FIMH 2021
Celebrating 20 Years of Research Excellence
Stanford University, California, USA

Cardiac Atlas Project

Cardiac Atlas Project:

Workshop on Congenital Heart Disease

(Monday, June 21, 2021)

08:00am - 10:00am (PDT)
11:00am - 13:00pm (EDT)
16:00pm - 18:00pm (GMT)
03:00am- 05:00am (NZST + 1 day)

08:00am - 08:30am (PDT) **Tetralogy of Fallot: Insights into the failing heart**

Kuberan Pushparajah

King's College London

08:30am – 09:00am (PDT) **Biventricular Shape Markers Discriminate Pulmonary Valve Replacement in Repaired Tetralogy of Fallot**

Sachin Govil

University of California San Diego

09:00am – 09:30am (PDT) **Right ventricular deformation and 4D flow analysis in tetralogy of Fallot**

Liang Zhong

National Heart Centre Singapore , Duke NUS Medical School, National University of Singapore

09:30am – 10:00am (PDT) **Biomechanical modeling for congenital heart diseases**

Radomir Chabiniok

University of Texas Southwestern Medical Center

Tetralogy of Fallot: Insights into the failing heart

Kuberan Pushparajah

King’s College London

Tetralogy of Fallot (TOF) is the most common cyanotic heart defect affecting 3 per 10,000 live births. Survival after primary repair is good, but patients have higher risk of heart failure, arrythmia and death, and often require regular follow up with imaging to determine optimal timing of interventions. These include palliation to increase pulmonary blood flow (right ventricular outflow tract stents, and arterial shunts), corrective surgery, and either percutaneous or surgical pulmonary valve replacement. Clinical indications for pulmonary valve replacement include symptoms (peak VO2 < 60% of predicted), hemodynamically significant lesions, or for asymptomatic patients a combination of right and left ventricular volumes and ejection fraction. Patients also have higher risk of sudden cardiac death and life-threatening arrhythmia, with QRS duration > 160 ms and sustained tachyarrhythmia being high risk indications. However, these features do not accurately predict outcomes. There is a need for better characterization of patient status in order to improve patient outcomes.

Dr Kuberan Pushparajah is a clinical senior lecturer in paediatric cardiology in the School of Biomedical Engineering & Imaging Sciences at King's College London. He is also an honorary consultant paediatric cardiologist at the Evelina London Children's Hospital, London. His interests are in cardiovascular imaging, namely in the fields of magnetic resonance imaging and advanced echocardiography including 3D echocardiography. He is the clinical lead for the Congenital Cardiac MRI programme, which encompasses congenital CMR from the fetus to the adult, and CMR guided catheteristaion.

Biventricular Shape Markers Discriminate Pulmonary Valve Replacement in Repaired Tetralogy of Fallot

Sachin Govil

University of California San Diego

Surgical repair of tetralogy of Fallot (TOF) often involves damage to the right ventricular (RV) outflow tract typically resulting in pulmonary valve impairment and subsequent pulmonary regurgitation (PR). Residual PR leads to progressive RV remodeling in the form of RV dilation, and plays an important role in long-term outcome. Patients with severe PR and RV decompensation undergo pulmonary valve replacement (PVR) to reduce the risk of arrhythmia, heart failure, and sudden cardiac death. However, the clinical decision on whether and when to perform PVR remains unclear. Current indications rely on global measures of ventricular volumes and masses, but these indications are widely debated, inconsistently applied, and lead to mixed outcomes. We aimed to test the hypothesis that specific markers of biventricular shape can discriminate differences in ventricular remodeling between rTOF patients that were and were not designated for follow-up PVR that may be early markers of adaptive *vs.* maladaptive remodeling. Multivariate regression techniques were used to quantify markers of biventricular shape associated with PVR status, while accounting for differences in sex, time after primary repair, and body habitus. Markers of biventricular shape associated with RV apical dilation, RV basal bulging, LV dilation, LV conicity, and pulmonary valve dilation were significant discriminators of PVR status. Clustering techniques were then used to compare the ability of these biventricular shape markers to discriminate PVR status against that of traditional clinical indices. Biventricular shape markers were able to discriminate PVR status with greater sensitivity, specificity, and accuracy than traditional clinical indices.

Sachin Govil is a doctoral candidate with the Cardiac Mechanics Research Group in the Department of Bioengineering at UC San Diego. His thesis research is focused on the computational analysis of cardiac structure and function in patients with congenital heart disease, with the overall aim of discovering novel biomarkers that can provide quantitative insight into the mechanisms, diagnosis, and treatment of disease. He obtained his B.S. in Biomedical Engineering and Mechanical Engineering at Duke University and M.S. in Biomedical Engineering at the Duke University Graduate School

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Right ventricular deformation and 4D flow analysis in tetralogy of Fallot

Liang Zhong

National Heart Centre Singapore , Duke NUS Medical School, National University of Singapore

Survivors of tetralogy of Fallot (TOF) constitute a large and growing population of patients. Although post-surgical outcome is generally favorable, as these patients move into adulthood, late morbidity is becoming more prevalent. Recent evidence suggests that adverse long-term post-surgical outcome is related to chronic pulmonary regurgitation (PR) and RV dilation. This process, also called RV remodeling, adversely affects ventricular function and may lead to development of heart failure. Repeat surgery with pulmonary valve replacement (PVR) may be necessary to preempt RV functional deterioration and malignant ventricular arrhythmias. Therefore, understanding and quantifying RV remodeling, function and intra-cardiac flow in repaired TOF patients is important for patient management and therapy planning.

