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Soo-Jung Choi
Byeong-Kyoo Choi
Hyeon Joo Kim
Soo Hyun Lee
Seong Hoon Choi
Sang Joon Park
Hyun Woo Goo
Jin Seong Lee
Chong Hyun Yoon

Lateral decubitus HRCT: a simple technique to replace expiratory CT in children with air trapping

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S.-J. Choi · B.-K. Choi · H.J. Kim
S.H. Lee · S.H. Choi · S.J. Park
H.W. Goo · J.S. Lee · C.H. Yoon (✉)
Department of Diagnostic Radiology,
Asan Medical Centre,
University of Ulsan College of Medicine,
388-1 Poongnap-Dong, Songpa-Gu, Seoul
138-736, South Korea
E-mail: chyoon@www.amc.seoul.kr
Tel.: +82-2-30104362
Fax: +82-2-4764719

Abstract *Objective*: To evaluate the effectiveness of lateral decubitus high-resolution CT (HRCT) in detecting air trapping in children. *Materials and methods*: HRCT scans of 21 children with heterogeneous lung attenuation caused by air trapping ($n=10$) or with infiltrative lung disease ($n=11$) were reviewed retrospectively. The air-trapping disease included bronchiolitis obliterans ($n=7$), bronchial obstruction due to mediastinal lymphoma ($n=1$), endobronchial haemangioma ($n=1$) and foreign body aspiration ($n=1$). HRCT was performed in both lateral decubitus positions as well as the supine position. The attenuation (Hounsfield units; HU) was measured in both the hypo- and adjacent hyper-attenuating areas of the heterogeneous lung portion, and the difference of attenuation between these two areas was calculated in the supine and both lateral decubitus scans, respectively. The attenuation differences of the three scans were compared in each group. *Results*: The attenuation difference was larger in the ipsilateral decubitus (207.95 ± 105.24 HU) scans than in the contralateral (121.25 ± 90.05 HU) or supine (162 ± 94.01 HU) scans in the air-trapping group ($P < 0.05$). There were no significant differences among the three scans in the infiltrative lung disease group ($P > 0.05$). *Conclusions*: Lateral decubitus HRCT is an effective adjunct to standard HRCT in the evaluation of air trapping as a cause of mosaic lung attenuation in uncooperative paediatric patients.

Keywords High-resolution CT · Lung · Bronchiolitis obliterans · Pneumonia

Introduction

Mosaic lung attenuation on thin-section high-resolution CT (HRCT) can result from air trapping as well as vascular, infiltrative or mixed conditions [1, 2, 3, 4, 5, 6]. Previous studies have reported the usefulness of expiratory HRCT for discriminating mosaic attenuation due to air trapping from other causes of heterogeneous lung attenuation [7, 8]. Unfortunately, this modality has limited diagnostic value for those patients who cannot suspend respiration. It is difficult to obtain satisfactory expiratory CT scans in some adult patients who cannot hold their breath; it is even more problematic to obtain adequate expiratory HRCT scans in infants or young children because of their inability to suspend respiration or refusal to cooperate. In 1972, Capitanio et al. [9] reported the usefulness of lateral decubitus chest radiographs for determining air trapping in children. The lateral decubitus position caused chest wall restriction and resulted in relative under-aeration of the dependent lung. Following that account, Franquet et al. [10] reported the usefulness of lateral decubitus CT in detecting air trapping as a substitution for expiratory chest CT in adults. Lucaya et al. [11] applied this technique to children who had various lung diseases. The purpose of this study was to evaluate the effectiveness of lateral decubitus HRCT in detecting air trapping in comparison with infiltrative lung disease in children.

Materials and methods

Between August 1998 and April 1999, 77 HRCT scans of 68 children were performed at our institution. All HRCT scans were reviewed retrospectively by two radiologists. Of the 68 patients, 18 with scans showing mosaic attenuation and 3 with different lung attenuation in the same lung were selected. Mosaic attenuation was defined as patchwork regions of varied attenuation. Different lung attenuation in the same lung was described as different attenuation between adjacent segments or lobes in the same lung.

The study subjects comprised 11 boys and 10 girls whose ages ranged from 1 to 144 months (mean 35 months). We also reviewed these patients' medical records. The subjects were then divided into two groups – those with air trapping and those with infiltrative lung disease. Diagnoses of the ten patients in the air-trapping group included bronchiolitis obliterans ($n=7$), bronchial obstruction due to mediastinal lymphoma ($n=1$), endobronchial haemangioma ($n=1$) and foreign body aspiration ($n=1$). The patients with bronchiolitis obliterans fulfilled the clinical criteria of persistent and chronic respiratory symptoms and signs (cough, wheezing, retraction and crackles) with previous episodes of bronchiolitis [12, 13]. Thereafter, diagnoses of bronchiolitis obliterans were made collectively using the radiological and clinical features in addition to the response to steroid therapy. The diagnoses and causes of bronchial obstruction were confirmed by bronchoscopy and pathology. For the 11 patients in the infiltrative lung disease group, viral pneumonia ($n=7$), bacterial pneumonia ($n=3$) and pulmonary oedema ($n=1$) were diagnosed. The diagnosis of viral pneumonia was based on an elevated serum level of anti-cytomegalovirus (CMV) antibody. Bacterial pneumonia and pulmonary oedema were confirmed by sputum culture and serial chest radiography with clinical correlation, respectively.

