

Fractal Dimension Based Texture Analysis of CT Perfusion Imaging

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Abstract — Computed tomography of blood flow (perfusion) in the cardiac ventricles is an established imaging diagnostic technique. In this work, a novel texture analysis method based on improved calculation of fractal dimension is proposed.

CT perfusion images were manually segmented to reconstruct 3D cardiac blood flow. A previously developed texture analysis algorithm for fractal dimension was further refined, and used to assess texture changes under vasodilation and cooled dialysate (therapeutic hypothermia) conditions.

It was found that dialysis treatment increases fractal dimension at the CT imaging resolution, indicating a drastic alteration of coronary vasculature due to dialysis.

Clinical Relevance — The new method will permit rapid semi-automatic computation of, and interpretable texture measure in clinical CT perfusion imaging.

I. INTRODUCTION

Our clinical research provides strong indications that cardiac blood flow heterogeneity increases due to treatments such as dialysis [1]. We use mechanistic mathematical modelling to gain further insights into our clinical observations [2]. It is essential to develop open source image and data analysis tools that bring the clinical and mathematical approaches together. A key clinical concern is the texture of blood flow in cardiac walls, which is used as a quantitative diagnostic parameter. In this work, we further developed our fractal dimension texture analysis and applied it to previously obtained computed tomography (CT) perfusion imaging data.

II. METHODS

Previous CT perfusion imaging data was re-processed in this work. Briefly, each stack of CT blood images was manually segmented to generate a 3D blood flow structured map of resolution 0.5 mm (X) x 0.5 mm (Y) x 5 mm (Z). The fractal dimension [2] was computed using the 3D map. The method assumes that coronary blood flow is primarily regulated by the status of the underlying fractal coronary arterial-capillary vasculature. It uses the 3D map's probability distribution function (PDF), and the relative dispersion of the PDFs to compute the fractal dimension heterogeneity index. We hypothesized that multi-thresholding provides further information regarding the underlying vasculature. To test, the 3D map was first thresholded at predefined maximum and minimum values, after which the fractal dimension was computed. The method was applied to seven data sets which consisted on CT blood flow images before and after dialysis.

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III. RESULTS

Dialysis as well as treatment were found to alter fractal dimension as discussed previously [2]. Vasodilation increased fractal dimension, and mild cooling promoted reduction of fractal dimension. Computing fractal dimension upon thresholding is shown for one data set in Fig. 1. It was found that thresholding maximal blood flow values in each voxel augmented the contrast between FD estimates.

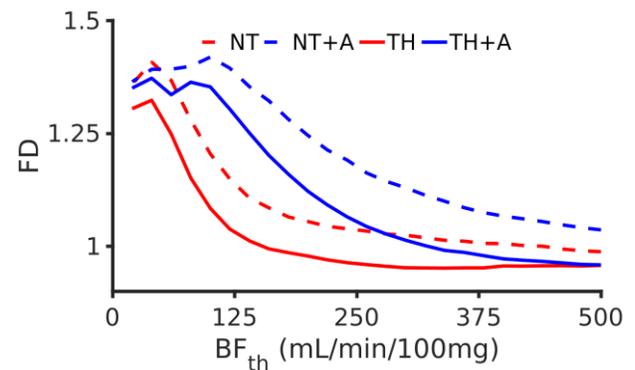


Figure 1. Fractal dimension (FD) with respect to thresholded values of blood flow (BF_{th}) in one CT perfusion data set. NT: normal temperature dialysate; NT+A: NT with vasodilator adenosine; TH: cooled dialysate simulating therapeutic hypothermia; TH+A: TH with adenosine.

IV. DISCUSSION & CONCLUSION

This preliminary study provides an open source texture analysis method. It permits clinical data interpretation in a biophysical modeling context thus providing further insights into the vasculature status based on the clinical observation.

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