Pulmonary Vascular Remodeling Quantification In Inspiratory Volumetric CT Using Scale-Space Particles

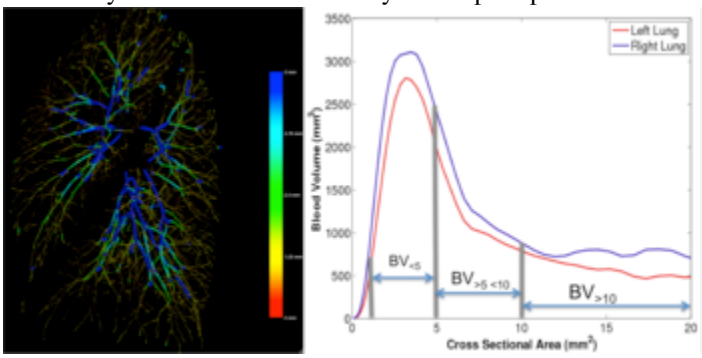
R. San Jose Estepar[1], J. C. Ross[2], G. L. Kindlmann[3], A. Diaz[4], G. Kinney[5], J. Hokanson[5], E. K. Silverman[6], G. R. Washko[1], and the COPDGene Investigators

[1]Brigham and Women's Hospital, Boston, MA, [2]Brigham and Women's Hospital, Boston, [3]University of Chicago, Chicago, [4]Brigham and Women's Hospital, Harvard Medical School, Boston, MA, [5]Colorado School of Public Health, Aurora, [6]Brigham & Women's Hospital, Boston, MA

Corresponding author's email: rjosest@bwh.harvard.edu

Rationale: It is estimated that 30 to 70% of subjects with advanced chronic obstructive pulmonary disease (COPD) have clinically significant pulmonary vascular disease (PVD). PVD is in part mediated by vascular remodeling including inflammation and endothelial dysfunction present even in smokers with normal lung function. Objective analysis of pulmonary vascular morphology on CT may provide robust metrics of vascular disease in smokers which are predictive of clinically meaningful processes.
Methods: We have previously developed a method based on scale-space particles to extract the lung parenchyma vasculature. Particles are placed in areas of high attenuation and the algorithm refines those locations, add new points and remove points in a fashion that is consistent with the tubular nature of a vessel. A final filtering step removes outlier particles (Figure 1a). Vascular physical radius was computed by inferring the relation between scale and radius. For a tubular model with flat density profile that undergoes a Gaussian spread function this relation is given by r=sqrt(2) sqrt(s_0^2 + s^2), where s_0 is the standard deviation of the Gaussian spread function and s is the scale detected by scale-space particles. Vascular remodeling was quantified by plotting the amount of blood volume per cross sectional area (Figure 1b). From these plots, two ratios were defined: blood volume for vessels less than 5 mm^2 (BV5) and larger than 10 mm^2 (BV10) divided by total intraparencymal blood volume. Intraparenchymal vasculature was extracted in 1386 subjects from the COPDGene cohort. Univariate and multivariate linear regression were used to show the association with 6 minute walk distance (6MWD) and BODE (a predictor of mortality).
Results: The cohort consisted of 49.6% males and 50.4% females with a mean age of 61.5±9.2 years and a mean tobacco smoke exposure of 46±24.7 pack-years. The mean FEV1%predicted of the cohort was 72.8%±27.6. After adjusting for FEV1%, BMI, %LAA and WA%, BV5 and BV10 were independent predictors of 6MWD with a positive regression coefficient (796.67, pval<0.0001) and a negative regression coefficient (-1735.64, pval<0.0001) respectively. BV5 and BV10 were also predictor of BODE after adjusting for LAA% and WA% with regression coefficients -1.76 (pval<0.0001) and 3.12 (pval=0.03) respectively.
Conclusions: Scale-space particles is a feasible approach to efficiently extract and objectively quantify intraparenchyma pulmonary vasculature remodeling in CT. Our results suggests that as the distal vessels constrict (BV5/TBV decreases) and proximal vessels dilate (BV10/TBV increases), patients become more symptomatic (lower 6MWD and higher BODE score).

Pulmonary vasculature extraction by scale-space particles



Extracted intraparenchymal vasculature with our approach (left) and quantification of vessel remodeling by blood volume distribution versus cross sectional area

This abstract is funded by: K25 HL104085