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A Novel 3D Imaging Approach to Evaluate Coronary Access Following ACURATE Neo Implantation to treat a Degenerated Surgical Bioprosthesis

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Short title: 3D evaluation of coronary access

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Coronary access following transcatheter aortic valve replacement (TAVR) can be challenging and is relevant as TAVR expands towards lower-risk younger patients[1]. Prior studies have used post-implantation computed-tomography (CT) scans to suggest several anatomical and device-related factors which can impact coronary access**[2–5]**. However, the two-dimensional (2D) images and measurements may not fully capture the complex 3D geometry underpinning the challenge of coronary access[4].

In this image, we present a novel CT-based, 3D multi-parametric imaging approach, which was used to evaluate geometrical factors relevant for coronary access.

A 72-year-old male underwent ACURATE neo valve implantation to treat a degenerated Mitroflow-25 surgical bioprosthesis (figure 1A). A post-procedural CT scan was performed and the following structures were segmented: left ventricle, aortic root, coronary arteries, surgical/transcatheter valves. Segmentation was performed using semi-automatic algorithms with additional manual correction in Slicer 3D (figure 1B-C). The segmentations were converted into 3D mesh structures and exported as stereolithography files to create a 3D digital model (figure 1D-E).

Key advantages of the digital model include, the enhanced visualisation which allows closely related structures to be easily distinguished, the ability to rotate and view the images from any 3D perspective and the possibility of adding or removing specific structures or regions of interest to perform selective analyses (figure 1E-H).

Using these properties, the geometrical relationship between the coronary ostia, valve frames and surrounding sinuses was evaluated. Both coronary ostia arise below the 'risk plane' for the ACURATE neo valve at the level of the upper crown (figure 1E) and there is evidence of commissural mis-alignment impacting both coronary ostia (figure 1G-H). The 3D visualisation highlights the importance of considering patient-specific implantation techniques to ensure commissural alignment between the implanted valve and surgical bioprosthesis or native cusps.

In this challenging scenario of low-lying coronary ostia, the sinus gap between the valve frame and coronary ostia becomes an important determinant of the challenge and feasibility of coronary access[4,5]. To date, this sinus gap has only been evaluated using 2D images and linear measurements[1,2].

In contrast, with the 3D models the sinus gap can be visually inspected from any angle and a more detailed analysis of its size and morphology can be obtained (Figure 1I-J, supplementary figure). The sinus access area (SAA) determines how much space is available for a catheter to enter into the aortic sinuses, whilst the sinus access volume (SAV) reflects the room available for catheter manipulation inside the sinus. These measurements can directly be applied to evaluate the sinus space when coronary ostia arise below the risk plane for other low-profile valves and if adapted, may still be relevant for higher-profile valve frames.

The SAA and SAV measurements provide further detail beyond previously reported measurements and in combination with the 3D visualisation and segmentation properties of the digital models may provide greater insights into the geometrical factors underlying the challenge of coronary access. This multi-parametric imaging approach may aid interventionists in understanding which catheter shapes, sizes and cannulation techniques should be considered for cannulation of challenging coronary ostia. (Supplementary figure 1)

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Figure legend

Figure 1: Multi-parametric 3D imaging evaluation of coronary access

Post-procedural CT scan was performed and specific structures and regions of interest deemed relevant for evaluating coronary access were segmented to create a 3D digital model (A-D). Further image processing was then applied to improve the visualisation and the understanding of the geometrical relationships between the aortic sinuses (grey), ACURATE neo valve (white), surgical bioprosthesis (green), right coronary artery (blue), left coronary artery (red) (E-H). In order to evaluate the complex 3D geometry of the sinus space, both the size and morphologies of the (I) area available between valve frame and aortic wall to enter the sinuses (sinus access area) and (J) volume available within the sinuses (sinus access volume) was determined for each ostium.

