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Development of a myocardial perfusion phantom

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Preface

[todo] this

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Contents

1 Introduction

Myocardial Perfusion Imaging (MPI), or, simply put, the imaging of the blood flow in the heart muscle, plays an important role in diagnosing heart failure or detecting Coronary Artery Disease (CAD). Imaging systems like Computed Tomography (CT), Magnetic Resonance Imaging (MRI), Single-Photon Emission Computed Tomography (SPECT), or Positron Emission Tomography (PET) can visualise a (radioactive) contrast bolus in the supplying arteries and in underlying myocardial tissue, whose flow can give an indication of narrowed or blocked blood vessels.

Many variations in the visualisation process of myocardial perfusion, including variations in hard- and software, can (significantly) influence the outcome and in turn have consequences for patient treatment. These variations need to be validated against a well-known baseline.

A myocardial perfusion phantom will be developed that is able to simulate the blood flow in the heart muscle, i.e. the myocardium, and is able to mimic cardiac defects like (significant) stenosis.

Document overview

[todo] This section

Abbreviations

CAD Coronary Artery Disease

CT Computed Tomography

HLA Horizontal Longitudinal Axis

MPI Myocardial Perfusion Imaging

MRI Magnetic Resonance Imaging

PET Positron Emission Tomography

SA Short Axis

SPECT Single-Photon Emission Computed Tomography

VLA Vertical Longitudinal Axis

2 Research methodology

This chapter serves as a summary of the previously answered research questions and gives an overview of the research questions to come.

2.1 Main research question

Can patient treatment reliably depend on the D-SPECT, using dynamic scanning, in myocardial perfusion imaging?

Answer

As of Friday 15$^{\text{th}}$ February, 2019, the main research question has not been answered.

Answered in

It will be answered in the final report of the master's thesis.

Based on

The answer will be based on the developed myocardial perfusion phantom and the experiments performed with it at the ZGT Hengelo.

2.2 Concept of Operations

Is the D-SPECT's dynamic scanning, in comparison with other modalities(CT, MRI, PET, or SPECT), suitable for quantitative perfusion imaging?

What must the myocardial perfusion phantom be able to simulate?

Answer

The D-SPECT is relatively new in the Netherlands, but it is more widely employed in Japan, Canada, France, and Great-Britain. The highly specialised nature (for cardiac purposes), the patient friendly design, the ability to scan faster and more accurate at significant dose reductions, make the D-SPECT suitable for quantitative myocardial perfusion.

The myocardial perfusion phantom will have to simulate a patient, with stenotic artery (or arteries), in a physiological way, which is compatible with clinical protocol and software.

Answered in

The answer to this research question can be found in the system requirements document section 2.2.1 and 2.2.2, respectively.

Based on

The answer to this research question is based on the literature review and background investigation performed in the project plan, chapter 2.

2.3 Requirements and Architecture

What are the requirements for a myocardial perfusion phantom that can be used in combination with commonly used clinical software?

Answer

The requirements are specified in tables corresponding in the system requirements document.

Answered in

The answer to this research question can be found int he system requirements document, chapters 2 and 3.

Based on

The answer to this research question is based on interviews with a part of the direct stakeholders, as specified in the project plan section 3.2.

2.4 Detailed Design

How can the myocardial perfusion phantom meet the clinical requirements and mimic the perfusion of a human heart?

Answer

It will be answered in the this detailed design document.

Answered in

The answer can be found in chapter 4.

Based on

The answer to this research question is based on a mind map which results in different concept. The most promising concept, based on the requirements, is developed further into a detailed design.

3 Concept design

This chapter defines the global restraints on the concepts and presents an overview of the different concepts.

3.1 Global restraints

This section describes the global restraints on the concepts, as stated in the system requirements.

3.1.1 Myocardium

To ensure compatibility to the clinical software, *4DM*, the myocardium's cross-sectional shapes must be physiological; i.e. the Horizontal Longitudinal Axis (HLA) and Vertical Longitudinal Axis (VLA) have the shape of a horseshoe and the Short Axis (SA) has the shape of a circle. 4DM requires these shapes to determine the contours and consequently determine the myocardial flow.

3.1.2 Modality

The main research question is based around the, relatively new in the Netherlands, D-SPECT's dynamic scanning. Therefore, the modality is bounded to the D-SPECT. As mentioned in section 2.2, the D-SPECT is a suitable choice for myocardial perfusion imaging but still requires validation, which is the goal of the PhD research of which this project is part of.

