ME Seminar

Heart and Hip Biomechanics: From Improved Understanding of Physiology to Assist in Personalised Surgical Planning

Dr. Arnab Palit, University of Warwick, Coventry, UK

ABSTRACT

The seminar would cover two following aspects: (a) a detailed description of human heart modelling to understand the physiology of normal diastolic functions, and (b) a brief overview of the hip joint motion modelling and visualisation to help in intervention planning to reduce post-surgical complications.

Diastolic heart failure (DHF) with normal systolic pump function has been typically observed in the majority of heart failure (HF) patients. DHF changes regular diastolic behaviour of left-ventricle (LV), and increases the ventricular wall stress. Therefore, normalisation of increased LV wall stress is the cornerstone of many existing and new therapeutic treatments. However, information regarding regional diastolic stress-strain distribution for healthy human LV is extremely limited in the literature. Therefore, estimation of the regional variation of diastolic stress-strain field in healthy human LVs with the following objectives will be presented: (a) subject-specific in vivo estimation of passive myocardium properties for heathy myocardium using routine clinical data, and (b) the effect of myocardial fibre orientation on diastolic mechanics. In this talk, construction of ventricular geometry from magnetic resonance imaging (MRI), implementation of fibre orientation using a rule based 'Laplace-Dirichlet-Region growing-Finite element (LDRF)' algorithm, application of structure-based orthotropic constitutive law and procedure of FE modelling of cardiac diastole will be demonstrated. A novel method was developed by combining FE modelling, response surface method (RSM) and genetic algorithm (GA) to identify the passive orthotropic myocardium properties for healthy human myocardium using routine MRI data. Numerical simulations demonstrating the applicability of the new method will be shown. Thereafter, it will be explained how this study identified that any pathological remodelling that decreased the amount of transmural fibre angle led to reduced LV inflation, and therefore, may contribute to the development of DHF with preserved ejection fraction (HFpEF). The study provided a greater insight into the underlying mechanics of human ventricle during diastole, and therefore, has impacts on both computational cardiac biomechanics as well as clinical cardiac physiology fields.

Following the presentation of cardiac modelling, translational research on hip joint mechanics will be demonstrated. Prosthetic impingement (PI) and bony impingement (BI) following total hip arthroplasty (THA), which arises due to the undesirable relative motion of the implants, results in adverse outcomes such as instability, accelerated wear, pain and dislocations. Identifying subject-specific PI and BI information is critical to plan optimal implant position on native bone geometry. In the later part of the talk, a brief overview of the developed a 'hip joint surgical planning tool' which identifies and visualizes subject-specific PI and BI area for both primary and revision surgery, will be presented. Various example will be shown to highlight the applicability of this tool from assisting in surgical planning to review the reason for dislocation, which eventually helps surgeons in revision THA. Finally, it will be demonstrated how this tool could potentially be used to examine the effect of different pre-operative plans and hip motions on PI, and BI and to guide bony resection during THA. The seminar demonstrates the importance of both basic science research through modelling of cardiac biomechanics for greater insight of the physiology and pathophysiology of human heart during diastole, and the significance of translational research through the hip joint motion modelling in helping surgeons for improved planning of THA for excellent intermediate to long-term outcome.

ABOUT THE SPEAKER

Dr Arnab Palit is a Senior Research Fellow at WMG, University of Warwick since 2018. He has been involved in various industrial and academic projects over the past five years of postdoctoral research in multi-disciplinary fields encompassing both biomechanical and manufacturing engineering sectors. His vision is to underpin these two sectors' beneficial effects by undertaking cutting-edge research with the specialisation in musculoskeletal joint and cardiac biomechanics. His main research interests involve realising and expanding the fundamental science of joint and cardiac biomechanics modelling to understand the physiology and pathophysiology of normal and diseased conditions as well as translational research for disease diagnosis, implant design, intervention plan and healthcare monitoring. Dr Palit received his PhD from the University of Warwick, UK in 2016 where he developed computational modelling of diastole for human ventricle. Prior to that, he obtained his MTech degree in Industrial Engineering and Management from IIT Kharagpur, India in 2011 and was awarded with the 'Institute Silver Medal' for standing first within the department. He was also recipient of the DAAD scholarship for undertaking the MTech Project in TU Dresden, Germany in 2010. He graduated with BEng in Production Engineering from Jadavpur University, India in 2007. He also has two-year's industrial experience while working as a technical associate in Tech Mahindra Ltd, India from 2007 to 2009.

March 5, 2021, 4:00 pm, Microsoft Teams