Preliminary Investigation

Glottis Closure Influences Tracheal Size Changes in Inspiratory and Expiratory CT in Patients with COPD

Nicholas Landini, MD, Stefano Diciotti, PhD, Monica Lanzetta, MD, Francesca Bigazzi, MD, Gianna Camiciottoli, MD, Mario Mascalchi, MD, PhD

Abbreviations and Acronyms

APD anteroposterior diameter

APDexp (CSAexp), APD (CSA) measured in expiratory CT scans

APDinsp (CSAinsp), APD (CSA) measured in inspiratory CT scans

BMI body mass index

COPD chronic obstructive pulmonary disease

CSA cross-sectional area

CT computed tomography

GOLD Global Initiative for Chronic Obstructive Lung Disease

PFT pulmonary function tests

TM tracheomalacia

Vexp lung expiratory volume

Vinsp lung inspiratory volume

Rationale and Objectives: The opened or closed status of the glottis might influence tracheal size changes in inspiratory and expiratory computed tomography (CT) scans. We investigated if the glottis status makes the tracheal collapse differently correlate with lung volume difference between inspiratory and expiratory CT scans.

Materials and Methods: Forty patients with chronic obstructive pulmonary disease whose glottis was included in the acquired scanned volume for lung CT were divided into two groups: 16 patients with the glottis closed in both inspiratory and expiratory CT, and 24 patients with the glottis open in at least one CT acquisition. Lung inspiratory (Vinsp) and expiratory (Vexp) volumes were automatically computed and lung ΔV was calculated using the following formula: $(Vinsp - Vexp)/Vinsp \times 100$. Two radiologists manually measured the anteroposterior diameter and cross-sectional area of the trachea 1 cm above the aortic arch and 1 cm above the carina. Tracheal collapse was then calculated and correlated with lung ΔV.

Results: In the 40 patients, the correlations between tracheal Δanteroposterior diameter and Δcross-sectional area at each level and lung ΔV ranged between 0.68 and 0.74 (ρ) at Spearman rank correlation test. However, in the closed glottis group, the correlations were higher for all measures at the two levels (ρ range: 0.84–0.90), whereas in the open glottis group, correlations were low and not statistically significant (ρ range: 0.29–0.34) at the upper level, and moderate at the lower level (ρ range: 0.51–0.55).

Conclusions: A closed or open glottis influences the tracheal size change in inspiratory and expiratory CT scans. With closed glottis, the tracheal collapse shows a stronger correlation with the lung volume difference between inspiratory and expiratory CT scans.

Key Words: Tracheal collapse; glottis; lung volume; CT; COPD.

Acad Radiol 2017; ■:■■–■■

From the Department of Clinical and Experimental Biomedical Sciences "Mario Serio," University of Florence, Viale Morgagni 50, Florence 50134, Italy (N.L., M.L., F.B., G.C., M.M.); Department of Electrical, Electronic, and Information Engineering "Guglielmo Marconi," University of Bologna, Via Venezia 52, Cesena 47521, Italy (S.D.). Received October 19, 2016; revised January 18, 2017; accepted January 25, 2017. **Address correspondence to:** N.L. e-mail: nikolandini@hotmail.it

http://dx.doi.org/10.1016/j.acra.2017.01.018

INTRODUCTION

Computed tomography (CT) is a valuable technique for imaging the tracheobronchial tree (1). However, its role in the analysis of tracheal collapsibility in normal or abnormal conditions, including tracheomalacia (TM) and tracheobronchomalacia, is still controversial (2).

Few studies analyzed the correlation between the degree of tracheal collapse and the lung volume difference between

inspiration and expiration. Ederle et al. (3) did not observe a relevant correlation between inspiration or expiration changes in the trachea and lung cross-sectional areas in patients with chronic obstructive pulmonary disease (COPD). On the other hand, two studies found substantial correlations between the difference of tracheal volumes and that of inspiratory and expiratory lung volumes in smokers (2) and patients with COPD (4).

Notably, in all the previously mentioned studies, the possible influence of an opened or closed glottis on the change of the tracheal size in inspiratory and expiratory scans was not addressed. In particular, based on the observation in a single patient with COPD that tracheal collapse was more pronounced in end expiration than in forced expiration, O'Donnell et al. (5) speculated that this unexpected finding might have been determined by the status of the glottis.

