same period were collected for control group. Multi-slice spiral CT was performed for children from both groups to observe the lung imaging characteristics. The wall thickness (WT), inner diameter of lumen (Din), wall area (WA) and wall area percentage (WA%) of the bronchi in the apical segment of upper left lung, apical segment of upper right lung, posterior segment of lower left lung and posterior segment of lower right lung were measured and compared respectively by Thoracic VCAR, a chest volume acquisition and reconstruction software. All children were treated with salbutamol and budesonide for three months and then measured with CT for retrospective study. The CT examination results showed that no special signs were detected in the lungs of children in control group while thick bronchial wall and bronchial stenosis were found in the lungs of children from observation group. The bronchus WT in each segment in observation group was significantly enlarged compared with that in control group ($P<0.05$). The bronchus Din from observation group was significantly smaller than that in control group, which indicated that the bronchus lumens of children with moderate and severe asthma are narrow ($P<0.05$). The bronchus WA in observation group was significantly enlarged compared with that in control group ($P<0.05$). As compared with those before treatment, the average values of WT, WA and WA% of children with asthma after treatment were all significantly decreased but the average value of Din was significantly increased ($P<0.05$). Our data demonstrates that multi-slice spiral CT can be used to measure the airway remodeling of children with asthma and evaluate the severity of asthma, which is valuable in predicting prognosis and provide beneficial guidance for the clinical treatment of asthma in children.

Keywords: Multi-slice spiral CT, asthma in children, airway remodeling

Introduction

Bronchial asthma is one of the most common chronic respiratory diseases currently. And children are particularly vulnerable to bronchial asthma, compared to adults. The clinical manifestations include anhelation, chest tightness, cough and even respiratory weakness with the characteristics of lingering course and recurrent attacks [1, 2]. As air pollution becomes gradually serious, the incidence rate of bronchial asthma is increasing year by year, and bronchial asthma has brought huge burdens and troubles to the child patients and their families [3]. Importantly, the pathological features of asthma are mainly manifested as airway inflammation and airway remodeling, and airway remodeling is one of the pathogeneses of asthma [4]. The observation methods of airway remodeling consist of direct observation and indirect observation. The former contains bronchoscopic mucosal biopsy and lung biopsy,

Table 1. Comparisons of baseline data between the two groups of children

Item	Control group n = 70	Observation group n = 70	t/χ^2	*P*
Gender (male/female)	33/37	36/34	0.114	0.735
Age (years old)	0-5	0-6		
Average age (years old)	4.28±1.25	4.56±1.36	1.268	0.207
Weight (kg)	12.73±1.24	12.82±1.35	0.411	0.682
Course of disease (month)	-	13.82±1.35		

while the latter involvespulmonary function testing and chest CT examination [5]. Through CT examination, the conditions of lung ventilation, bronchiectasia and bronchial wall thickness of children with asthma can be observed. With the rapid development of CT technology, multi-slice spiral CT presents advantages of short scan time, less disturbance of motion artifact and higher resolution. With the help of multi-slice spiral CT, the major airway and small airway morphological changes of children with asthma can be displayed clearly and accurately and the influences of man-made factors can be effectively avoided through quantitative assessment [6]. In this research, the bronchus WT and WA of children with asthma in clinic were measured with multi-slice spiral CT and were compared with those of health children, thus providing information for the observation of airway remodeling of children with asthma and the assessment of treatment effect.

Data and methods

General data

A total of 70 children with moderate and severe asthma admitted and treated in our hospital from June 2016 to May 2017 were include enrolled as observation group. Inclusion criteria: (1) Children who met the diagnostic criteria for asthma [7] and were diagnosed with moderate and severe asthma; (2) children aged from 0-6 years; (3) children whose parents signed the informed consent. Exclusion criteria: (1) Children with severe cardiovascular, hepatic and renal dysfunctions; (2) children who were allergic to the drugs adopted in this research; (3) children who were given hormone drugs in the latest 30 days. And 70 healthy children in the same period were involved as control group. This research was reviewed and approved by the Ethics Committee of our hospital, and there were no significant differences in the general data between the two groups of children ($P>0.05$) (**Table 1**). The work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Theinformed consent was obtained for experimentation with human subjects. The privacy rights of human subjects must always be observed.

