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Application of Computational Biomechanics in Bioprosthetic Heart Valve Design

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For more than 40 years, the replacement of diseased natural heart valves with prosthetic devices has dramatically improved the quality and length of the lives of millions of patients. Bioprosthetic heart valves (BHV), which are composed of biologically derived tissues, have good hemodynamic performance and do not require the anticoagulation therapy necessary when mechanical heart valves are implanted. However, these bioprostheses continue to fail due to structural failure resulting from poor tissue durability and faulty design. AHA/ACC guideline recommends use of BHV for patients 65 years or older, primarily due to its current 10–15 years of limited durability. Clearly, an in-depth understanding of the biomechanical behavior of BHV is essential to improving BHV design to reduce rates of failure and increase its durability. Objective: develop a robust computational model to simulate BHV deformations and optimize its design. Methods: Experimentally driven, nonlinear, anisotropic material models are used for modeling the mechanical properties of valve leaflets; A novel method of constructing parametric finite element models is used to rapidly generate 3D free-from geometries of BHV for valve design optimization; Valve design parameters, such as peak stresses and effective orifice area (EOA) are evaluated. Results: multiple applications of the approach demonstrate the feasibility of utilizing computational biomechanics in BHV design. The computational approach provides us with an efficient new platform to develop and optimize the next generation heart valve design such as transcatheter valve and valve repair device design.

