PhD1

Sparsity sampling cardiac CT for perfusion quantification and dose reduction

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Application Area: Cardiovascular **Modality:** CT **Related:** PhD 2-5, 7, 8

Background

Although CT accounted for only 9% of all radiological and nuclear medicine examinations in the year 2012, CT is responsible for around 62% of all medical radiation exposure in Germany (www.bfs.de). While temporally resolved CT techniques are very promising for improving our understanding of tissue perfusion such as that of the myocardium in coronary artery disease,[1] current radiation dose levels to pursue dynamic CT are prohibitive for clinical use and require substantial reduction.

Hypothesis

To what extent can radiation exposure be reduced in time-resolved (4D) cardiac CT perfusion measurements (4D CTP, **Figure 1**) by applying methods of compressed sensing theory.

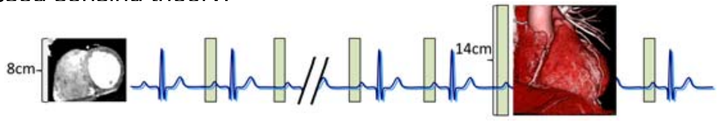

Figure 1. Concept of 4D myocardial CT covering the entire heart every beat.

Methods

The project is centered on the application of compressed sensing[2] ideas in order to reduce radiation exposure of 4D CTP. High orders of dose reduction would open new avenues of CT-based pathophysiological decision making.

Own preliminary work

We will build on the foundation of our pilot study work on 4D CT perfusion of the heart in which we have shown the feasibility of this approach.[3,4] We have developed the representation system of shearlets[5] as a means for sparse approximations of data governed by directional features (**Figure 2**).[6,7]

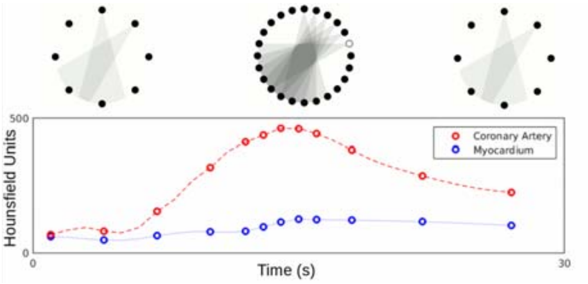

Figure 2. Dose reduction by limiting the number of angular projections and output (top row) and restricting the acquired time points (bottom row).

Work Packages

WP1: Algorithmic development

WP2: Numerical validation

WP3: Physical validation

WP4: Clinical validation

← *year 1* → ← *year 2* → ← *year 3* →

WP1: We will go beyond existing approaches and devise an extended framework, capable of modeling both spatio-temporal displacements (incurred between different heart beats) and intensity shifts (from tracer uptake).

WP2: Creating a virtual phantom for cardiac perfusion under realistic scan conditions which allows, e.g. also cardiac and respiratory motion and tracer propagation modeling, for the systematic assessment of the dose reduction potential.

WP3: Ensuring consistency of perfusion estimates across modalities by conducting an experimental cross-modality validation on a physical reference phantom for quantification of myocardial blood flow in cooperation with T. Schaeffter.

WP4: We will compare clinical cardiac perfusion data with other imaging markers obtained from MRI, CT, and PET using our dose-optimized acquisition protocols in patients with known or suspected coronary artery disease.

Clinical Translation

A clinical pilot study is planned already within the second stage of WP4. Based on this study initial conclusions on the clinical feasibility of radiation exposure reduction in 4D CTP can be drawn.

Literature

1. Rossi, A., *et al.* Stress myocardial perfusion: imaging with multidetector CT. *Radiology* **270**, 25-46 (2014).
2. Davenport, M., Duarte, M., Eldar, Y. & Kutyniok, G. Introduction to Compressed Sensing. in *Compressed Sensing: Theory and Applications* (eds. Kutyniok, G. & Eldar, Y.) 1-64 (Cambridge University Press, 2012).
3. Kendziorra, C., Meyer, H. & Dewey, M. Implementation of a phase detection algorithm for dynamic cardiac computed tomography analysis based on time dependent contrast agent distribution. *PloS one* **9**, e116103 (2014).
4. Kendziorra, C., *et al.* Four-dimensional whole-heart computed tomography perfusion of the myocardium with visual analysis using temporal averaging of three-dimensional datasets: feasibility study. *ECR*, B-0243 (2015).
5. Kittipoom, P., Kutyniok, G., and Lim, W.-Q. Construction of Compactly Supported Shearlet Frames. *Constr. Approx.* **3**, 21-72 (2012).
6. Kutyniok, G. and Lim, W.-Q. Compactly Supported Shearlets are Optimally Sparse. *J. Approx. Theory* **163**, 1564-1589 (2011).
7. Kutyniok, G., Lemvig, J., and Lim, W.-Q. Optimally Sparse Approximations of 3D Functions by Compactly Supported Shearlet Frames. *SIAM J. Math. Anal.* **44,** 2962-3017 (2012).