A Statistical Hypothesis Test For Threshold-Based Emphysema Quantification

G. Vegas Sanchez-Ferrero[1], **G. Washko**[2], **F. N. Rahaghi**[1], **M. Ledesma Carbayo**[3], **R. San Jose Estepar**[1]

[1]Brigham and Women's Hospital, Boston, MA, [2]Brigham and Women's Hospital, Harvard Medical School, Boston, MA, [3]Biomedical Image Technologies, Madrid, Spain

Background: A threshold-based approach, also known as density masking, is the de-facto standard for emphysema quantification. Emphysema is detected when the CT voxel intensity falls below a given threshold (-950 HU has been proposed for high resolution CT based on histology correlation). However, there is no statistical test available to assess the significance of the detection. We derive a formal statistical hypothesis test and propose a new emphysema quantification using the results of the hypothesis test.

Methods: We model the distribution of intensities within a secondary pulmonary lobule as a non-central gamma distribution. This model fits well realizations of both normal and emphysematous lung parenchyma. We propose a test statistic defined as the truncated mean density of the voxels that are below a given threshold. This statistic can be interpreted as the mass of the detected emphysema regions. We then derive the exact probability and cumulative density functions (PDF and CDF respectively) for the test statistic as a function of the threshold and the number of voxels that are below the threshold. A sample is defined as emphysema if the test reaches the significance level. We use a database with 1,337 lung region of interest of size 24 mm^2 with normal (n=370) and emphysema (n=967) from HRCT with a nominal voxel size of 0.6 mm^3, 120 kVp, 200 mAs and 9 different models. We compute the ROC and compare this approach with the standard density masking.

Results: The statistical test approach and density masking have an AUC of 0.98 and 0.93, respectively. The optimal operational point for our method has a sensitivity and specificity of 94.62% and 93.25% respectively while density masking at -950 HU has a sensitivity of 85.52% and spec. of 89.19%. Based on the analysis of the response of our statistical test, the asymptotic convergence for large number of detections is -951.8 HU that is interestingly very closed to the threshold that has been empirically shown to be optimal and is largely used in imaging studies.

Conclusions: We propose a new statistical hypothesis test for threshold-based emphysema detection based on a non-central gamma distribution. This test provides a constructive way to do emphysema quantification as a hypothesis test. Based on our testing dataset, this approach is superior to traditional density masking.

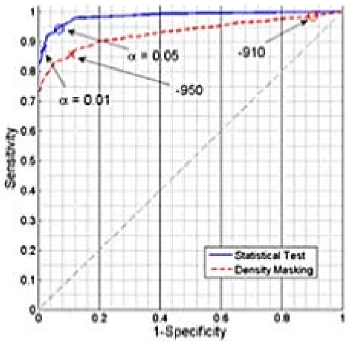

Fig. 1: ROC curve. The area under curve for the statistical test is 0.98 while the AUC for density masking is 0.93. The proposed statistical method increases a 9% of sensitivity and 4% in specificity.

This abstract is funded by: K25 HL104085, 1R01HL116931