In the present study, we preliminarily explored in lung CT examinations if the open or closed glottis status influences the correlation between inspiratory and expiratory tracheal size changes and corresponding lung volume difference in 40 patients with COPD.

MATERIAL AND METHODS

Subjects

The present investigation was based on data obtained for a previous study (6) in 132 smokers or former smokers with COPD (103 men and 29 women, age 66 ± 8 [mean ± SD] years), who were evaluated with pulmonary function tests (PFT), classified according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria (7), and then underwent inspiratory and expiratory CT examination.

Subjects within 1 month of an exacerbation or with clinical conditions that could have interfered with the assessment of pulmonary function or chest CT quantitative parameters were excluded. All patients provided a written informed consent to participate in the study that was approved by the local ethical committee.

From the original 132 patients, for the present investigation, we excluded 29 patients: three for presence of pleural effusion, and 26 due to failed or imperfect results of the automated lung segmentation procedure described in the following. From the 103 remaining patients, one operator with 5 years of experience in chest CT selected 45 patients with the glottis included in both inspiratory and expiratory CT scans. The 45 patients (38 men and 7 women, age 70 ± 7 [mean ± SD] years, smoking exposure of 49.0 ± 26.9 [mean ± SD] pack-years) were classified with the GOLD system guideline as follows: 25 GOLD I, 11 GOLD II, 2 GOLD III, and 7 GOLD IV. The same operator then divided the patients into two groups according to glottis status: 16 patients (closed glottis group) with the glottis closed (Fig 1a) in both inspiratory and expiratory CT scans, and 29 patients (open glottis group) with the glottis open (Fig 1b) at least in one of the CT acquisitions (14 subjects with the glottis opened in both scans, 6 subjects with the glottis opened only in inspiration, and 7 subjects with the glottis opened only in expiration).

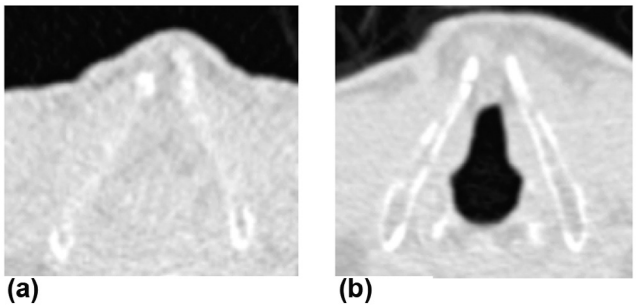

Figure 1. Portions of a computed tomography (CT) slice showing a closed **(a)** and open **(b)** glottis. The complete closure of the glottis ensures airways closure.

Pulmonary Function Tests

Patients underwent complete pulmonary function evaluation with the use of a mass flow sensor and a multi-gas analyzer (V6200 Autobox Body Plethysmograph; Sensor Medics, Yorba Linda, CA). Pre- and post-bronchodilator spirometric data, static lung volumes, and single-breath diffusing capacity for carbon monoxide were measured according to American Thoracic Society/European Respiratory Society guidelines (7–9).

CT Acquisition

All subjects performed a volumetric chest CT within 48 hours of PFT, both at full inspiration and at end expiration. Patients had been previously instructed on how to perform the respiratory maneuver. In particular, they were requested to perform a full (not forced) expiration and then to breath-hold. No contrast medium was used. All examinations were obtained with the same CT scanner (Sensation 64; Siemens, Erlangen, Germany) with the following acquisition and reconstruction parameters: 120 kVp, 200 mAs (inspiratory), 50 mAs (expiratory), B31f reconstruction kernel, section thickness of 0.75 mm, and section interval of 0.5 mm.

Measurements of Lung Volumes on CT

Lung inspiratory (Vinsp) end expiratory (Vexp) volumes were computed by an automated segmentation algorithm (10), composed by the following steps: (1) a gray-level thresholding procedure, (2) a connected component analysis, (3) removal of trachea and main bronchi, and (4) filling of pulmonary vessels.

Failed segmentations included cases in which the trachea or the main bronchi were even partially included in the segmented object and cases in which ventilated portions of the lung were outside the segmented object.