P3734

Feasibility of percutaneous pulmonary valve implantation in the native right ventricle outflow tract from in vivo dynamic regional strain analysis

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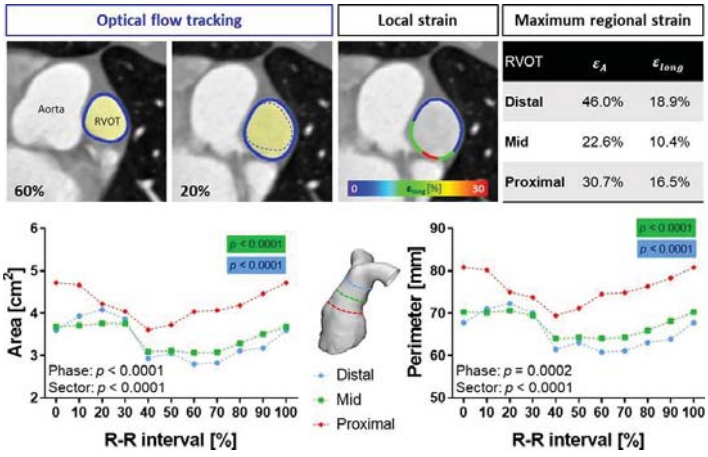
Background: Patients surgically treated for congenital heart disease (e.g., Tetralogy of Fallot) frequently report long-term dysfunctions (i.e., pulmonary stenosis and/or incompetence) of the native right ventricle outflow tract (RVOT). The efficacy of percutaneous pulmonary valve implantation (PPVI) is recognized worldwide; however, the procedure is only feasible in RVOTs with appropriate size and functional substrate. Accordingly, a three-dimensional (3D) and dynamic assessment of the native RVOT function can be crucial to identify patients who can effectively benefit from PPVI, thus avoiding the risk of device embolization or fracture.

Purpose: We herein exploited an optical flow-based approach to develop a novel 3D framework for the quantitative in vivo assessment of dimension and dynamic changes of the native RVOT throughout the cardiac cycle. PPVI candidates (n=15) with previous surgery of the native RVOT were enrolled to demonstrate the additional contribution of our 3D patient-tailored analysis to the decision-making process.

Methods: Contrast-enhanced computed tomography (CT) was performed on a 64-slice dual-source multidetector CT system with retrospective ECG-gating. Multi-phase images of the RVOT were acquired at each 10% increment of the cardiac cycle (slice thickness = 1.5mm, increment = 1mm, pixel spacing = 0.35mm). We implemented a dedicated in-house framework, based on the optical flow tracking algorithm, to dynamically follow three anatomical cross-sections (i.e., proximal, mid and distal) of the native RVOT. The time course of area, perimeter and other relevant parameters (e.g., equivalent radius, elliptical ratio) were extracted and both areal (ϵA) and longitudinal strain ($\epsilon long$) were computed on each the RVOT tracked cross-section. Maximum regional strain were calculated between the maximum and minimum value over the cardiac cycle. Dynamic changes in CT-derived variables were assessed using analysis of variance ($p<0.05$, statistically significant).

Results: All the enrolled anatomies were successfully analysed, locally pinpointing the in vivo pattern of deformation within each 3D RVOT anatomy (a). Anatomical regional RVOT dimensions ($p<0.0001$) and changes proved to be significantly different ($p\leq0.0002$) throughout the cardiac cycle. In addition, the dysfunctional RVOT anatomy exhibited an irregular pattern of contraction and dilation: maximum regional strains markedly differed between RVOT regions, e.g., comparing the ϵA between RVOT mid (22.6%) and distal (46.0%) regions.

Conclusions: The combination of patient-specific in vivo imaging and bio-engineering strategies can improve our understanding of RVOT dysfunctions in congenital patients referred to PPVI. Our optical flow-based and clinically-oriented framework can support the patient selection process and the planning of the percutaneous procedure in order to enhance its efficacy and shorten the operating time while improving the patient safety.



In vivo tracking of RVOT dynamic changes