Development and characterization of calcific aortic valve models for clinicians training in transcatheter cardiovascular procedures

Introduction: Calcific aortic valve (AV) stenosis represents the most common valvular heart disease in elderly and the leading cause of valve replacement in USA and Europe[1]. Recently, minimally invasive transcatheter procedures have revolutionized its treatment by reducing patients' recovery and hospitalization. However, these approaches require adequate surgical training that currently involves the use of biological cadaver samples resulting in ethical problems and availability. Therefore, the goal of this work was to develop a polymeric model of calcific AV that can provide surgeons with a reliable and faithful tool for training in transcatheter procedures.

Methods: Five different mixtures of epoxy resin (ER) and calcium phosphate (CP) in solution with water (W) were mechanical characterized by a three-point bending test to identify which calcification mixture replicates the physiological properties[2]. Paradigmatic polymeric aortic roots with two different silicone shore were obtained by injection molding and, with embedding technique, calcifications were integrated on AV leaflets, reproducing different calcification patterns (radial and arc) and severity of pathology. Calcified AV models were tested in a pulsatile mock loop simulating different working conditions (stroke volume of 50ml, 65ml and 80ml; mean aortic pressure of 100mmHg; frequency of 60bpm). Transvalvular pressure was acquired, and effective office area (EOA) was calculated.

Results: ER22%-CP67%-W11% calcification mixture exhibited maximal force (52.8N) and flexural strength (3.37MPa) comparable with literature results[2]. Calcified AV models with arc pattern in higher silicone shore better replicated pathological values of systolic transvalvular pressure (63.6mmHg) and EOA (0.56cm^2) at 80ml of stroke volume than radial pattern (45.0mmHg and 0.67cm^2, respectively) and lower silicone shore (14.6mmHg and 1.17cm^2 for severe arc pattern model).

Conclusions: This work provided a method to develop biomechanical faithful calcific AV models capable of replicating pathological conditions and a reliable tool for surgical training in transcatheter procedures.

[1] N. M. Rajamannan, R. O. Bonow, and S. H. Rahimtoola, "Calcific aortic stenosis: An update," *Nature Clinical Practice Cardiovascular Medicine*, vol. 4, no. 5. pp. 254–262, May 2007. doi: 10.1038/ncpcardio0827.

[2] A. Paknahad, N. W. Kucko, S. C. G. Leeuwenburgh, and L. J. Sluys, "Experimental and numerical analysis on bending and tensile failure behavior of calcium phosphate cements," *J Mech Behav Biomed Mater*, vol. 103, Mar. 2020, doi: 10.1016/j.jmbbm.2019.103565.