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Title: Taking Surgery out of Reality: a Virtual Journey into Double Outlet Right Ventricle.

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Author(s): Claudio Capelli, UCL Institute of Cardiovascular Science and Great Ormond Street Hospital for Children NHS Foundation Trust

Elena Milano, UCL Institute of Cardiovascular Science & Great Ormond Street Hospital for Children, London, UK and Cardiorespiratory Unit, Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK

Endrit Pajaziti, UCL Institute of Cardiovascular Science & Great Ormond Street Hospital for Children, London, UK

Emilie Sauvage, UCL Institute of Cardiovascular Science & Great Ormond Street Hospital for Children, London, UK.

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Andrew Cook, Institute of Cardiovascular Science, UCL

Silvia Schievano, University College London

Kristian Mortensen, Great Ormond Street Hospital for Children NHS Foundation Trust

Andrew Taylor, Centre for Cardiovascular Imaging, UCL Institute of Cardiovascular Science, London, United Kingdom

Jan Marek, UCL Institute of Cardiovascular Science & Great Ormond Street Hospital for Children, London, UK and Cardiorespiratory Unit, Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK

Martin Kostolny, The Great Ormond Street Hospital

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Taking surgery out of reality:

A virtual journey into double outlet right ventricle

Milano-Virtual reality in congenital heart disease

Elena Giulia Milano, MD[1,2] ,Endrit Pajaziti, BEng[1], Emilie Sauvage, PhD[1], Andrew Cook, PhD[1], Silvia Schievano, PhD [1] , Kristian H. Mortensen, MD PhD [2], Andrew M Taylor, MD PhD [1,2], Jan Marek, MD PhD [1,2] , Martin Kostolny, MD[3,4], Claudio Capelli, PhD[1]

[1] UCL Institute of Cardiovascular Science & Great Ormond Street Hospital for Children, London, UK.

[2] Cardiorespiratory Unit, Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK

[3] Department of Cardiothoracic Surgery, Great Ormond Street Hospital for Children NHS Foundation Trust, London, UK

[4]Slovak Medical University, Bratislava, Slovakia

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Corresponding Author:

Dr Claudio Capelli

Great Ormond Street Hospital for Children
Great Ormond Street
London, WC1N 3JH
c.capelli@ucl.ac.uk
+44 (0) 2074059200 ext.8106

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An 11-month-old patient with a postnatal diagnosis of double outlet right ventricle (DORV) with side-by-side great arteries, large non-committed ventricular septal defect (VSD) and a small muscular apical VSD was evaluated for feasibility of biventricular repair, after a previous palliation with pulmonary artery (PA) banding at age of 14 days. Transthoracic echocardiography showed tricuspid chordal attachment to the crest of the interventricular septum, a non-committed VSD (Figure 1), a small additional apical muscular VSD and moderate flow acceleration below the pulmonary valve secondary to double conus. Cardiac CT confirmed the presence of significant sub-pulmonary obstruction with right ventricular (RV) hypertrophy (Figure 2a-b). A 3D volume reconstructed from CT (Figure 2c-d) was used as an input for a virtual reality (VR) application which was setup at our Centre (Supplement Figure).

The VR platform was adopted for the first time by our surgical team during the planning phase. Intra-cardiac structures of the patient-specific model were explored and the views from the standard surgical access were mimicked (Supplemental Video 1). This allowed a full estimation of the spatial relationship between VSD and the great vessels. The VR-based model allowed the surgeons to simulate an unobstructed baffle path with no interference with the tricuspid valve apparatus (Figure 3a-b), in multiple cross-sectional views in 3D.

The patient underwent successful intra-cardiac biventricular repair with VSD enlargement, division of mid cavity RV muscle bundles and an intra-ventricular tunnelling through the VSD to the aorta. Post-operative imaging showed patent LV to aorta tunnel (Figure 3, Supplemental Video 2) with laminar flow and no residual VSD.

DORV represents a spectrum of congenital heart defects with a wide range of anatomical variations, often unique. The DORV anatomical type is known to influence patient outcomes; with non-committed VSDs being associated with higher risks of

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death, reoperation [1] and late onset of left ventricular outflow tract obstruction. Intraventricular repair performed with arterial switch is the procedure that carries the highest risk of early mortality irrespective DORV anatomy [1]. Therefore a careful multidisciplinary approach is needed.

VR provides a unique experience to interact easily with digital 3D complex objects, completely immersed within a simulated environment, through the use of a VR headset, which contains a stereoscopic display and tracking capabilities via external sensors. Early examples in literature show the use of VR for enhanced evaluation of VSD [2] and in a case of Truncus arteriosus [3] as well as for educational purposes [4].

In this specific case, the VR setup allowed the leading surgeon to navigate inside and interact with the patient specific model not only from conventional surgical views, but also by approaching the defect from unconventional surgical angles (left cardiac chambers), usually not accessed during DORV repair. This increases the spatial understanding of the anatomy before the surgery. In addition, the possibility to display the VR on a separate monitor while being used by the leading surgeon (Supplement Video) helped other members of the team to understand the procedure before and after theatre. Finally, compared with 3D printing, increasingly used in the management of CHD, VR has the advantage to allow unlimited ways of navigation and manipulation of the patient-specific model by the surgeon himself at no costs. Such tools can become a very valuable educational tool which can support interdisciplinary communications.

