A CT-BASED DEEP LEARNING SYSTEM FOR AUTOMATIC ASSESSMENT OF AORTIC ROOT MORPHOLOGY FOR TAVI PLANNING

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Introduction

Transcatheter aortic valve implantation (TAVI) is an alternative to traditional open-heart surgery for severe aortic stenosis [1]. Pre-TAVI planning is crucial for minimizing risk for complications and should include an accurate anatomic assessment of the aortic root (AR) apparatus [2]. Three-dimensional (3D) computed tomography (CT) angiography is the preferred imaging modality to evaluate both AR shape and structure prior to TAVI. However, there is currently no standardized fully automated solution for this process. Hence, we combined deep learning techniques and tools from differential geometry to build a fully CT-based automatic system able to segment AR, extract AR-specific anatomical landmarks and compute measurements relevant for TAVI planning.

Methods

Two convolutional neural networks (CNNs) with 3D U-Net architectures (model 1 and model 2) were trained to perform automatic AR segmentation (model 1), and identification of aortic annulus and sinotubular junction (STJ) contours (model 2). The training set included 379 cases and validation was performed on 31 cases. Once trained, the CNNs were embedded in a fully automatic pipeline for AR analysis.

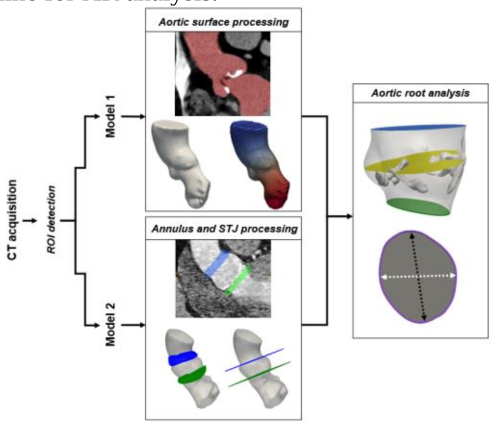

Figure 1: schematic representation of the implemented automatic pipeline

The devised system performs a series of steps to automatically quantify AR metrics. Briefly, AR region of interest (ROI) is detected through a template-matching approach and subsequent refinement of annulus and STJ planes is achieved through a min-cut algorithm. By computing the eigenvectors of the Laplace-Beltrami operator (LBO) [3], the plane of the Valsalva sinuses is automatically identified. Finally, minimum, maximum, and mean diameters, together with areas and perimeters are automatically computed for the detected planes. Automatic measurements were validated against a separate dataset of 178 CT scans of TAVI candidates for whom AR measurements were previously obtained using commercial software (3mensio, Pie Medical Imaging, Maastricht, Netherlands).

Results

The trained CNNs effectively segmented the aortic region, annulus and STJ, resulting in mean Dice scores of 0.93 for the AR, and mean surface distances of 1.16 mm and 1.30 mm for the annulus and STJ, respectively. Automatic measurements were in good agreement with manual annotations, yielding annulus diameters that differed by 0.52 [-2.96, 4.00] mm (bias and 95% limits of agreement for manual minus algorithm). Discrepancies in minimum diameters were 0.92 [-2.93, 4.78] mm. Significantly smaller discrepancies between the two techniques were obtained for the annulus area. Evaluating the area-derived diameter, bias and limits of agreement were 0.07 [-0.25, 0.39] mm. STJ and sinuses diameters computed by the automatic method slightly underestimated manual measurements, yielding differences of 0.16 [-2.03, 2.34] and 0.1 [-2.93, 3.13] mm, respectively.

Conclusions

We developed a fully automatic CT-based pipeline for the quantification of morphological biomarkers relevant for pre-TAVI planning, validating the analysis against ground-truth data from commercial software. Hence, the method proved to be quick and effective to assess AR anatomy, with potential for time and cost savings.

References

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