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Virtual reality-guided aortic valve leaflet reconstruction for type 0 bicuspid aortic stenosis

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Abstract

Although virtual reality (VR) techniques that enable visualizing a patient's anatomy stereoscopically have been developed recently, these techniques are still scarcely used in clinical settings, and their benefits remain uncertain. Herein, we demonstrate how VR preoperative planning facilitated the efficiency of a complex surgical procedure. A 53-year-old male was diagnosed as type 0 bicuspid aortic stenosis. To take haemodynamical advantage and to lower valve-related reoperation risks, an aortic valve reconstruction was scheduled; however, anatomical tri-leaflet neocuspidalization for type 0 bicuspid aortic root is particularly challenging. To optimize the procedure, VR preoperative planning was applied to create a blueprint of the aortic root rearrangement and suture line design. This allowed for a competent aortic valve to be reconstructed speedily, resulting in an excellent postoperative course.

Keywords: Virtual reality • Preoperative planning • Aortic valve reconstruction • Aortic root anatomy

CASE REPORT

A 53-year-old male was admitted to our hospital and diagnosed as type 0 bicuspid aortic valve with symptomatic aortic stenosis (Fig. 1A) and an aortic valve reconstruction was scheduled. Axial electrocardiogram-gated computed tomography (CT) images were obtained and transferred to Vesalius3D (PS-Medtech, Amsterdam, Netherlands) to construct a holographic image. Using the device, aortic root geometry was measured to develop an appropriate surgical strategy (Video 1 and Fig. 2A–C). A suitable leaflet template with a 30-mm sinotubular junction (STJ) was then selected from the set (Fig. 2D) based on the measurements. In the actual surgery, rearrangement of the aortic root and selection of a neo-leaflet size were performed according to the preoperative planning (Video 2). Eventually, a competent aortic valve was reconstructed (Fig. 1B) with a myocardial ischaemia time of 103 min. Postoperative echocardiography revealed a maximum transvalvular pressure gradient of 12.5 mmHg, an average transvalvular pressure gradient of 6.0 mmHg and an effective orifice area of (EOA) 2.34 cm^2. The patient was discharged on the 12th postoperative day. Echocardiography performed during the past 5 years of routine follow-ups has revealed neither aortic stenosis nor aortic regurgitation. The patient consented to the publication of this report.

DISCUSSION

Since aortic valve reconstruction enables taking haemodynamical advantage and lowering valve-related reoperation risks without using any prosthesis [1], we consider it as an effective option for aortic stenosis. On the other hand, this procedure is among the most complex cardiac surgeries for patients with type 0 bicuspid aortic root. Preoperative planning is often the key success factor [2]; however, conventional visualization of CT images on a 2-dimensional screen lacks crucial spatial information that surgeons demand. In contrast, virtual reality (VR) techniques, a conspicuous development in medicine [3], can display CT datasets as stereoscopic objects that can be handled freely. In this case, VR was successfully applied to the aortic root rearrangement and suture line design; this improved the surgeon's mental preparation. Thus, neocuspidalization was completed with a short myocardial ischaemia time, which led to an excellent postoperative course. Demonstratedly, VR preoperative planning can facilitate the efficiency of complex cardiac surgeries. As a consequence, this futuristic technology ought to become an indispensable tool for cardiovascular surgeons.

