Aortic Root Numerical Model: Operative Effective Height Predicts AV Repair Coaptation Area

Raanani, Ehud[1]; Marom, Gil[2]; Haj-Ali, Rami[2]; Rosenfeld, Moshe[2]; Schäfers, Hans Jochen[3]
[1]The Olga and Lev Leviev Heart Center, Affiliated to the Sackler School of medicine, Department of Cardiac Surgery, Sheba Medical Center, Ramat Gan, Israel, Tel-Aviv University; [2]Tel-Aviv University, School of Mechanical Engineering, Tel Aviv, Israel; [3]Uniklinikum-saarland,, Department of Cardiothoracic surgery, Homburg, Homburg, Germany

Objective: The aim of this study was to determine the influence Aortic Annulus (AA) diameter on the coaptation area and the effective height in the aortic valve.

Methods: Five cases of aortic roots with AA diameters between 20 and 30 mm were modeled.

The coaptation length and area were calculated from three dimensional (3D) Fluid Structure Interaction (FSI) models of the aortic valve (AV) and root. The simulations were based on coupled structural and fluid dynamics models. The structural model included flexible leaflets in compliant aortic valve with material properties closed to physiologic tissues. The fluid dynamics model included blood hemodynamics under physiological diastolic pressures at the left ventricle and ascending aorta.

The effective height was calculated for no-flow cases, similar to the clinical measurements. The no-flow cases included the transvalvular pressure drop as the load on the leaflets. All the other parameters were identical to the FSI models.

Results: The AV models with AA diameter of 20 to 24 mm were fully closed while the models with AA diameter of 26 to 30 mm were only partially closed. Increasing the AA diameter from 20 to 30 mm decreases the coaptation length on specific cutting plane and the relative coaptation area from 6.1 to 0.5 mm and from 80 to 35%, relatively. Increasing the AA diameter from 20 to 28 mm decreases the effective height from 10.8 to 5.3 mm. The effective height could not be calculated for the case of 30 mm AA diameter because this case could not be closed.

Conclusions: Decreasing in the AA diameter increases the coaptation length and area. Intra-operative effective height measurements predict the coaptation length and area during the diastole phase of the cardiac cycle.