Clinical Imaging 40 (2016) 594–600

Contents lists available at ScienceDirect

Clinical Imaging

journal homepage: http://www.clinicalimaging.org

Original Article

Lung density standard deviations obtained using high-pitch dual-source computed tomography are valid predictors of bronchopulmonary dysplasia in preterm infants☆

Yi-Shan Tsai [a], Yi-Sheng Liu [a], Yu-Hsiang Shih [a], Ming-Tsung Chuang [a], Yuh-Jyh Lin [b], Chyi-Her Lin [b], Yung-Chieh Lin [b,*]

[a] Department of Radiology, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan
[b] Department of Pediatrics, National Cheng Kung University Hospital, College of Medicine, National Cheng Kung University, Tainan, Taiwan

ARTICLE INFO

Article history:
Received 13 August 2015
Received in revised form 18 January 2016
Accepted 11 February 2016

Keywords:
Bronchopulmonary dysplasia
BPD
Dual-source CT
High-pitch
Prematurity

ABSTRACT

Purpose: This study aimed to validate standard deviations of lung densities obtained using high-pitch dual-source computed tomography (DSCT) densitometry as indices of bronchopulmonary dysplasia (BPD) severity in premature infants.
Methods: Data of preterm, late preterm group, and early term groups were evaluated. Mean and median standard deviations (SDmean, SDmedian) of CT lung density (CTLD) were calculated from CT images.
Results: SDmean of CTLD in infants with severe BPD was significantly higher than that of infants without BPD (198.1 vs. 140.9, respectively; $P=.002$).
Conclusions: Study results support using high-pitch DSCT for BPD diagnosis and quantitative evaluation in prematurity.

1. Introduction

Bronchopulmonary dysplasia (BPD) is a common respiratory complication of infants born prematurely, and the most common cause of chronic lung disease in infancy (CLDI) [1–3]. The condition was initially described by Northway in 1967 as characteristic chest x-ray findings of hyperinflation and development of cystic areas with disease progression [4]. In extremely premature infants, the lungs are characterized by decreased septation and alveolar hypoplasia [1–3], and gas exchange in the lungs correlates with alveolar surface area [5].

BPD has traditionally been defined as the presence of persistent respiratory signs and symptoms, the need for supplemental oxygen to treat hypoxemia, and an abnormal chest x-ray at 36 weeks' postmenstrual age (PMA), that is, gestational age (GA) plus chronological age [1–3,6]. However, this definition is not specific and does not take into account clinical distinctions related to extremes of prematurity or variable criteria for using prolonged oxygen therapy, and some methods of describing BPD severity use physiological criteria rather than oxygen dependency [3,7,8]. Without using physiological tests to determine oxygen requirements, BPD severity may be overestimated [7,8]. However, severity correlates with long-term clinical outcomes, which makes an accurate determination of BPD severity essential [1–3,9–11]. In addition, advances in neonatal care, including the use of prenatal corticosteroids and surfactant to treat premature infants and applying shorter ventilation times with lower pressure and inspired oxygen concentrations, have altered our understanding of BPD pathogenesis so that BPD is currently referred to as the "new" BPD [1].

Lung volume determined using computed tomography (CT) imaging is similar between infants at 36 weeks' PMA born prematurely and near-term babies [12,13]. Qualitative CT findings of BPD in premature infants have been reported extensively [9–11], and a number of other imaging methods have been examined for quantitative determination of BPD severity [12,14–16]. Second generation dual-source CT (DSCT) with a high-pitch scan technique acquires adequate volumetric chest CT images with less respiratory motion artifact and lower radiation dose than conventional CT [17–19]. Therefore, we wanted to test the ability of high-pitch DSCT to establish lung alveolarization by low-radiation chest CT and correlate it with BPD severity in infants born prematurely. We hypothesized that obtaining volumetric chest images using high-pitch DSCT may allow for calculation of reliable standard deviations of lung densities in preterm infants as predictors of BPD. The purpose of this study was to validate standard deviations of lung densities obtained

☆ Declaration of conflicting interests: None declared.
* Corresponding author. Department of Pediatrics, National Cheng-Kung University College of Medicine and Hospital, No.138, Sheng Li Road, Tainan 704, ROC, Taiwan. Tel.: +886 2353535x2401; fax: +886 62761110.
E-mail address: appledr@hotmail.com (Y.-C. Lin).

http://dx.doi.org/10.1016/j.clinimag.2016.02.010

Table 1
Lung scoring systems

Reference	Imaging modality	Scoring system	Score range	Categories	Worse BPD severity
Ochiai et al. [15]	CT	CT BPD score	0–6; each category scored from 0 to 2	Hyperexpansion, emphysema, or fibrous/interstitial abnormalities	Higher total score
Faix et al. [22]	Chest radiograph	Respiratory distress syndrome grade	Grades 1–4	Grade 1, hypoexpansion and diffuse, fine granular densities; grade 2, air bronchograms caused by atelectatic air sacs; grade 3, ground-glass appearance; grade 4, white lungs due to diffuse bilateral atelectasis	High grade
Toce et al. [23]	Chest radiograph	Roentgenographic severity of BPD	0–8, each category scored from 0 to 2	Cardiovascular abnormalities, hyperexpansion, emphysema, fibrous/interstitial abnormalities	Higher total score

BPD, bronchopulmonary dysplasia; CT, computed tomography.

using high-pitch DSCT densitometry as indices of BPD severity in premature infants. Our results may support the use of high-pitch DSCT for the diagnosis and quantitative evaluation of BPD in this population.

