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Optimal imaging protocol for measuring dynamic expiratory collapse of the central airways

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AIM: To compare measurements of expiratory collapse obtained using multidetector computed tomography (MDCT) of the central airways on routine axial and multiplanar reformatted (MPR) images.

MATERIALS AND METHODS: Fifty volunteers with normal pulmonary function and no smoking history were imaged using a 64 MDCT system (40 mAs, 120 kVp, 0.625 mm collimation) with spirometric monitoring at end-inspiration and during forced expiration. Measurements of the trachea, right main (RMB) and left main bronchus (LMB) were obtained on axial and MPR images. Inspiratory and dynamic-expiratory cross-sectional area (CSA) measurements were used to calculate the mean percentage expiratory collapse (%Collapse). A paired *t*-test was used to assess within-subject differences and a Bland–Altman plot was used to assess agreement between the methods.

RESULTS: Among 24 men and 26 women (mean age±standard deviation 50±15 years), CSA values were significantly greater on axial than MPR images (all $p<0.001$); however, the mean difference in %Collapse values for axial versus MPR were small: trachea ≈1% (55 ±19 versus 56±18, $p=0.338$); LMB identical (60±20 versus 60±17 $p=0.856$); and, RMB 4% (62 ±19 versus 66±19 $p<0.001$). On average, creation of MPR required 12 minutes of additional time per case (range=10–15 min).

CONCLUSION: Differences in mean %Collapse for axial versus MPR images were small and unlikely to influence clinical management. This finding suggests that MPR may not be indicated for routine assessment of central airway collapse.

Introduction

Multidetector computer tomography (MDCT) is increasingly used to evaluate individuals with suspected excessive dynamic airway collapse or tracheobronchomalacia (TBM).[1]

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In this setting,[2,3] MDCT has been shown to be comparable to bronchoscopy, which has traditionally been considered the reference standard.[1] Moreover, MDCT has proven to be a reproducible and effective minimally invasive method to quantify expiratory collapse.[4]

The bronchi often course obliquely to the axial plane, and this angular inclination introduces parallax error, which is an apparent difference in the shape and dimension of an object viewed along two different lines of sight.[5] Parallax error can be minimised by the use of multiplanar reformatted (MPR) imaging, which has proven to be more precise than axial images in assessing fixed airway stenosis.[6–8] MPR imaging is thus routinely recommended for this indication,[9] but requires additional time and post-processing imaging facilities.[10]

To date, the magnitude of parallax error on MDCT measurements of central airway expiratory collapse has not been determined.[11] Therefore, the aim of the present study was to compare MDCT measurements of tracheal and bronchial expiratory collapse obtained on routine axial and MPR images obtained perpendicular to the airway lumen.

Material and methods

This study was approved by the Beth Israel Deaconess Medical Center (BIDMC) institutional review board, Committee on Clinical Investigations, (2007-P-000348) and was performed in compliance with Health Insurance Portability and Accountability Act guidelines. Written informed consent was obtained from all participants. The prospective sample of healthy volunteers was originally studied to determine the normal range of forced expiratory tracheal and bronchial collapse using MDCT.[12,13] The separate aim of this retrospective analysis was to compare central airways collapse in axial versus MPR images in order to determine the utility of this resource-intensive post-processing technique.

Patient population

The initial study population was comprised of 51 healthy volunteers who were asymptomatic, lifetime non-smokers with normal pulmonary function, and no history of chronic lung disease. One participant was excluded due to poor CT image quality (motion artefact from respiration). Thus, 50 participants comprised the final study population.

Imaging technique

All participants were imaged using a 64-MDCT scanner (Light Speed VCT; General Electric Medical Systems, Milwaukee, WI, USA) with the following imaging parameters: 120 kVp, 40 mAs, 0.625 mm collimation, 0.5 second gantry rotation, pitch of 1.375, and 10 cm field of view. To reduce radiation exposure, helical scanning was performed in the craniocaudal direction from 2 cm above the aortic arch to 2–3 cm below the carina, corresponding to a length of approximately 8–9 cm. Images were acquired at end-inspiration and during forced exhalation with active respiratory coaching and spirometric monitoring by a respiratory physiologist. The physiologist ensured that image acquisition was performed at both total lung capacity (TLC) and during dynamic expiration.[14] A dry-seal, volume displacement spirometer (Eagle II Survey spirometer; Collins Sensormedics, Yorba Linda, CA, USA) was used to monitor end-inspiratory and forced expiratory MDCT acquisition. Images were reconstructed at 2.5 mm collimation with 1.25 mm reconstruction intervals in a standard algorithm and transferred to a picture archiving and communication system workstation for analysis of the airway lumen.[15]

Image post-processing and analysis

Each scan was analysed at an imaging workstation (Advantage Workstation, GE, General Electric Healthcare, USA) by one of three independent, thoracic radiologists experienced in assessing dynamic airway collapse using MDCT. Axial and MPR measurements of the right and left main bronchi (RMB and LMB, respectively) were measured. Axial and MPR measurements of the trachea were performed using the technique described below. Post-processing of MDCT data for the trachea, RMB and LMB was accomplished by generating a double oblique true coronal reformation of the trachea and each bronchus and subsequently obtaining a reformatted transverse image that was perpendicular to the long axes of the airways. The images were then evaluated with standard lung window display settings (window level, −650 HU; window width, 1500 HU).[16]

For each case, end-inspiratory and dynamic forced expiration images of the trachea and bronchi were assessed at three standard anatomical levels: trachea, 1 cm above the aortic arch; RMB and LMB, 1 cm below the carina (Fig 1).[12,13] The cross-sectional area (CSA) of the lumens of the trachea and main bronchi were measured with an electronic tracing tool using a magnified field of view. The %Collapse was calculated as follows

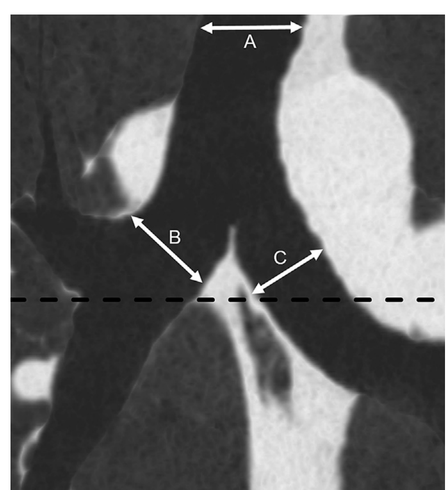

Figure 1 Coronal reconstructed CT image shows assessment of tracheobronchial tree at three anatomic levels: (a) trachea (arrow) 1 cm above the aortic arch; (b) RMB (arrow) 1 cm below carina; and (c) LMB (arrow) 1 cm below carina. Dashed line indicates the standard transverse plane.