In conclusion, this case-report shows the feasibility of planning a complex DORV repair by means of 3D models within a VR environment. VR is a promising tool to enhance the surgical planning for complex cases.

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Disclosures

None

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Figure legends

Figure 1 a. 2D echocardiography subcostal four-chamber view demonstrating right ventricle (RV) giving rise to right anterior aorta (AO) with pulmonary trunk (PA) left and slightly anterior; b. Colour flow mapping confirmed left-to-right shunt across interventricular communication (yellow arrow); c. Echocardiographic 3D reconstruction better visualised the location and size of VSD (yellow arrow) and considered pathway from the left ventricle (LV) through the VSD towards aorta.

Figure 2 a. CT view showing the systemic and pulmonary outlets from the right ventricle (RV); b. CT view showing the ideal pathway (blue dots) from the left ventricle (LV) to the aorta (Ao); c. 3D reconstruction from CT images showing full heart, with significant subpulmonary obstruction (white arrow) and pulmonary artery (PA) band; d.3D reconstruction from CT images showing intra-cardiac anatomy, viewed from the RV.

Figure 3 The patient specific 3D model is used as input fro the VR environment. a. Pre-surgical anatomy with possible baffle pathway to connect VSD to aorta; b. Post surgical results with unobstructed left ventricle to aorta baffle; c. 3D reconstruction of the post-operative left sided structures.