2. Materials and methods

2.1. Study design

This study included both prospective observation and data evaluation of preterm infants ($n = 9$) selected for this study, and retrospective evaluation of the corresponding data of a subgroup of late-preterm infants ($n = 8$) and a subgroup of early-term infants ($n = 7$) as the comparative controls.

2.2. Subjects

Preterm infants under 34 weeks' GA and late-preterm infants of 34 to 36 ± 6 days were included in this study, and all infants received chest high-pitch DSCT at 36–37 weeks' PMA [6]. The data of early-term infants at 37–38 weeks' GA who had received chest CT with contrast within 3 days of delivery served as a comparison group. All late-preterm and early-term infants received CT for evaluation of congenital anomalies. Data of the preterm infants were collected and their CT records were reviewed on the picture archiving and communication system (PACS). Data of infants receiving CT performed at 36 weeks' PMA were evaluated because BPD is defined on the basis of oxygen requirements at 36 weeks' PMA [3].

2.3. Ethical considerations

Signed informed consent was obtained from all parents prior to enrollment of their infants in the study. Informed consent was not required for the early term group as their records were reviewed retrospectively. The study protocol was approved by the institutional review board of National Cheng Kung University Hospital.

2.4. BPD severity

BPD clinical severity was based on the National Institutes of Health (US) criteria of BPD for neonates treated with more than 21% oxygen for at least 28 days [3]. Briefly, mild BPD was defined as breathing room air at 36 weeks' PMA or discharge (whichever comes first) for babies born before 32 weeks, or breathing room air by 56 days' postnatal age, or discharge (whichever comes first) for babies born after 32 weeks' gestation. Moderate BPD was defined as the need for <30% oxygen at 36 weeks' PMA age, or discharge (whichever comes first) for babies born before 32 weeks, or the need for <30% oxygen to 56 days' postnatal age, or discharge (whichever comes first). Severe BPD was defined as the need for >30% oxygen, with or without positive pressure ventilation or continuous positive pressure at 36 weeks' PMA; or discharge (whichever comes first) for babies born before 32 weeks; or need for >30% oxygen with or without positive pressure ventilation or continuous positive pressure at 56 days' postnatal age; or discharge (whichever comes first) for babies born after 32 weeks' gestation.

2.5. High-pitch DSCT and radiation dose

Nonenhanced volumetric chest CT images were obtained in the premature group without a respiratory-trigger using a DSCT scanner (Definition-Flash; Siemens Corp., Munich, Germany). The CT scan protocol parameters were as follows: 80 kV, quality reference mAs 36, collimation thickness 0.6 mm, pitch 2.5, and rotational speed 0.28 s. To assess the radiation dose, the effective dose in mSv was estimated from the dose-length product (DLP) [20] by multiplying the DLP by 2.3, since the machine uses a 32-cm phantom for evaluation of the body surface area. The DLP conversion coefficient was 0.0823 for newborns who had received chest CT imaging [21]. Continuous positive airway pressure (CPAP) ventilation was maintained during the examination. CPAP was maintained via a prong in the nasal cavity with room air or a low concentration of oxygen, and the pressure was approximately 5–6 cm H_2O. CPAP usually keeps the larynx and the upper airway open and has less effect on the lower airway. We used a pitch of 2.5 (8 cm) because in our tests, a pitch of 3.2 resulted in a high level of noise and a higher radiation dose while the scan time was almost the same. Scan times for high-pitch scan modes were as follows:

Pitch: 2.0, table feed: 27 cm/s	8 cm: 0.296 s
Pitch: 2.5, table feed: 34 cm/s	8 cm: 0.235 s
Pitch: 3.2, table feed: 43 cm/s	8 cm: 0.186 s
Pitch: 3.4, table feed: 46 cm/s	8 cm: 0.174 s

Table 2
Infant characteristics by group

	Gestation weeks			*P*
	<34, Preterm ($n = 9$)	34–36 + 6 days, Late preterm ($n = 8$)	37–38, Early term ($n = 7$)	
Sex				
Male	2 (22.2)	7 (88.5)	5 (71.4)	.022
Female	7 (77.8)	1 (12.5)	2 (28.6)	
Birth weight (g)	763 ± 265 (559, 967)	2313 ± 227* (2119–2599)	2566 ± 418* (2179–2953)	<.001
Body length (cm)	33.2 ± 3.5 (30.5–35.9)	47.8 ± 3.3* (43.9–51.4)	46.4 ± 2.2* (44.4–48.5)	<.001
Plain film thoracic area day of birth (mm^2)	1944 ± 679 (1422–2467)	5127 ± 1435* (3674–6861)	4,730 ± 890* (3906–5554)	<.001

Data are presented as count and percentage or mean±standard deviation with 95% confidence interval.
* Indicates a significant difference compared to preterm infants.