Methods

CT measurement: The children were measured with a 64-slice spiral CT scanner (produced by GE Inc., USA) after they were asleep or after they were treated by oral 10% chloral hydrate (0.5 ml/kg) before measurement. Plain scan was performed for children from the basis pulmonis to the apex pulmonis and the related parameters are as follows: voltage = 120 kV, electric current = 80 mA, collimator width = 40 mm, matrix = 512×512, display field = 32.0 cm, rotation time = 0.6 s/cycle. Conventional reconstruction image (slice thickness: 5 mm, space: 5 mm) and thin-slice reconstruction image (slice thickness: 0.625 mm, space: 0.625 mm) were recorded from children in the two groups.

Treatment: Seventy child patients in control group were treated with budesonide aerosol (manufacturer: AstraZeneca AB, approval number: NMPN J20140047) combined with oral salbutamol tablets (manufacturer: Shandong Renhetang Pharmaceutical Co., Ltd., approval number: NMPN H10983170), of which the usage and dosage were as follows: (1) budesonide aerosol: for children aged <7 years old: twice a day (morning and evening), with 100 μg each time, and in severe cases, once every 6 hours, with 100 μg each time. For children aged ≥7 years old: twice a day (morning and evening), with 200 μg each time, and in severe cases, once every 6 hours, with 200 μg each time. (2) salbutamol tablets: three times a day with 1 tablet each time, treated for 3 months.

Evaluation indicators

Criteria to judge the severity of asthma: (1) mild: asthma symptoms occur every 1 day at most and the seizure frequency of asthma at

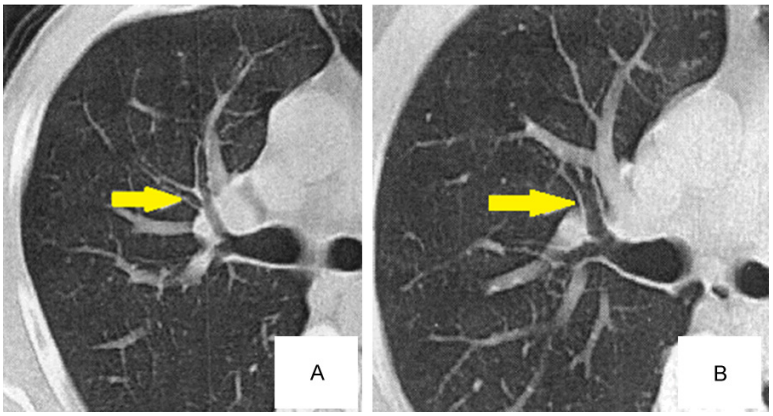

Figure 1. A: CT image of a child with asthma (male, 3 years old) shows that he has bronchial stenosis. B: CT image of a healthy child (female, 4 years old) with normal results.

night is once a week at most; (2) moderate and severe: asthma symptoms occur every day and the seizure frequency of asthma at night is more than once every week.

Imaging diagnosis was performed by two senior radiologists with double blind method to observe the morphological changes of lung and the condition of airway remodeling

A slice with clear bronchus imaging was selected to measure the wall thickness (WT), inner diameter of lumen (Din), wall area (WA) and wall area percentage (WA%) of the bronchi in the apical segment of upper left lung, apical segment of upper right lung, posterior segment of lower left lung and posterior segment of lower right lung by Thoracic VCAR software.

Statistical processing

Statistical Product and Service Solutions (SPSS) 19.0 (SPSS Inc., Chicago, IL, USA) software was utilized for data processing. Measurement data were presented as mean ± standard deviation ($\bar{x} \pm s$), and *t*-test was performed. Enumeration data were presented as ratio, and x^2 test was adopted. F-test was used for difference between groups. $P<0.05$ suggested that the difference was statistically significant.