3.1.3 Flow Type

Based on background information on the 4DM software, a decision has been made to use a non-pulsatile flow. The D-SPECT uses gated measurements such that images are extracted at the same point in time of the cardiac cycle. Furthermore, initial experiments with the D-SPECT, with non-pulsatile flow, have been performed on February 5, 2019. The prototype set-up from the individual project, with a dialysis tube, was placed in the D-SPECT and the TAC was extracted. This curve showed proper similarity to TACs extracted from patients.

3.2 Concept overview

Each concept is based on the mind map shown in appendix A. The following sections describe each aspect of the five main categories, respectively:

- Myocardium,
- Modality,
- Design,
- Tracer, and
- Flow.

3.2.1 Myocardium

The myocardium has two subcategories, the shape and the model. As described in section

Shape

As described in section 3.1.1, the shape of the myocardium is especially important for the 4DM software since it looks for the contours of the left ventricle's walls. Therefore, the shape of the myocardium is fixed (as per system requirements):

- VLA: Horseshoe.

- HLA: Horseshoe.
- SA: circle.

Model

[todo] this section, depending on 4dm.

3.2.2 Modality

As described in section 3.1.2, the modality is fixed (as per system requirements) to the D-SPECT's dynamic scanning.

3.2.3 Design

3.3 Concepts

3.3.1 Concept 1

3.3.2 Concept 2

3.3.3 Summary

Table 3.1: Concept overview

		Concept 1	Concept 2	Concept x
Myocardium	Shape			
	Model			
Modality				
Design				
Tracer				
Flow	Generator			
	Supply			
	Disposal			
	Configuration			
	Type			
	Perfusate			

4 Detailed design

A Appendix: Mind map

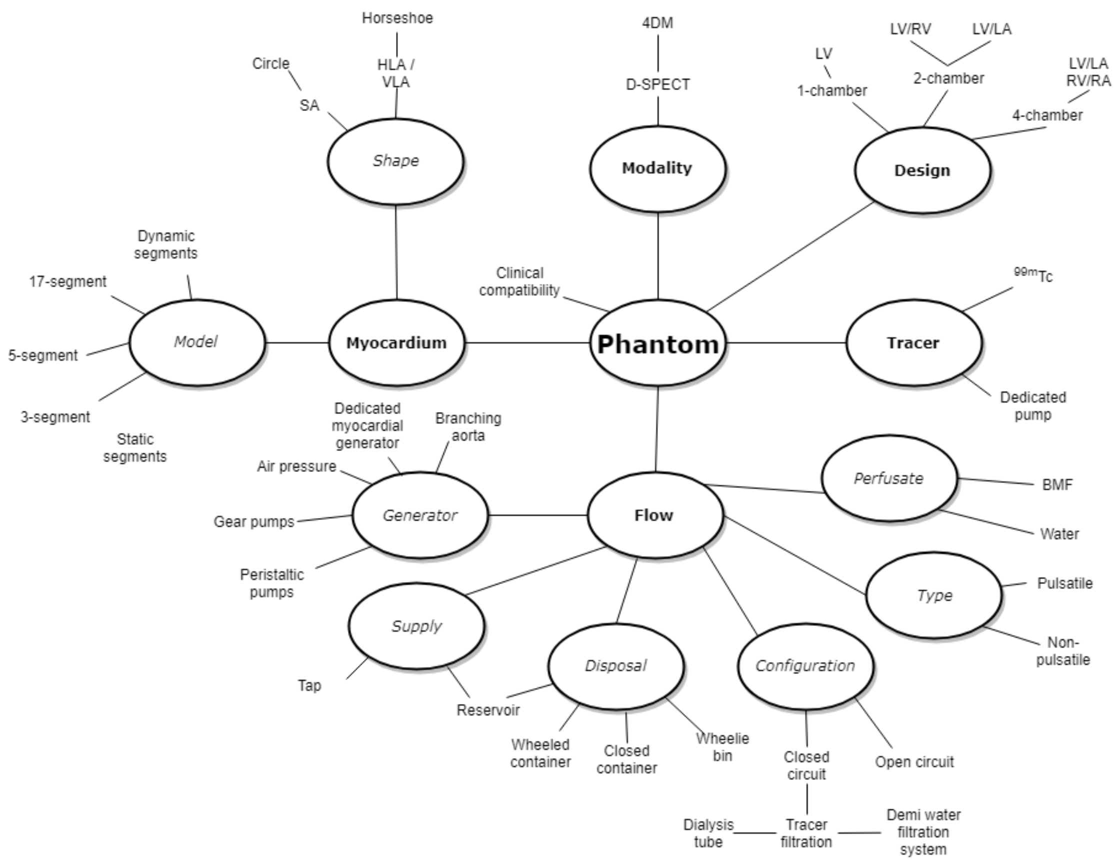

Figure A.1: Mind map for concept designs