Automated model-based assessment of the aortic root for optimal planning of TAVI procedures using CMRI – A comparison with manual measurements

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Introduction: Degenerative valve disease is a highly prevalent and serious health problem in the aging population [1]. Transcatheter aortic valve implantation (TAVI) is a minimally invasive intervention that is based on balloon valvuloplasty followed by the implantation of a stent-based prosthesis. Recent studies have proven the benefits over more invasive, surgical techniques [2]. Exact imaging of the concerned anatomical structures is a prerequisite for the safety and accuracy of the procedure. Therefore, a comprehensive, multi-modal imaging-based planning of the TAVI intervention is essential for optimal device selection. In this context, cardiac MR imaging is of growing relevance due to its benefits in omitting nephro-toxic, iodine-based contrast-agents as well as ionizing radiation and due to it's flexibility to assess function, morphology and geometry in a single study [3]. Methods for automatic aortic valve planimetry can complement or even replace cumbersome manual measurements and may increase the accuracy and reproducibility of aortic root assessment.

Methods: Based on previous work carried out for CT [4], we developed a MR-based, shape-constrained anatomical model of the heart (Figure 1). With this model the aortic root and its surrounding structures can be automatically segmented from whole-heart MR acquisitions. Furthermore, essential geometrical parameters for therapeutic device selection such as the mean aortic valve annulus diameter, the aortic root width and the mean diameter of the sino-tubular-junction (STJ) can be derived from the model-based segmentation results. To minimize hardware and protocol dependency we used data acquired with different phased-array RF coils and different, non-contrast, navigator-gated balanced turbo field echo (B-TFE) based MR sequences on a 1.5 T MR system (Philips Achieva, Best, The Netherlands) during model training.

We enrolled 48 patients with severe aortic stenosis and related the automatically derived, model-based aortic root measurements from MR to manual measurements, performed by a medical expert in two perpendicular views of a multi-planar reformat of the MR whole-heart volume. The inter-operator variability of the manual measurements was studied in a sub-cohort of 12 randomly selected patients and was based on the evaluations of three cardiologists of different experience-level. In another sub-study we enrolled 36 patients that underwent multidetector CT scanning in addition to MRI. We aligned the data sets according to the cardiac phase of the MR whole heart acquisition (early to late diastole) and performed inter-modality comparisons of the model-based measurements.

Results: Figure 2 shows the results of the Bland-Altman analysis [5] selectively for the mean annulus diameter. The correlation coefficient between manual and model-based measurements is 0.80 for the annulus measurement, 0.97 for the aortic root width and 0.94 for the STJ diameter. The inter-observer-variability was assessed via the intraclass-correlation (ICC) [6] and amounts to -0.02 for the annulus measurement (compare Figure 3), 0.84 for the aortic root width and 0.29 for the STJ diameter. Figure 4 compares the automatically derived annulus diameters between CT and MR. The correlation between model-based measurements in CT and MR is 0.81 for the annulus, 0.97 for the aortic root width and 0.97 for the STJ dimension.
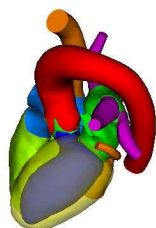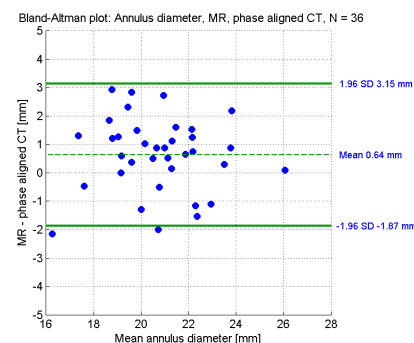

Figure 1 Anatomical model of the heart and the aortic valve
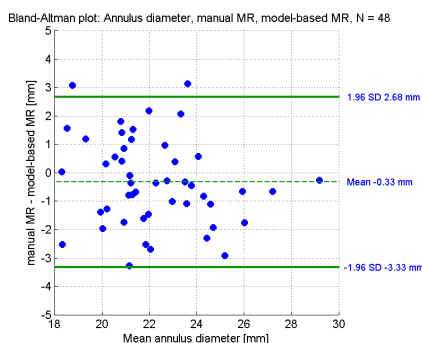
Figure 2 Comparison of model-based and manual measurements of the mean aortic annulus diameter for 48 patients via Bland-Altman analysis
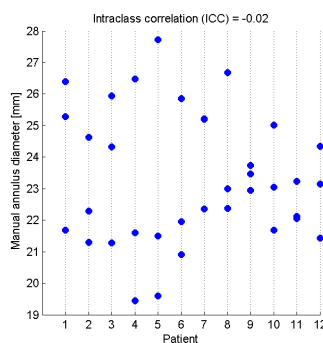
Figure 3 Dot plot of the inter-observer variability of manual annulus diameter measurements for 3 operators and 12 patients

Figure 4 Comparison of model-based measurements of the mean aortic annulus diameter in CT and MR for 36 patients via Bland-Altman analysis

Discussion: Model-based automated aortic root measurements in MR correlate well with manual evaluations and with CT-based measurements. Thus, geometrical modelling proves to be an accurate, precise and reliable technique to systematically select TAVI devices for aortic stenosis patients. In the future, patient-specific modelling can play a key role to make treatment planning for TAVI easier, faster and less operator-dependant. Furthermore this study shows that cardiac MRI may be able to reduce the necessity of CT angiography in current, pre-interventional TAVI screening protocols.

Literature:

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