Results

Bronchial stenosis appearedin children with asthma

The lung imaging characteristics showed that no special signs were detected in the lungs of children in control group and no abnormality was detected in the bronchi, whereas obviously thick bronchial wall, bronchial stenosis and bronchiectasis were found in the lungs of children in observation group (**Figure 1A** and **1B**).

Bronchus wall thickened in children withmoderate and severe asthma

We then evaluated the wall thickness of bronchus between two groups. Of note, the wall thickness significantly increased children with moderate and severe asthmain comparison to normal control ($P<0.05$) (**Table 2**).

Bronchus Din in children with moderate and severe asthma was weakened

The results showed that the bronchus Din in asthma children was significantly impaired compared to that in control group ($P<0.05$), which indicated that the bronchus lumens of children with moderate and severe asthma becamenarrow (**Table 3**).

Bronchus wall area in children expandeddue to asthma

In comparison to the healthy individuals, the asthma led to the significant expansion of the wall area of bronchus ($P<0.05$) (**Table 4**). Likewise, the bronchus WA% in patients with asthma was significantly increased compared with that in control group ($P<0.05$) (**Table 5**).

The asthma was improved after the treatment based on the evaluation with WT, Din, WA and WA%

We finally assessed the efficacy of treatment by using multi-slice spiral CT. As compared with those before treatment, the average values of WT, WA and WA% of children with asthma after treatment for 3 months were all significantly decreased with the statistical elevation of the average value of Din ($P<0.05$) (**Table 6**).

Discussion

Asthma represents a type of the airway hyperreactivity and airflow obstruction disease and

Table 2. Comparisons of bronchus WT in each segment between two groups (mm, $\bar{x} \pm s$)

Group	n	Apical segment of upper left lung	Apical segment of upper right lung	Posterior segment of lower left lung	Posterior segment of lower right lung
Observation group	70	1.03±0.22	1.23±0.24	1.35±0.28	1.34±0.23
Control group	70	1.45±0.24	1.54±0.32	1.66±0.29	1.67±0.35
t		10.793	6.484	6.434	6.592
P		<0.001	<0.001	<0.001	<0.001

Table 3. Comparisons of bronchus Din in each segment between two groups (mm, $\bar{x} \pm s$)

Group	n	Apical segment of upper left lung	Apical segment of upper right lung	Posterior segment of lower left lung	Posterior segment of lower right lung
Observation group	70	2.92±0.39	2.88±0.38	3.25±0.46	3.26±0.45
Control group	70	2.14±0.33	2.09±0.35	2.24±0.38	2.27±0.36
t		12.774	12.794	14.163	14.373
P		<0.001	<0.001	<0.001	<0.001

Table 4. Comparisons of bronchus WA in each segment between two groups (mm^2, $\bar{x} \pm s$)

Group	n	Apical segment of upper left lung	Apical segment of upper right lung	Posterior segment of lower left lung	Posterior segment of lower right lung
Observation group	70	8.54±1.08	8.36±1.29	10.78±1.09	10.67±1.54
Control group	70	13.68±1.27	13.89±1.64	15.82±1.53	15.48±1.46
t		25.796	22.174	22.447	18.964
P		<0.001	<0.001	<0.001	<0.001

Table 5. Comparisons of bronchus WA% in each segment between two groups (%, $\bar{x} \pm s$)

Group	n	Apical segment of upper left lung	Apical segment of upper right lung	Posterior segment of lower left lung	Posterior segment of lower right lung
Observation group	70	65.54±3.76	69.75±3.26	68.48±3.07	67.04±3.23
Control group	70	76.38±3.42	79.47±3.63	79.25±3.15	78.34±3.18
t		17.844	16.668	20.486	20.858
P		<0.001	<0.001	<0.001	<0.001

