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Fast and Non-Invasive Patient-Specific Optimization of Left Ventricle Assist Device Implantation

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Abstract : The use of left ventricle assist devices (LVADs) in patients with heart failure has been a proven and effective therapy for patients with severe end-stage heart failure. Due to the limited availability of suitable donor hearts, LVADs will probably become the alternative solution for patient with heart failure in the near future. While the LVAD is being continuously improved toward enhanced performance, increased device durability, reduced size, a better understanding of implantation management becomes critical in order to achieve better long-term blood supplies and less post-surgical complications such as thrombi generation. Important issues related to the LVAD implantation include the location of outflow grafting (OG), the angle of the OG, the combination between LVAD and native heart pumping, uniform or pulsatile flow at OG, etc. We have hypothesized that an optimal implantation of LVAD is patient specific. To test this hypothesis, we employ a novel in-house computational modeling technique, named InVascular, to conduct a systematic evaluation of cardiac output at aortic arch together with other pertinent hemodynamic quantities for each patient under various implantation scenarios aiming to get an optimal implantation strategy. InVacular is a powerful computational modeling technique that integrates unified mesoscale modeling for both image segmentation and fluid dynamics with the cutting-edge GPU parallel computing. It first segments the aortic artery from patient’s CT image, then seamlessly feeds extracted morphology, together with the velocity wave from Echo Ultrasound image of the same patient, to the computation model to quantify 4-D (time+space) velocity and pressure fields. Using one NVIDIA Tesla K40 GPU card, InVascular completes a computation from CT image to 4-D hemodynamics within 30 minutes. Thus it has the great potential to conduct massive numerical simulation and analysis. The systematic evaluation for one patient includes three OG anastomosis (ascending aorta, descending thoracic aorta, and subclavian artery), three combinations of LVAD and native heart pumping (1:1, 1:2, and 1:3), three angles of OG anastomosis (inclined upward, perpendicular, and inclined downward), and two LVAD inflow conditions (uniform and pulsatile). The optimal LVAD implantation is suggested through a comprehensive analysis of the cardiac output and related hemodynamics from the simulations over the fifty-four scenarios. To confirm the hypothesis, 5 random patient cases will be evaluated.

Keywords : graphic processing unit (GPU) parallel computing, left ventricle assist device (LVAD), lumped-parameter model, patient-specific computational hemodynamics
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