Cardiac MR imaging (MRI) is considered as "best" imaging choice for assessing the remodeled RV without exposing the patient to ionizing radiation. 4D flow CMR is an emerging approach to gain additional insight of RV remodeling and dysfunction [1,2]. In this talk, we will discuss the predominantly qualitative measures of RV deformation using CMR feature tracking [3, 4], 4D flow component and kinetic energy indexes using 4D flow CMR. All these would satisfactorily express the full range of quantitative information related to the remodeling process.

1. Zhong L et al. Intracardiac 4D flow MRI in congenital heart disease: recommendations on behalf of the ISMRM flow & motion study group. J Magn Reson Imaging 2019;50:677-681.
2. Zhao XD, et al, Zhong L. Insight of right ventricular dysfunction and impaired efficiency via 4D flow CMR in repaired tetralogy of Fallot. ISMRM 2021.
3. Ouyang RZ et al Zhong L, Zhong YM. Detection of persistent systolic and diastolic abnormalities in asymptomatic pediatric repaired tetralogy of Fallot patients with preserved ejection fraction: a CMR feature tracking study. Eur Radiol 2021.
4, Leng S et al Zhong L. Cardiovascular magnetic resonance-assessed fast global longitudinal strain parameters add diagnostic and prognostic insights in right ventricular volume and pressure loading disease conditions. JCMR 2021;23:38.

Liang Zhong, Ph.D., is a Principal Investigator in National Heart Research Institute, National Heart Centre Singapore (NHCS) and Associate Professor at Duke-NUS Medical School, and Guest Professor at Union Hospital, HUST University. He graduated from HUST with a double major in Mechanical Engineering and in Economy and completed his PhD (Engineering) in Nanyang Technological University. After a postdoctoral training with Prof LP Chua at Nanyang Technological University and short training with Prof Romano Zannoli at Bologna University

(Italy), he joined National Heart Centre Singapore and Duke-NUS to start research group. His research interests include cardiovascular imaging, cardiovascular mechanics, hemodynamics and physiology, ageing and metabolomics, and health service research. His work has been supported by National Medical Research Council, Biomedical Research Council, National Research Foundation, A*STAR and SingHealth Foundation. He has published more than 180 peer-reviewed articles in international journal and conference. He has published a book "computational and mathematical methods for cardiovascular physiology" and co-authored more than 10 patents.

Biomechanical modeling for congenital heart diseases

Radomir Chabiniok

University of Texas Southwestern Medical Center

Over last decades, clinical management of patients with chronic cardiac conditions associated with congenital heart diseases has substantially advanced. However, it is known that patients – even with the same clinical diagnosis – differ. For instance, early-stage heart failure in a patient with single-ventricle physiology may have various causes (e.g. increased resistance in circulation; decreased venous return into the ventricle; limited oxygen supply for myocardial cells or already irreversible changes of the myocardial tissue) and distinguishing the main component of their heart failure may contribute to optimal clinical strategy. Similarly, the patients with tetralogy of Fallot after complete surgical repair (rTOF) are not the same. An objective assessment of the level of their ventricular overloading as well as the knowledge about their previous clinical course (starting from the initial baseline anatomy, type of repair and their long-term geometrical remodeling) can together shed light on the current trends of clinical management and even challenge some of them. Biomechanical models of the heart and cardiovascular system have the potential to synthesize multiple clinical inputs (e.g. ECG, imaging or invasive hemodynamics), when monitoring a long-term progress of a chronic cardiac disease and represent a functional complement to statistical atlases.

Radomir Chabiniok, M.D., Ph.D., is an Assistant Professor of Pediatrics at University of Texas Southwestern Medical Center Dallas in the Division of Pediatric Cardiology and acts also as an external collaborator at French National Institute for Digital Sciences Inria, visiting lecturer at King's College London and part-time associated researcher at Czech Technical University. He has a dual background (M.D. and applied mathematics) and experience in cardiovascular magnetic resonance particularly for congenital heart diseases. He has been working on translation of cardiovascular modeling into clinic and advancing these methods into routine clinical application. This intrinsically multi-disciplinary goal can only be achieved in tight collaborations between teams of cardiovascular clinicians; mathematical and biomechanical modelers; and researchers in advanced data acquisition and processing. Clinical and research labs have been contributing together within a collaborative clinical-modeling venture TOFMOD (Tetralogy Of Fallot & Modeling Of Diseases), created in 2017 primarily between Inria France and UTSW Medical Center Dallas.