

Computer automated algorithm to evaluate cavitory lesions in adults with pulmonary tuberculosis

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Introduction

The presence of a cavitory lesion is a radiographic hallmark of pulmonary tuberculosis (TB). The sizes of the cavitory lesion and its proximity to the bronchial tree have been associated with mycobacterial burden (1). However, the task of evaluating the size of a cavitory lesion is problematic due to differences in reporting methods (e.g., uni-dimensional maximum in the axial plane *vs.* bi-dimensional) and inter-observer variance (2,3). The evaluation of a cavitory lesion is often complicated by their irregular shape, thus the radiographic reporting of the lesion (e.g., spherical volume) might underestimate or overestimate its actual size. The problem with having several methods of reporting is that global communication becomes impaired, and results from different groups more difficult to compare. A computer-aided algorithm would help to diminish the inter-rater differences in reporting, and provide a more precise evaluation of the size of a lesion and its distance from the bronchial tree.

The objective of this correspondence is to report an improved computer-aided algorithm to automatically (A) detect a cavitory lesion, (B) report its size, and (C) find the closest distance from the bronchial tree in patients with pulmonary TB.

Methods

Our previously reported algorithm evaluated cavitory lesions in rabbits (4). This algorithm uses a machine learning method which calculates the volume based on the voxel size. To assess cavitory lesions in humans, we improved the lung segmentation technique to cover smaller cavities (5). The improved algorithm automatically detects the presence of a cavitory lesion, reports its size, and calculates the minimum distance between the lesion and the bronchial tree from a person's computerized tomography (CT) scan. The minimum distance was calculated based on Euclidean distance transformation methods (6). To test this improvement, we evaluated human CT scans available from patients with pulmonary TB who were enrolled in a TB cough frequency study in Peru (7).

In brief, this study evaluated adults with suspected pulmonary TB that was confirmed with auramine smear and by the microscopic observation drug susceptibility (MODS) broth culture assay (8-10). Characteristics of the patients' cough were obtained with the ambulatory Cayetano Cough Monitor (CayeCoM) device (7), which measures and groups consecutive coughs that are within 2 seconds from each other to be part of the same episode. CT scans were performed with a 1.25-mm slice thickness.

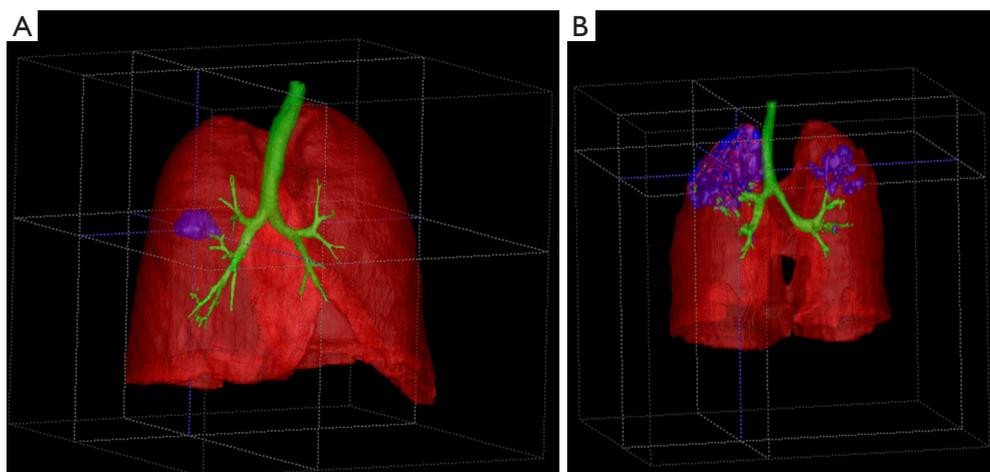


Figure 1 3-D rendering of a cavitory lesions in TB drug-susceptible HIV-negative patients. (A) Shows a lung volume of 6,402.2 mL with a single 20.1 mL cavity in the patient's right lung; (B) shows a lung volume of 2,646.3 mL, with 12 cavities in both lungs (133.6, 9.9, 1.6, 1.4, 1.2, 1.1, 0.7, 0.6, 0.2, 0.2, 0.2, 0.1 mL).

Results

Two CT scans were evaluated. The first one from a 49-year-old HIV-negative male, whose initial sputum sample was smear positive (++) and culture positive according to MODS culture. This patient was started on standard quadruple TB treatment (first line). Baseline time to positivity of the MODS culture was 5 days, and the isolate was susceptible to Rifampicin and Isoniazid. The CayeCoM device recorded this patient for 20 continuous hours on the day of treatment initiation (day 0), and showed a cough rate of 1.7 cough episodes per hour. The CT scan with 273 slices was obtained 4 days after treatment started. The algorithm 3D-rendering results are shown in *Figure 1A*. The lung volume was 6,402.2 mL, and a single 20.1 mL cavity was observed in the right lung, yielding a cavity-to-volume percentage of 0.3%. The shortest distance between the bronchial tree and the cavitory lesion was 5.2 mm in this case.

The second CT scan was obtained from a 48-year-old HIV-negative female, whose initial sputum sample was smear positive (+++) and MODS culture positive for TB, with a baseline time to positivity on MODS of 6 days and a fully sensitive isolate. This patient was also started on standard quadruple TB treatment. The CayeCoM device recorded this patient for 24 continuous hours on day 1 of treatment, and showed a cough rate of 0.8 cough episodes per hour. The CT scan with 217 slices was obtained 26 days

after treatment started. The algorithm 3D-rendering results are shown in *Figure 1B*. The analysis found that lung volumes were of 2,646.3 mL, with 12 cavities in both lungs. The volumes of the cavities were as follows: 133.6, 9.9, 1.6, 1.4, 1.2, 1.1, 0.7, 0.6, 0.2, 0.2, 0.2, 0.1 mL, and the cumulative cavity-to-volume percentage were 5.7%. The closest distance between the bronchial tree and a cavitory lesion was of 0.7 mm.

Discussion

Our results are promising, we were able to (I) detect cavitory lesions, (II) assess the size of each cavity, and (III) to calculate the closest distance of the lesions from the bronchial tree, in patients with pulmonary TB. With use of this algorithm we hope to standardize the reporting of cavitory lesion findings, which can in turn help researchers and clinicians communicate better regardless of radiologist background and clinical setting. We anticipate that results from this algorithm will not only help us to speak a common language in the clinical management of patients, but will also provide a significant contribution to TB research by providing important information into the role a cavitory lesion plays in TB pathophysiology and transmission.

In a separate study, we will use the algorithm results to test the previously stated association between cavity size and distance from the airways, and mycobacterial burden. We hope to make this algorithm easier to implement in clinical

settings ideally providing clinicians a fast, reproducible, and precise method of evaluating cavitory lesions in patients with pulmonary TB. Its usage may additionally help clinicians and researchers improve TB diagnostics, methods of monitoring treatment response, and assessment of transmission risk.

Finally, this algorithm has the potential of evaluating cavitory lesions from not only pulmonary TB, but also from other etiologies such as lung cancer or *Staphylococcus aureus* (11).

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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