Table 6. Comparisons of the WT, Din, WA and WA% of children with asthma before and after treatment ($\bar{x} \pm s$)

Time	n	WT (mm)	Din (mm)	WA (mm^2)	WA% (%)
Before treatment	70	1.58±0.33	2.18±0.31	15.64±1.64	77.43±3.42
After treatment	70	1.21±0.28	2.94±0.35	10.52±1.67	66.12±3.47
t		7.153	13.60	18.302	19.422
P		<0.001	<0.001	<0.001	<0.001

causes chronic airway inflammation. During the growth and development period of children, asthma is more likely induced by outside stimulations then in adultsand leads to severe symptoms and recurrent attacks [8, 9]. It is generally considered that various allergens are the major precipitating factor of asthma attack [10, 11]. Airway remodeling was first proposed in the 1920s and it referred to the changes in the structure, constituent and quantity of airway cells and the extracellular component [12]. Currently, there is no consensus definition of airway remodeling [13]. The main reason for air remodeling and recurrent attack of asthma is airway stenosis and airflow obstruction caused by the imbalance of the degradation and deposition of extracellular matrix [14]. Notably, in our study, the clinical data showed

variable degrees of wheeze, cough, shortness of breath, chestairflow limitation and distinct patternsof inflammation in children with moderate and severe asthma.

However, the diagnosis of asthma remains unsatisfactory. Bronchoscopic biopsy, as an invasive detection, it is not suitable for repeated measurement and is especially difficult to perform on child patients. In addition, biopsy is often disturbed by the thickening of smooth muscle and so its application is limited [15]. CT has been deployed in clinic since the 1970s, it plays a significant role which cannot be replaced by other radiological examinations [16]. CT scanning is featured as with rapid scanning speed, clear image and unaffected by adjacent organs. With the rapid development of CT technology, multi-slice spiral CT has emerged and can effectively solve the contradiction between scanning speed and breath-holding time, which makes it possible for complete scanning towards some children with poor cooperation. At present, it has become the main means of diagnosis for many diseases in clinic [17, 18]. In this research, chest scanning was performed on all research subjects with a 64-slice spiral CT scanner, which can directly and accurately reflect pulmonary morphological changes. The high spatial resolution of 64-slice spiral CT with a minimum slice thickness enables clear observation on bronchi via reconstructed images in any direction without the use of contrast medium. The use of lower scanning dose can reduce the effect of radiation on children and guarantee the accuracy and reliability of data. Moreover, the operation of 64-slice spiral CT is simple and practicable and has certain repeatability [19].

Of note, our results showed that, in asthmatic children,the WT, WA and WA% of the bronchi in the apical segment of upper left lung, apical segment of upper right lung, posterior segment of lower left lung and posterior segment of lower right lung were remarkably increased compared to those of healthy children while Din was significantly reduced, which indicated pathological changes in bronchus. The thickening of airway wall was mainly caused by the aggregation of extravascular cellulose and plasmexhidrosis. Due to the continuous deposition of collagen in smooth muscle, airway was narrowed by the contraction of smooth muscle contracts and the resistance of smooth muscle against the contraction of smooth muscle was weakened by the protein degradation in matrix. Consistently, the results detected by multi-slice spiral CT in our study indicated the clinical change in bronchus related to asthma as previously reported [20]. Also, the multi-slice spiral CT was employed after the combined treatment of budesonide and salbutamol, and the data revealed that the four indexes (including WT, WA, Din and WA%) of child patients after treatment were significantly improved, demonstrating the asthma of child patients was effectively controlled and the spasm and hyperreactivity of airway remodeling were improved.

In conclusion, our result suggests that the measurement with multi-slice spiral CT has the features of non-invasion, accurate positioning, simple operation and direct viewing and exhibits significant values in clinical application of quantitative analysis on airway, observation of airway remodeling, evaluate the severity of asthma and treatment effect.

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Disclosure of conflict of interest

None.

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