HRCT was performed using a Somatom Plus-S (Siemens, Erlangen, Germany) or a 9800 (General Electric Medical Systems, Milwaukee, Wis., USA) scanner using 1.5-mm section thickness, 10-mm intervals, 140 kVp, 170 mAs and 512×512 matrix from the lung apices to the bases during quiet respiration. All image reconstruction was performed with a high-spatial-frequency algorithm. After performing HRCT in the supine position, scans in both decubitus positions were also obtained at three levels (top of the aortic arch, the carina, and 1 cm above the diaphragmatic dome) using the same parameters during quiet breathing. Orally administered sedation was used routinely in children 6 years or younger.

CT attenuation values (Hounsfield units; HU) were measured in hypo- and hyper-attenuating areas by placing 0.5–1.0-cm sized regions of interest (ROI) on the mosaic attenuating lung, and the attenuation difference between the two areas was calculated. In the cases where CT showed different lung attenuation in the same lung, the attenuation difference was calculated between the hypo-aerated lung and adjacent different attenuation lung on the same side in the same manner. This procedure was performed on the supine scan and the matched sections on both decubitus scans. Because nearly all of these cases had multifocal mosaic attenuation, one or more regions of the lung with mosaic attenuation were measured in each case. However, in 5 of the 21 cases, only one portion of the lung with mosaic attenuation was available because of motion artefact and limited scan levels.

As a result, the attenuation differences of 20 regions from 10 cases of air trapping and 18 regions from 11 cases of infiltrative lung disease were calculated. Changes in attenuation difference between supine and both decubitus positions in each group (air-trapping and infiltrative lung disease group) were compared. The Wilcoxon signed rank test was used for statistical analysis.

Results

In the air-trapping group, the mean attenuation difference was maximal in the dependent (ipsilateral decubitus scans; 207.95 ± 105.24 HU) position and minimal in the non-dependent (contralateral decubitus scans; 121.25 ± 90.05 HU) position. The mean attenuation difference on supine scans was 162.0 ± 94.01 HU. There were statistically significant differences between ipsilateral decubitus versus supine scans, supine versus contralateral decubitus scans, and ipsilateral versus contralateral decubitus scans ($P < 0.05$, Fig. 1). However, in the infiltrative lung disease group, the attenuation difference was not statistically significantly different in the supine (431.27 ± 195.19 HU), non-dependent (contralateral decubitus scans; 405.11 ± 268.18 HU) or dependent position (ipsilateral decubitus scans; 374.16 ± 233.07 HU).

Discussion

When a child is placed on his or her side, the dependent hemithorax is splinted, resulting in restriction of movement of the thoracic cage on that side and causing the dependent lung to be under-aerated and the non-dependent lung to be hyper-aerated [9]. Therefore, the lung attenuation in the dependent lung is increased because of normal gravitational density [14], and the non-dependent lung attenuation is decreased because it is usually in

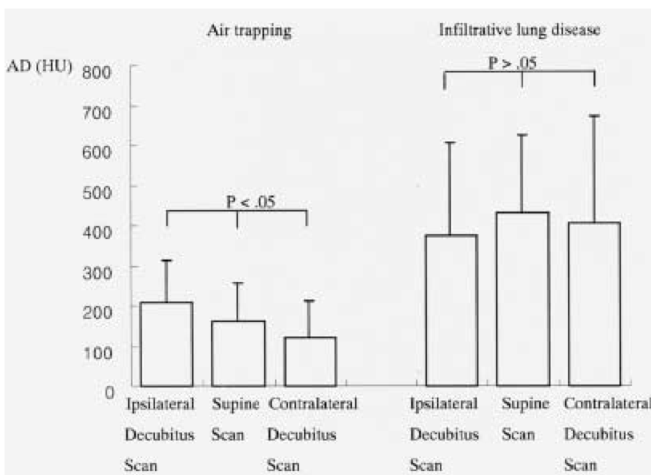

Fig. 1 The mean attenuation difference (± SD) between hypo- and adjacent hyper-attenuating regions of heterogeneous lung attenuation. *AD* attenuation difference

