Current and emerging computational pre-surgical planning tools for Tetralogy of Fallot repair

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Approximately 1 in 100 children are born with a clinically significant congenital heart defect (CHD), representing 1,300,000 children worldwide. While many of these infants failed to survive during the first half of the previous century, the past 60 years has produced dramatic advances in their palliation. Likewise advances in cardiovascular engineering improved our understanding of complex CHD physiology and lead to clinical computational tools. For the Tetralogy of Fallot (TOF) disease template [1] having large aorta, underdeveloped pulmonary arteries, ventricular septal defect and right ventricular hypertrophy [1, 2], our earlier bioengineering studies focused on improving right ventricle outflow tract conduits with valve [3], lumped parameter and computational fluid dynamic models of 1st stage palliation using idealized anatomic geometries [4]. In addition, we have implemented our methodology in patient-specific TOF surgeries, exploring the effect of graft diameter, first time in the literature [5]. We have analysed the pulmonary perfusion in terms of the size of the right and left pulmonary arteries (RPA and LPA, respectively) and the shunt anastomosis angle with respect to the RPA [6]. For fast decision making, we have introduced a novel volumetric index to assess the outcome of the TOF surgeries [7]. The most crucial component of surgical planning is in vivo validation which was demonstrated partly in commercially available TCPC conduits [8]. In addition to the current status and opportunities of presurgical hemodynamic planning approaches, here we will also present a novel computer-aided pre-surgical design framework for patch reconstruction which is a fundamental technique employed in TOF and Pulmonary Atresia palliation surgery. The framework is the result of our extensive interactions with several practicing pediatric cardiovascular surgeons, thus represents a realistic picture that can be applicable to the patients. The bioengineering performance parameters of patch surgeries are defined and computed first-time in literature [9]. The novelty of this framework is its ability to aid the clinician to choose the optimal graft type and to provide the best-reconstructed vascular geometry before the in vivo execution considering both the three-dimensional vascular growth in the long term of the native tissue as well as effect of changes in pre-, intra and post-operative pulmonary arterial pressure.

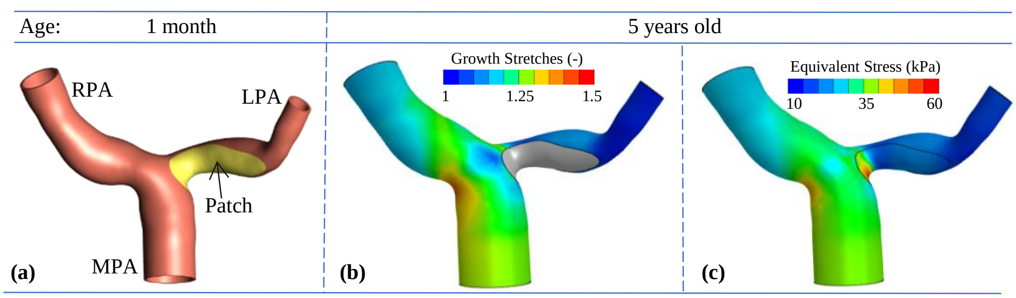

Figure 1: (a) Shows the unloaded configuration of the pulmonary artery anatomy of a 1-month-old TOF patient. Severe stenosis on LPA has been recovered by in silico PTFE patch implantation. Growth of the arteria wall (b) and stress distribution on both patch and artery (c) under physiological blood pressure computed for 5 years (long term) after the surgery.

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