

GENERATION OF A VIRTUAL POPULATION OF CORONARY ARTERIES THROUGH STATISTICAL SHAPE MODELLING

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Introduction

Arterial anatomic attributes are crucial in conditioning local hemodynamics and its adverse action on the endothelium leading to the development and progression of coronary artery disease [1]. Statistical shape models (SSMs) promise to be an effective approach capable to identify peculiar vascular anatomic features and generate large dataset of virtual anatomies with realistic attributes. Here a SSM-based approach is adopted to (i) describe the geometric variability of a population of diseased left anterior descending (LAD) coronary artery models, and (ii) generate a synthetic population of diseased LAD coronary arteries suitable for large-scale *in silico* studies.

Methods

Sixty-nine models of mildly stenosed LAD coronary artery previously reconstructed from quantitative angiography [2] were used to construct a SSM based on principal component analysis (PCA). The interquartile range of percentage area stenosis was equal to 40.03-58.54%. Based on a non-parametric approach [3], the SSM was built according to the workflow outlined in Fig. 1A, already proposed elsewhere [4]. Technically, the open-source code *Deformetrica* was adopted to extract the template \bar{T} , representing the mean anatomical shape, and the moment vectors β_i gathering the shape features of each i^{th} vessels. PCA was then applied to the moment vectors matrix to derive the SSM through the identification of the shape features accounting for the largest variability in the LAD population. PCA shape components were sampled to generate new geometries *via latin hypercube sampling*. Computational fluid dynamics (CFD) simulations, based on finite volume method, were conducted in hyperemic conditions to evaluate the translesional pressure drop (ΔP).

Results

Nineteen shape modes explained 95% of the total shape variability of the LAD coronary artery cohort. The first 3 shape modes, which explained respectively 41%, 11% and 9% of such a variability, are presented in Fig. 1B. As an example of output from the model generation strategy, 5 virtual geometries generated taking the first 19 modes into account are shown in Fig. 1C. The CFD estimates of the translesional ΔP in the explanatory 5 virtual geometries fall within the ΔP distribution of the original cohort (Fig. 1D), thus being representative of

the LAD population from both anatomical and hemodynamic viewpoints.

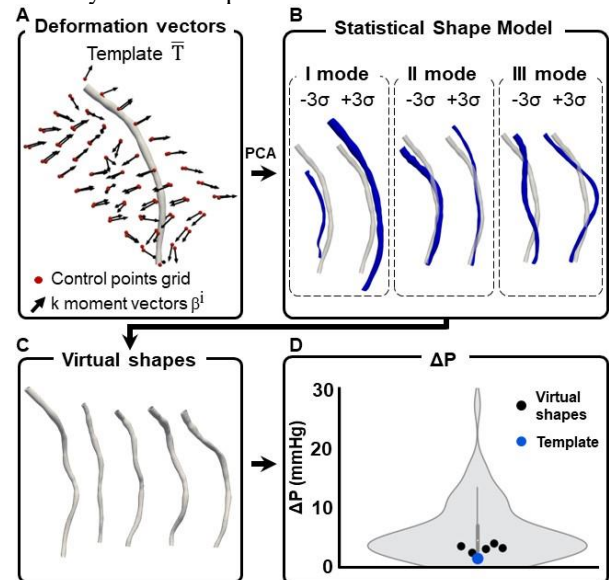


Figure 1: A) Deformation vectors centered at the control points grid on the template; B) First 3 shape modes shown as ± 3 standard deviations (σ) in blue, from the template (grey); C) 5 virtual shapes; D) Violin plot of ΔP in the original cohort and ΔP data points of the generated shapes (black) and of the template (blue).

Discussion

The presented approach allowed to successfully derive a SSM of LAD coronary artery 3D geometries. The obtained results suggest that the SSM-based strategy not only identifies the main anatomical attributes of coronary arteries, but also robustly generates a virtual population with functional features closely in line with the original population (in terms of ΔP). A robust SSM-based approach (i) will enable the exploration of associations between clinically relevant coronary anatomic and hemodynamic quantities, and (ii) will promote the adoption of *in silico* trials, thus minimizing social and economic impacts.

References

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