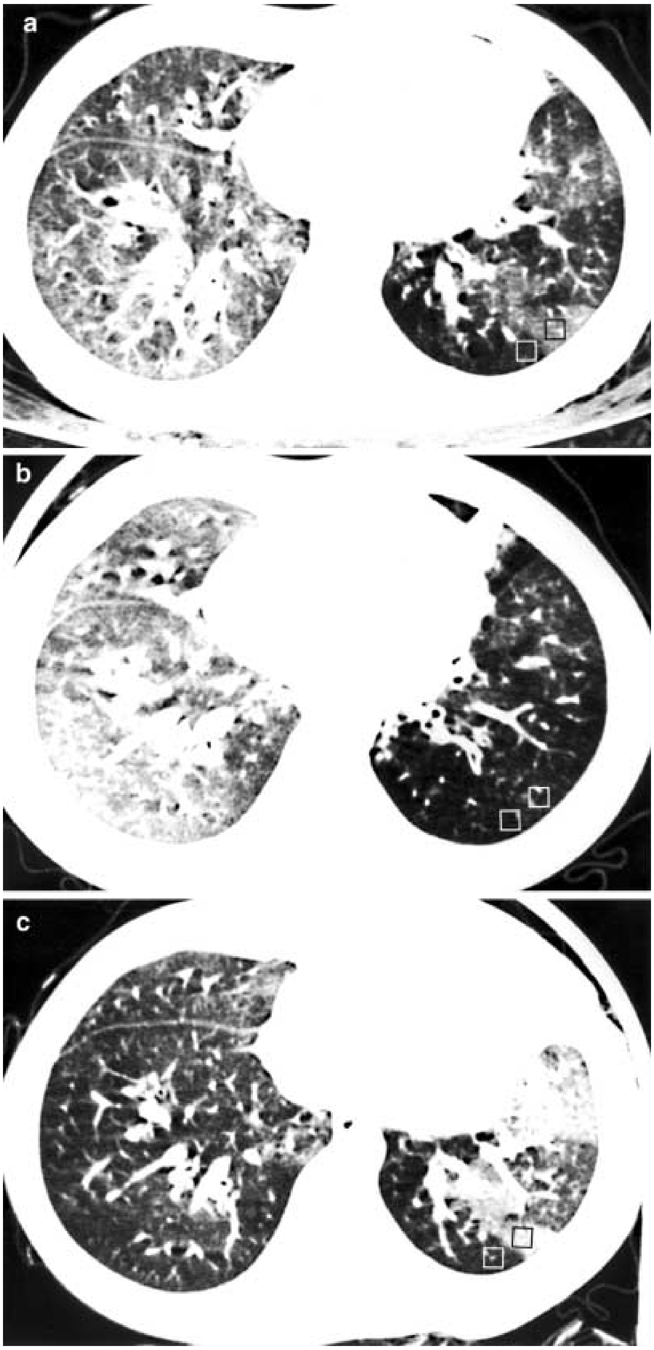

Fig. 2a–c A 24-month-old boy with air trapping due to bronchiolitis obliterans. **a** At the basal lung level, mosaic attenuation is noted in the left lung on a supine scan. The attenuation difference between hypo- and adjacent hyper-attenuating areas is 131 HU. **b** In the right lateral decubitus position, the mosaic attenuation becomes faint. The attenuation difference is 50 HU. **c** In the left lateral decubitus position, mosaic attenuation becomes more obvious. The attenuation difference is 244 HU

