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Cardiovascular simulations for the assessment of treatments against COVID-19: ECMO and Cardiotoxicity of Antibiotics and Antimalarials (CardioVacular-COVID)

As the pandemic developed, the cardiovascular mechanics researchers in tight collaboration with Medical Doctors started applying Alya, a high performance computing, multi-physics, multi-scale solver, to two main problems that require the quick generation of evidence and information towards their use by clinicians:

1. Venous-Arterial Extracorporeal membrane oxygenation therapy (ECMO) and the North-South Syndrome on patients with profound respiratory failure. For many patients, infection with the COVID-19 (SARS-CoV-2) virus results in profound respiratory failure, requiring ventilatory support in the intensive care unit (ICU). A portion of these patients have such refractory disease that they also develop acute heart failure. This subset of patients is unable to be supported by traditional ventilator therapy and require an external device to provide oxygenation/ventilation as well as circulatory support. This device is referred to as Venous-Arterial Extracorporeal Membrane Oxygenation (VA-ECMO) and is a cardiac bypass device, similar to devices used in open-heart surgery, but can be used in an ICU. VA-ECMO is associated with many complications, one of which is referred to as Nord-South Syndrome (NSS). NSS is a hemodynamic situation that only occurs when there is concomitant heart and lung failure that leads to impaired oxygenation of the brain. When NSS occurs, if it is not rapidly recognised and treated it will lead to irreversible brain damage and death. Due to the rarity of this condition, very little is known about the complex blood flow resulting in impaired oxygenation of the brain. The objective of this work was to employ computational fluid dynamics (CFD) to better understand the complex hemodynamics associated with NSS. This research provided information regarding the flow conditions at which NSS occurs, but also identified an important aspect on the hemodynamic conditions of the flow in the coronary arteries. This work was done in collaboration with the Visible Heart Laboratory, and the University of Minnesota Medical Centre, of the University of Minnesota.

2. Antimalarial and Antibiotic cardiotoxicity study. At the start of the pandemic, an urgent need for re-purposing available drugs to combat Covid-19 became obvious. Anti-malarial and antibiotic drugs were selected to assess their effectiveness to combat the disease; however some of those drugs were known to present some cardio-toxic effects by prolonging the QT interval. It was, however, unknown if the effect of using both drugs in combination may increase their arrhythmic risk for patients being treated for COVID-19 (SARS-CoV-2). Comprehensive cardiac computational models are a unique tool that can model the heart’s electrophysiological function and assess drug cardiotoxicity. COVID-19 (SARS-CoV-2) has infected an ample spectrum of demographics. Males and females seem to have different risks and propensities to drug-induced cardiac arrhythmias. The aim was to create an HPC framework capable of identifying the arrhythmic risk after the administration of two potentially cardio-toxic drugs on a male and female population. The results obtained have been compared to clinical trials performed on COVID-19 (SARS-CoV-2) patients. An in-silico cardiac population was capable of providing similar percentages of subjects at risk, as were identified in the clinic. Furthermore, the virtual population allowed the identification of phenotypes at risk of drug-induced arrhythmias.

Bio

Jazmín Aguado-Sierra obtained her Biomedical Engineering degree from Universidad Iberoamericana, Mexico in 2000. She obtained her PhD degree at Imperial College London, UK, at the Bioengineering Department under the supervision of Emeritus Professor Kim H. Parker developing one-dimensional models of blood flow in coronary and arterial circulations. She did PostDoctoral research at the Cardiac Mechanics Research group of the University of California San Diego, under supervision of Prof. Andrew McCulloch, where she worked on electro-mechanic models of the heart from 2008 until 2011. She worked as a PostDoctoral Fellow at the Universitat Pompeu Fabra and as a Visiting Researcher at the University of Sheffield. From 2012 she has been a Senior PostDoc researcher at the Barcelona Supercomputing Center developing multi-scale, multi-physics, high performance models of the cardiovascular system.