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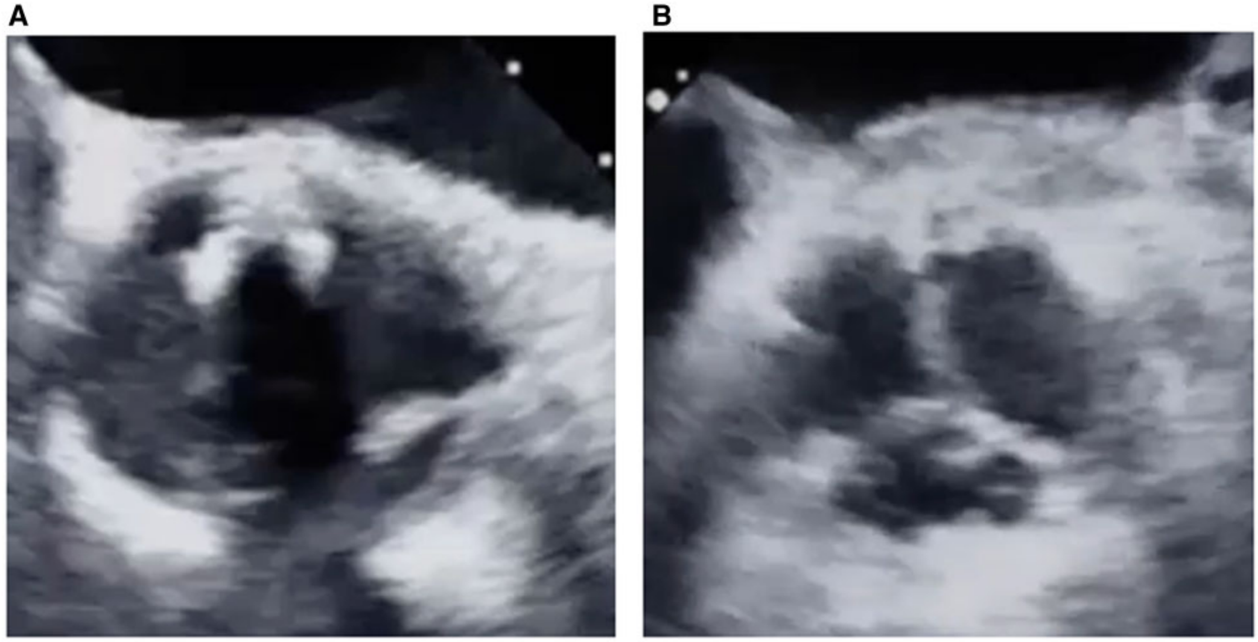


Figure 1: (**A**) Preoperative transoesophageal echocardiography. (**B**) Intraoperative transoesophageal echocardiography. TEE: transoesophageal echocardiography

