Measurement of heterogeneous distribution on Technegas SPECT images by three-dimensional fractal analysis

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This review article describes a method for quantifying heterogeneous distribution on Technegas (99mTc-carbon particle radioaerosol) SPECT images by three-dimensional fractal analysis (3D-FA). Technegas SPECT was performed to quantify the severity of pulmonary emphysema. We delineated the SPECT images by using five cut-offs (15, 20, 25, 30 and 35% of the maximal voxel radioactivity), and measured the total number of voxels in the areas surrounded by the contours obtained with each cut-off level. We calculated fractal dimensions from the relationship between the total number of voxels and the cut-off levels transformed into natural logarithms. The fractal dimension derived from 3D-FA is the relative and objective measurement, which can assess the heterogeneous distribution on Technegas SPECT images. The fractal dimension strongly correlate pulmonary function in patients with emphysema and well documented the overall and regional severity of emphysema.

Key words: heterogeneity, SPECT, Technegas, fractal analysis, pulmonary emphysema

INTRODUCTION

TECHNEGAS (99mTc-carbon particle radioaerosol; Daiichi Radioisotope Co. Ltd., Tokyo, Japan) has been used recently for ventilation studies of the lung. Burch et al. reported that Technegas has particles of a considerably smaller size, and these can reach the peripheral parts of the lung. Technegas has the advantage of not being cleared from the lung once the particles stick to the alveolar wall and therefore is suitable for SPECT studies. Technegas SPECT images reveal peripheral irregularity in mild emphysema and further hot spot formation and regional defects in severe emphysema (Fig. 1). The consequent heterogeneous appearance of Technegas distribution has been used as a diagnostic index for emphysematous severity, but an objective quantification of such severity is difficult to make because of the lack of a convenient and widely accepted standard for quantifying spatial heterogeneity. We thought that the three-dimensional fractal analysis (3D-FA) could be applied as a reproducible and sensitive quantification of emphysematous severity. Fractal analysis is potentially suitable for an objective quantification of spatial heterogeneity because it is believed to be effective in helping to characterize complex systems that are hard to describe by means of conventional Euclidean geometry.

In this review, we introduce 3D-FA for quantifying the heterogeneous distribution on Technegas SPECT images and investigate the meaning and clinical application of 3D-FA.

THREE-DIMENSIONAL FRACTAL ANALYSIS

Characteristics of Technegas

The ideal size of aerosol droplets in order to get good uniformity in the lungs during deep tidal volume breathing was considered to be between 0.1 and 0.5 μm. Because particles larger than 2 μm are likely to be deposited in the proximal bronchial trunci, 99mTc-phytate aerosol images had a limitation due to intense bronchial foci in cases with severe chronic obstructive pulmonary
Fig. 1  A: 45-year-old healthy male. Technegas SPECT images show homogeneous distribution in whole lung. His fractal dimension for total lung is 0.46. B: 65-year-old male with mild emphysema. Technegas SPECT images show heterogeneous distribution in whole lung. His fractal dimension for total lung is 0.79. C: 63-year-old male with severe emphysema. Technegas SPECT images show heterogeneous distribution of cold and hot spots throughout peripheral lung field. His fractal dimension for total lung is 2.54.

disease.²³ Technegas is ultra fine carbon particles of the order of 0.005 μm.¹ Technegas imaging also provides similar or better diagnostic information on lung ventilation imaging than ¹³³Xe and ⁸¹mKr.²¹¹ ⁸¹mKr and ¹³³Xe scintigraphy needs a ventilation system. Technegas is readily available, is easy to use, is inexpensive, and delivers a low radiation dose.¹²

Data acquisition for Technegas SPECT
Technegas was generated in a proprietary generator (Technegas Generator, Tetley Manufacturing Ltd., Sydney, Australia) by the resistive heating of a graphite crucible to 2500 °C in which a saline solution of 266–600 MBq of ⁹⁹mTc-pertechnetate had been placed and dried. After generation of the aerosol, it was dispersed in a lead-lined chamber in an atmosphere of 100% argon. Technegas was administered through a mouthpiece, with a nose clip in situ, to patients in the sitting position. The patients slowly inhaled Technegas and then held their breath for 5 seconds at the maximal point of inspiration. This procedure was repeated three to five times.

SPECT imaging was performed with a three-headed system (TOSHIBA GCA9300, Toshiba, Tokyo, Japan) equipped with low-energy high-resolution collimators (full width at half maximum = 12 mm) and interfaced with a dedicated computer. Projection data were acquired with 5° angle intervals on a 128 × 128 matrix over 360° by rotating each detector head 120°. The acquisition time