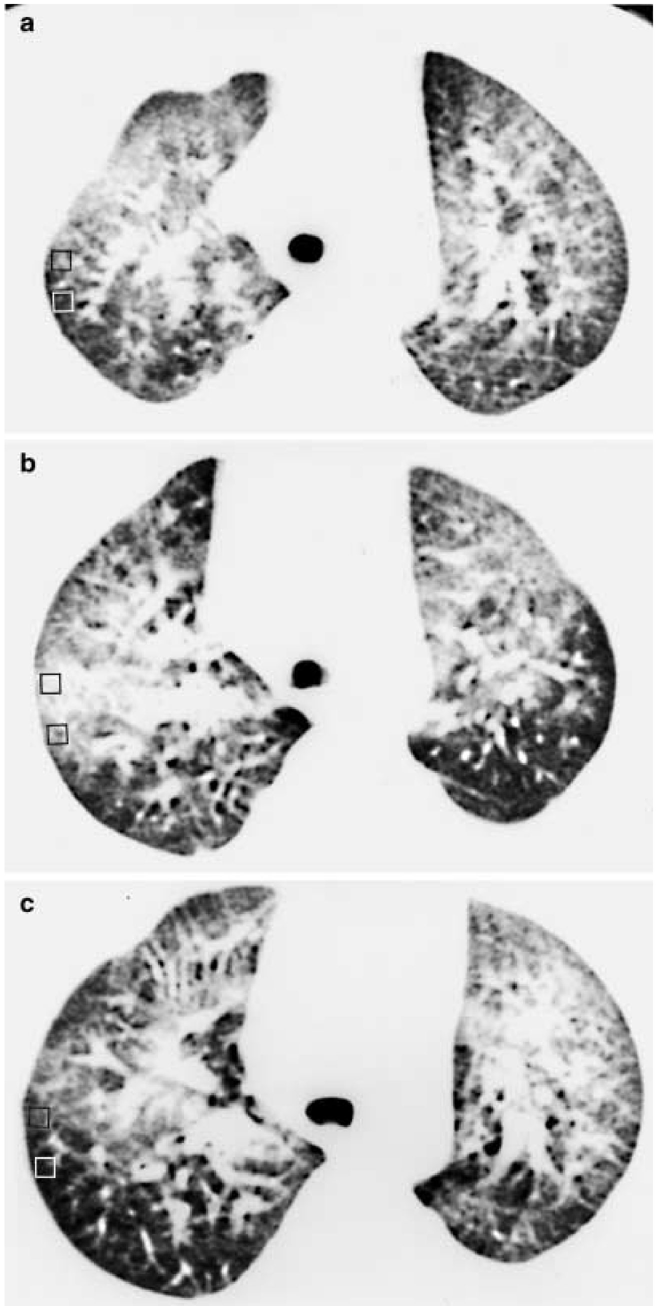

Fig. 3a–c An 8-month-old boy with CMV pneumonia. **a** At the apical lung level of the supine scan, wide spread ground-glass opacity is noted in both lungs. **b** Right and **c** left lateral decubitus positions demonstrate that the attenuation difference of the mosaic lung attenuation does not significantly change

inspiration. The lateral decubitus position also allows radiologists to take advantage of gravitational gradients, thereby accentuating the differences in lung attenuation [10]. In our study, the difference of mosaic lung attenuation was more accentuated in the ipsilateral decubitus position in the air-trapping group, similar to an expiratory scan in an adult (Fig. 2). This result was easily conceivable considering that gravitational lung attenuation can variously affect local lung areas depending upon lung compliance. Consequently, mosaic lung attenuation was accentuated in the ipsilateral decubitus position. Conversely, the non-dependent lung position minimised the effect of the mosaic lung attenuation because of the decrease of gravitational density of normal lung parenchyma. Therefore, characteristic attenuation patterns of mosaic lung attenuation were seen in the three scans of the air-trapping group: the mean attenuation difference was maximal in the dependent position and minimal in the non-dependent position. In the infiltrative lung disease group, the difference in mosaic lung attenuation was not accentuated on the ipsilateral decubitus scans, and the attenuation difference was not statistically significantly different among the three scans (Fig. 3). These observations led us to suggest that if mosaic attenuation becomes more obvious in the ipsilateral decubitus position and less apparent in the contralateral decubitus position, air trapping could be the cause. Therefore, lateral decubitus scans could be helpful in deciding whether mosaic attenuation on HRCT is due to air trapping.

In this study, lateral decubitus scans were obtained at three pre-selected levels – the apex, carina and base – irrespective of the findings on supine scans. Although a large majority of the patients in this study had diffuse or multifocal abnormalities that were adequately imaged with pre-selected levels, targeting lateral decubitus scanning to lung regions that appear abnormal on supine scans would also be a valuable technique.

Our study is limited in several aspects. First, comparison between air trapping and compensatory hyperinflation from a vascular disorder was not performed because no CT scans of those cases were available. Second, the sampled ROI were not from exactly the same area for all three scans as the lung is tilted and distorted in the lateral decubitus position. However, we could see that the mosaic attenuation caused by air trapping became grossly obvious in the dependent position, in contrast to the cases of infiltrative lung disease. Scanning with a greater range than the preselected levels will be helpful in overcoming this limitation. Third, the diagnoses of our subjects, except those with endobronchial masses, were not pathologically proven. Bronchiolitis obliterans in adults is usually diagnosed by open-lung biopsy and by the obstructive pattern of the pulmonary function test. However, because most paediatric patients cannot perform pulmonary function testing and because of the high risks involved in surgical open-lung biopsy, the diagnosis is usually made using only clinical history and physical examination.

In summary, if the attenuation difference of mosaic attenuation observed on HRCT increases on ipsilateral decubitus scanning and decreases on contralateral decubitus scanning, air trapping is likely to be the cause. Lateral decubitus HRCT is an effective adjunct to supine HRCT for evaluation of air trapping as a cause of mosaic lung attenuation in paediatric patients.

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