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Catheter intervention in complex congenital heart disease planned with the help of patient-specific computer models

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Introduction:
Patient-specific models, based on each individual clinical images and data, can potentially be used to plan intervention for complex congenital heart disease. Overall to date, the translation of such computational tools has been limited to only single case reports. In this work, we report the results of our effort to develop a modelling framework that allows the use of realistic simulations of cardiovascular devices to prospectively predict clinical outcomes.

Methods:
A small cohort of patients (n=14) who were referred to our Centre for percutaneous pulmonary valve implantation (PPVI) and aortic coarctation stenting in complex anatomies was included in this study. Image data routinely acquired for clinical assessment (MRI, CT, echocardiography, x-ray) were post-processed to set up the patient-specific models of the implantation site together with functional characteristics. Various models of devices were virtually implanted and analysed in each patient-specific model by means of finite element and computational fluid dynamics simulations in order to predict structural and haemodynamic changes. The analysis results were presented during our clinical unit's multidisciplinary meeting where the optimal treatment strategy was decided. Measurable clinical outcomes from the real procedures were compared with the computer model predictions.

Results:
A visual evaluation of many potential post-operative scenarios, as generated by computer simulations, supported the assessment of intervention feasibility. The computational outcomes provided additional quantitative information such as contact areas between device and implantation site, distributions of stresses on the vessel wall and flow data such as velocity and pressure fields. These measurements contributed to assess the different device options in each case and to indicate the optimal approach. Decision on the procedures including feasibility, choice of the device and size were in accordance with the computational predictions in all cases except one PPVI.

Conclusions:
Computer simulations are a mature tool to predict outcomes of cardiovascular interventions. The early results of our Centre in translating patient-specific models to support treatment planning in complex cases of congenital heart disease are promising. These tools can provide information about the performance of existing devices and indications for the development of new ones.