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Technical and clinical evaluation of non-invasive coronary imaging using advanced three- and four-dimensional visualization techniques.

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8.1 ~ SUMMARY

In recent years, developments in radiological acquisition techniques such as computed tomography and magnetic resonance have enabled a marked improvement in the non-invasive visualization of the heart. These techniques do not need the introduction of catheters or instruments into the body. Images are acquired using X-rays or magnetic fields with a venous injection of contrast medium to enhance the visibility of the intravascular space. This in contrast to catheter angiography, where a depiction of the vessels is obtained by a selective injection of contrast medium using a catheter that has been guided to the heart from a small incision or puncture in a peripheral artery. The non-invasive techniques generate three- and four-dimensional datasets that have to be interpreted after various complex data processing and rendering techniques. This thesis investigates the application of advanced three- and four-dimensional visualization techniques for the evaluation of the coronary arteries.

After a general introduction in chapter 1, chapter 2 describes the coronary anatomy. This chapter provides an introduction to the anatomy of the coronary arteries and shows the anatomy using three-dimensional visualization in correlation with conventional coronary angiography in which only a projection image of the contrast filled lumen is visible. First, the physiological and anatomical basics are described. Next, the normal coronary anatomy is presented using both conventional catheter angiography and Multi Detector Computed Tomography (MDCT). Finally, a description is given of common anomalies of the coronary artery tree.

In chapter 3, an introduction on the different non-invasive scan techniques is given. It is demonstrated that CT-based techniques are more promising at this moment than Magnetic Resonance Imaging (MRI) based techniques. Therefore, the remaining chapters of this thesis are especially focused on the two CT-based techniques, Multi Detector Computed Tomography (MDCT) and Electron Beam Computed Tomography (EBCT). In the second part of this chapter it is shown that CT-based coronary angiography not only is preferred to MRI, but that it also provides for a tool with a clinical impact and that several of the pitfalls in conventional catheter angiography can be overcome by using this new technique.

In chapter 4 three-dimensional visualization of the coronary artery tree is described. Several techniques, of which Surface Rendering and Volume Rendering are the most important ones, are available to obtain this visualization. First it is demonstrated that Volume Rendering provides better results than Surface Rendering. Next, the application of different visualization techniques to obtain correct and clinically relevant results based on coronary artery MDCT datasets is shown. Furthermore, the specific application areas of the different techniques are described.

A new application of an existing visualization technique is proposed in chapter 5. The two articles in this chapter show that a virtual fly-through through the coronary arteries using both EBCT and MDCT is feasible, despite the small caliber of the arteries. However, possible application areas have yet to be established and the incremental value of this novel technique in diagnosis of coronary artery disease is not yet proven.

Chapter 6 covers the three-dimensional visualization of coronary anomalies. Coronary anomalies are anatomical variations in which the coronary arteries show unusual branching and therefore do not follow the usual course. Such variations may cause compression or kinking of the anomalous artery induced by the mechanical movement of the heart. This can cause a cyclic decrease or a full occlusion of the blood flow through the artery which can cause a heart attack. In the evaluation of these anomalies, accurate visualization and assessment of the three-dimensional course of the arteries is vital. Since MDCT does not only visualize the vascular structures, like with catheter angiography, but also provides an accurate three-dimensional visualization the whole cardiovascular anatomy, this technique is very suitable for this type of evaluation.

In chapter 7 the transition to the four-dimensional visualization is made. In four-dimensional visualization the time domain is added to the dataset. This means that different three dimensional images are generated during one heart cycle and by displaying these consecutively, a four-dimensional visualization is achieved. First the concept of four-dimensional imaging of the heart using gated MDCT data is shown. Next, a possible clinical application of the time domain is shown for the anomalous coronary arteries. It is shown that four-dimensional visualization might help to better understand the mechanisms of the heart and that more accurate diagnosis of certain clinical questions is feasible. The evaluation of anomalous coronary arteries using four-dimensional visualization can provide insight in the mechanisms during the heart cycle that lead to the manifestation of these anomalies.