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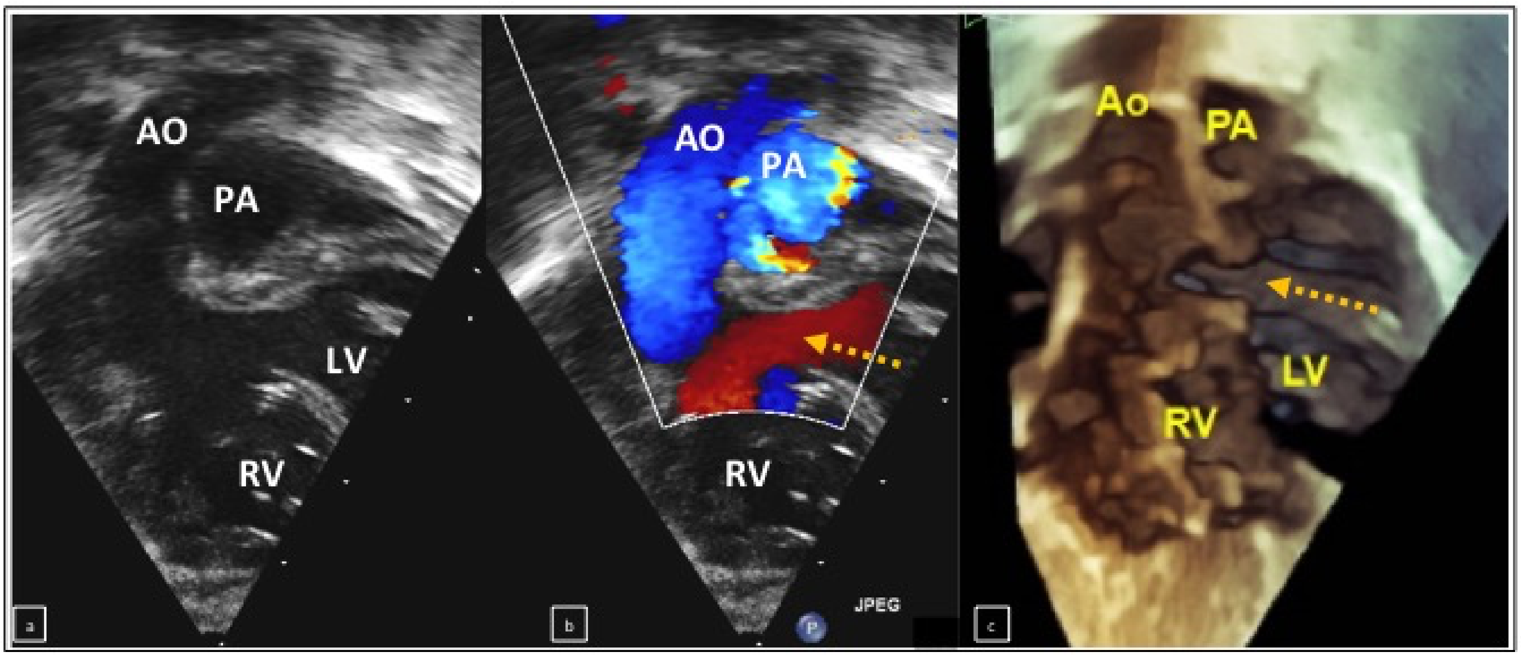
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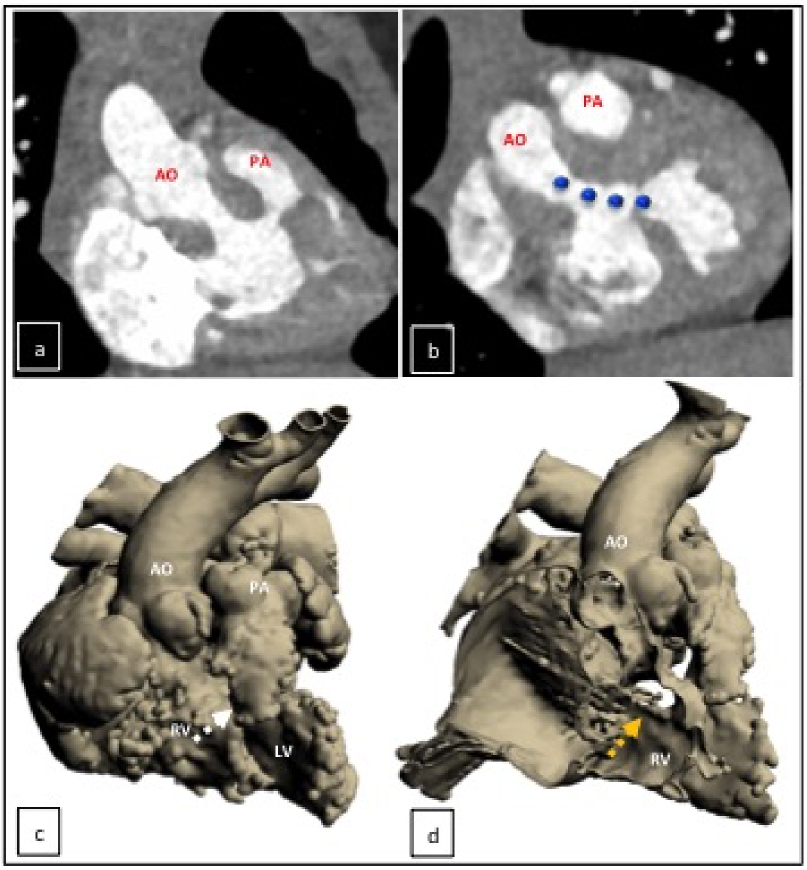
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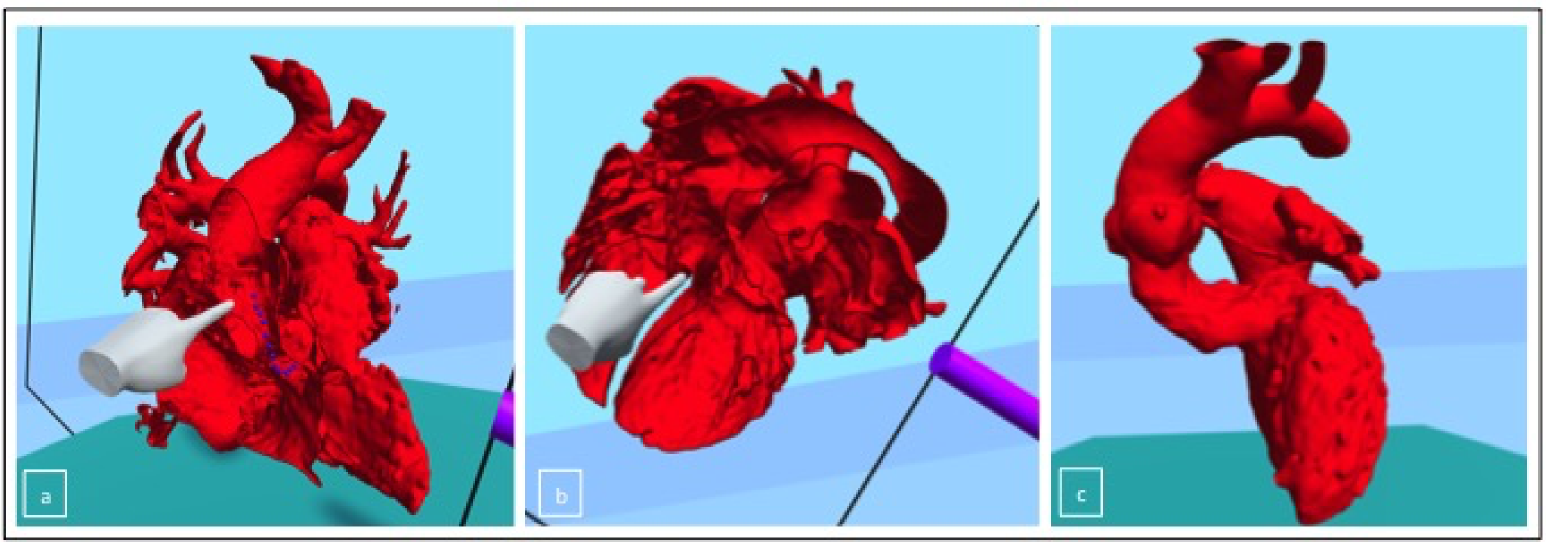
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