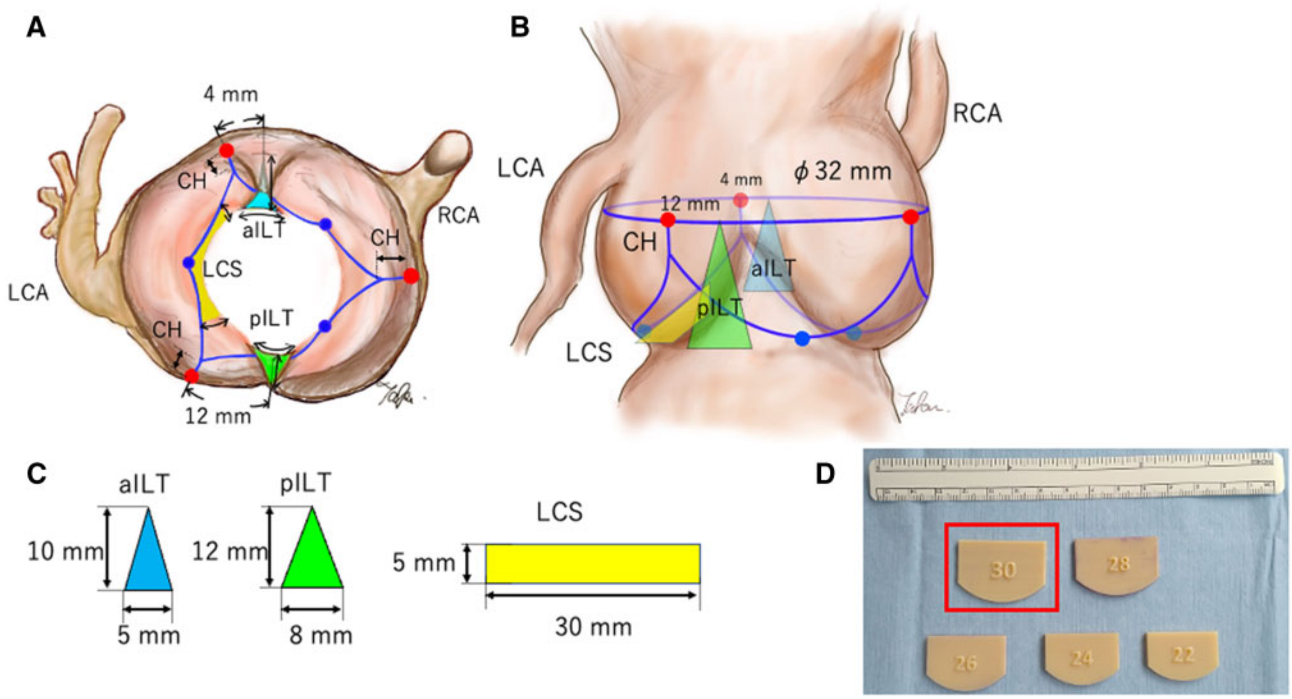
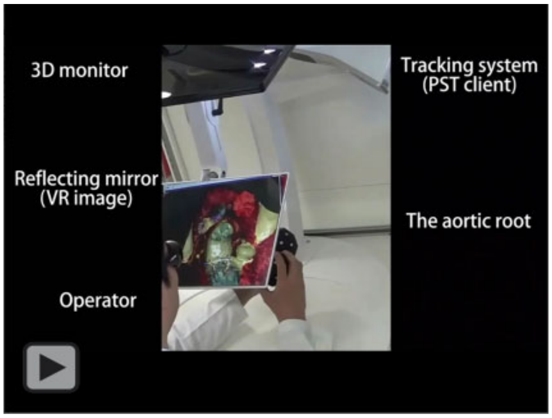
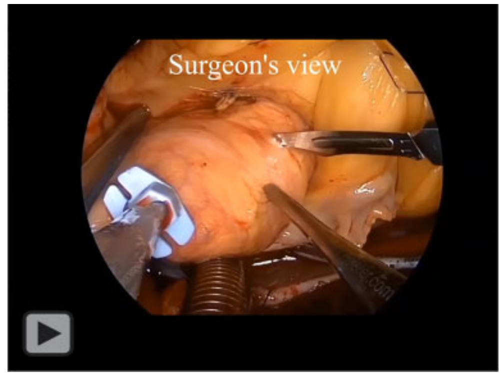


Figure 2: Schematic bird's-eye view (**A**) and front view (**B**) of preoperative planning. Blue lines: designed suture lines, blue circles: references of neo-nadir, red circles: references of neo-commissure, blue triangle: posterior inter-leaflet triangle, green triangle: anterior inter-leaflet triangle, and yellow rectangle: left coronary sinus. (**C**) The size of planned plication areas. (**D**) The set of templates produced according to [1] to create a pericardial autologous patch. Red rectangle: the chosen template by the measurement. aILT: anterior inter-leaflet triangle; CH: coaptation height; LCA: left coronary artery; LCS: left coronary sinus; pILT: posterior inter-leaflet triangle; RCA: right coronary artery.

CASE REPORT



Video 1: First, the references of neo-commissure and neo-nadir were placed so that each central angle is equivalent to 120 degrees without disturbing coronary orifices. After setting the coaptation height as 5 mm, suture lines were designed to plan the plication area (Figure 2A-C). Finally, a whole suture line blueprint was completed.



Video 2: The video was taken from the surgeon's view. (Patient's cranial side on the left) After exposure and removing the native aortic valve, both inter-leaflet triangle and left coronary sinus were plicated as specified by the plan (Fig. 2A–C). Three same-sized leaflets were produced from autologous pericardium using the chosen template (Fig. 2D). These were then attached according to the blueprint, suturing leaflets on cusp-suture-line in 3/2 ratio (leaflet/annulus) from the nadir to commissure height and in 1/1 ratio in commissure part. Commissure coaptation stitches were added between each leaflet to prevent coronary orifice occlusion. Lastly, STJ fixation was performed using a pericardial stripe to prevent dilation.

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Conflict of interest: none declared.

Reviewer information

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