Towards automated TAVI device size selection using artificial intelligence

Patricio Astudillo *(FEops, UGent)
Peter Mortier (FEops)
Matthieu De Beule (FEops)
Johan Bosmans (UZA)
Ole De Backer (Rigshospitalet)
Peter de Jaegere (Erasmus MC)
Joni Dambre (UGent)

FEops, Technologiepark 19, Zwijnaarde, 9052, Belgium
Department of Electronics and information systems, UGent, Technologiepark 15, Zwijnaarde, 9052, Belgium
University Hospital Antwerp (UZA), Antwerp, Belgium
Department of Cardiology, Rigshospitalet University Hospital, Copenhagen, Denmark
Department of Cardiology, Erasmus MC, Rotterdam, The Netherlands

corresponding author's email address: patricio@feops.com

Introduction

Transcatheter aortic valve implantation (TAVI) has become the preferred treatment for patients with aortic stenosis at high risk for surgical valve replacement and more recently, also an alternative for surgical treatment of intermediate risk patients. Multi-detector computed tomography (MDCT) is the gold standard imaging modality used during pre-operative planning of TAVI. Based on the dimensions of the aortic annulus (AA), amount of calcium, and other measurements, a prosthesis size is selected. Correct sizing is of paramount importance for optimal procedural outcome but depends on image quality and operator experience. Given that the amount of TAVI procedures is increasing rapidly each year, an automated method that can detect the AA size directly from MDCT images within acceptable accuracy could reduce operator variability and speed-up pre-operative planning.

Purpose

In this work, we present and validate a method that can quantify the AA perimeter automatically using deep learning.

Methods

The MDCT images of a cohort of 455 patients from multiple centers was used during this study. All images were used during the pre-operative phase of a TAVI procedure. During this phase, an expert (observer 1) used the AA plane (AAP) to annotate the AA, from which the perimeter was derived to identify the appropriate prosthesis size. A second expert (observer 2) blindly re-annotated the AA from the AAP of 100 patients. These 100 patients were also used to evaluate the proposed method. The data of observer 1 is considered the ground truth and the data of observer 2 is used to evaluate inter-operator variability.

The AAP and the ground truth AA annotations were used to create the training dataset. The Hounsfield units of the AAPs were used together with binary masks, which were created from the AA annotations (Figure 1).

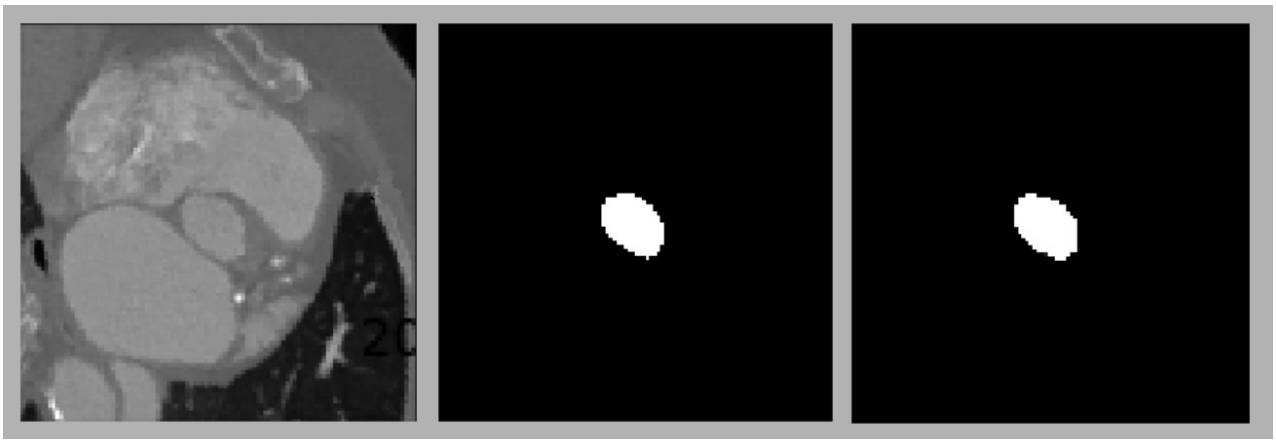

Figure 1: Examples of the data used during training and prediction: the AAP (left) and the associated binary mask (middle) and the predicted sample (right).

Three models were trained with a convolutional neural network (CNN) architecture based on U-Net. During training, the images of 355 patients were used. The three models predicted the remaining 100 patients and during the post-processing step, the perimeter of the predicted area was extracted from the predictions. As a final step, the perimeter was used to determine the correct TAVI size.

Results

The perimeters of all 100 patients were detected. The difference between observer 1 and the predicted measurements was 0.01 [-0.81 – 1.08] (mm) ($p = 0.7$). The difference between observer 1 and observer 2 was 0.20 [-0.50 – 0.94] (mm) ($p = 0.3$). There were 89 patients with equal Medtronic Evolut sizes between the observer 1 and the predictions. From the 11 other patients, the predictions of 3 patients were in agreement with observer 2 whereas the predictions of 8 patients differed by 1 size (4 over- and 4 undersized). Total detection time per patient from AAP to Medtronic Evolute size was 1.1 [0.9 – 1.4] (sec).

Conclusion

The proposed method detects the aortic annular perimeter in seconds, while the inter-operator study confirmed that our method is within acceptable accuracy. This clearly shows the potential of using artificial intelligence (deep learning) for pre-operative planning of cardiovascular intervention.