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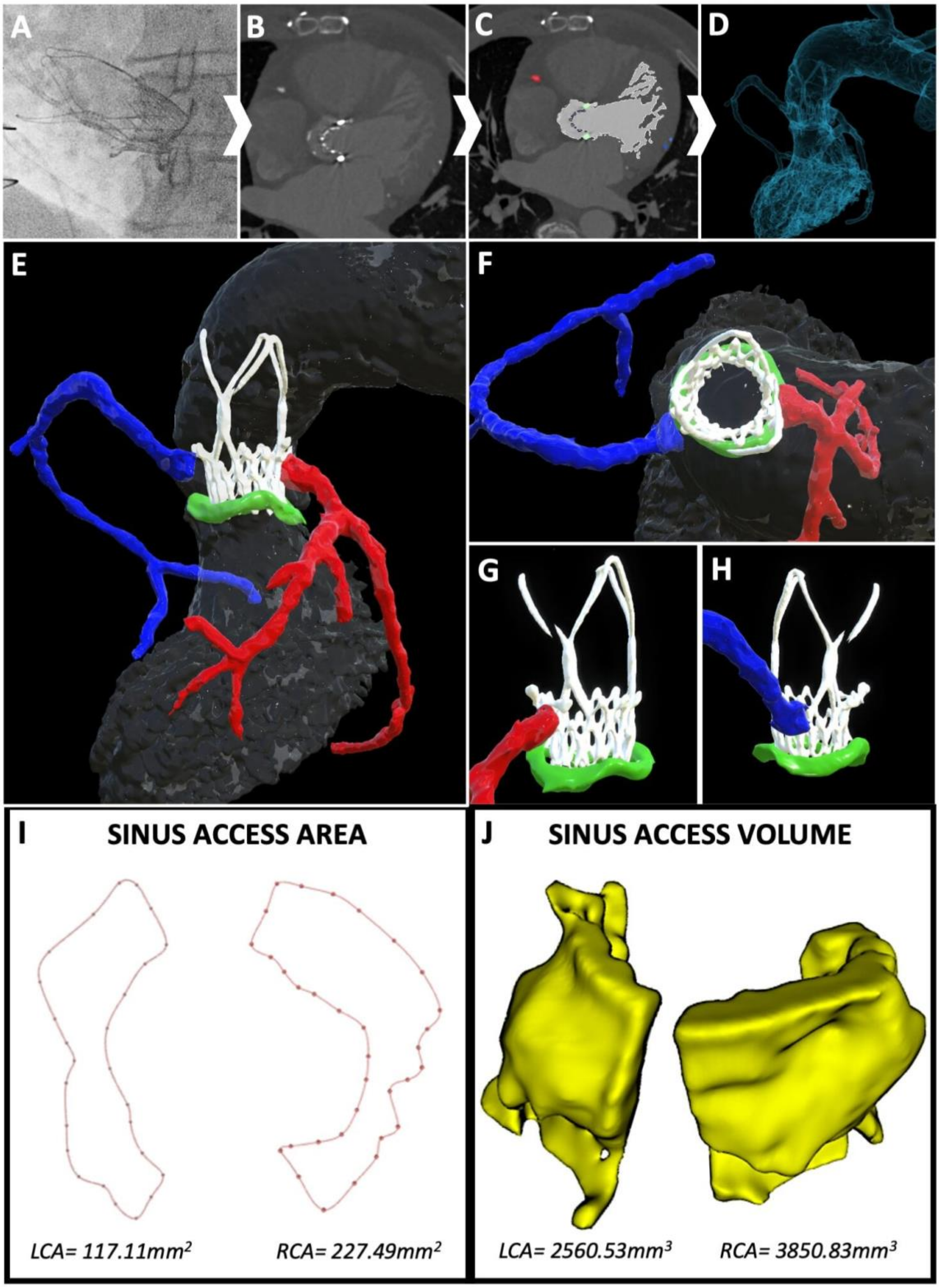
A
B
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SINUS ACCESS AREA
LCA= 117.11mm2
RCA= 227.49mm2
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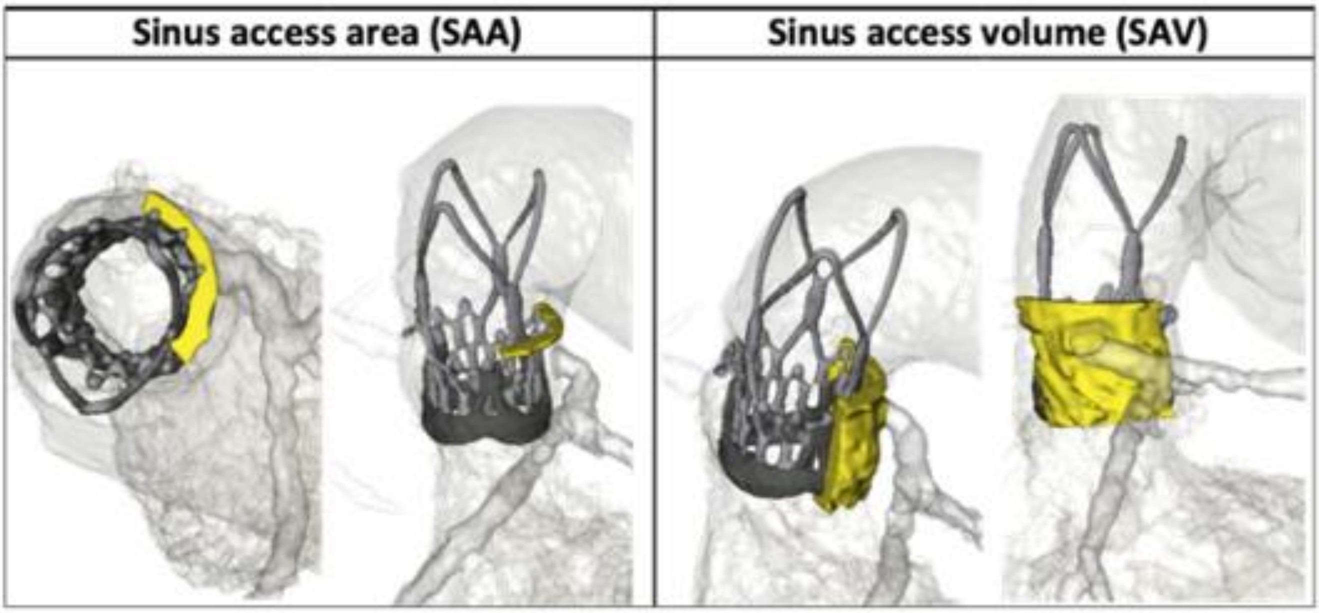
SINUS ACCESS VOLUME
LCA= 2560.53mm3
RCA= 3850.83mm3

Supplementary material



Supplementary figure 1: measurement of sinus space

Given that the 3D models were derived from post-implantation CT scans, precise measurements of relevant structures and regions of interest were possible. In order to capture the geometry of the sinus space between the valve frames, coronary ostia and surrounding aortic wall, we developed the following novel measurements: the sinus access area (SAA) represents the area (mm^2) between the upper crown of the ACURATE neo valve and the surrounding aorta within a 120 degree arc centred around the coronary ostium. The sinus access volume (SAV) represents the volume (mm^3) available between the coronary ostia, surrounding aortic sinus and the THV frame within a 120 degree arc centred around the coronary ostium. A 120-degree arc was selected to reflect native tricuspid valve cusp anatomy and transcatheter heart valve design. A 60-degree arc was felt to provide sufficient room for catheter entry and subsequent manipulation inside the aortic sinuses.