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Computer simulated "Virtual TAVR" to guide TAVR in the presence of a previous Starr-Edwards mitral prosthesis

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Running title: Virtual TAVR with pre-existing Starr-Edwards

Abstract

Background: We evaluated the utility of the HeartNavigator III software (Philips Healthcare, Netherlands) to create a patient specific three-dimensional model using ECG-gated CT images to plan Transcatheter Aortic Valve Replacement (TAVR) in a patient with previous Starr-Edwards mitral prosthesis.

Methods: A patient with a previous Starr-Edwards mitral prosthesis considered too high risk for conventional surgery required TAVR. It was uncertain whether this would be possible whilst avoiding the complication of the aortic prosthesis interacting with the high-profile Starr-Edwards cage and ball valve mechanism. To ensure it would be feasible and aid in the planning of the procedure a patient specific three-dimensional model was created from ECG-gated CT images using HeartNavigator III software (Philips Healthcare, Netherlands).

Results: The patient specific model allowed simulated “virtual” TAVR implantations to be performed with different models and sizes of aortic prosthesis. These pre-implant simulations allowed a safe and feasible implant strategy to be chosen. The images were also co-registered with fluoroscopy to guide deployment.

Conclusion: Using a patient-specific CT simulation technique we performed TAVR with a high level of precision, achieving a clear margin between a Portico (Abbot Vascular, US) TAVR and the Starr-Edwards cage.

Key-words: Heart navigator; Portico; TAVR; computational simulation; ball and cage; Starr-Edwards.

Abbreviations

CT – computed tomography

TAVR – trans-catheter aortic valve replacement

LVOT – left ventricular outflow tract.

1. *Introduction*

Transcatheter Aortic Valve Replacement (TAVR) is a minimally invasive alternative for patients who require aortic valve replacement but are high-risk for surgery (1). Patients with pre-existing mechanical mitral valve replacements were initially excluded from landmark trials(2, 3) due to concerns that TAVR deployment may impinge on the mitral prosthesis.

The HeartNavigator III software (Philips Healthcare, Netherlands) creates a patient specific computer model of the aortic root and surrounding structures from ECG-gated cardiac CT images. This was used to run simulated TAVR implantations with different aortic prothesis at their recommended implant depth to determine the feasiblilty of perfoming the procedure in a patient with a previous Starr-Edwards ball and cage mitral valve replacement and facilitate selection of the most appropriate aortic valve prothesis.

2. *Methods*

2.1 Patient

An 81 year old woman presented with severe aortic stenosis having undergone mitral valve replacement in 1975 with a Starr-Edwards ball and cage prosthesis. She was high-risk for conventional aortic valve surgery and the heart team decided to proceed with transcatheter aortic valve replacement (TAVR). Transesophageal echo and ECG-gated cardiac CT revealed the close proximity of the Starr-Edwards ball and cage prothesis to the aortic annulus and the extent to which it protuded into the left ventrular outflow tract (LVOT) (Figure 1A and B).

2.2 Cardiac CT

Prospective ECG-gated Cardiac CT was performed on a 320-slice CT scanner with 320×0.5 mm detector rows (Aquilion One, Toshiba Medical Systems, Japan) and 75mls of intravenous contrast (Omnipaque 300, GE Healthcare, USA). Acquisition was timed for 35% of the RR interval to capture a systolic dataset where the encroachment of the Starr-Edwards mitral prothesis into the LVOT would be maximal. Multiplaner reformat images were created using a dedicated 3D workstation (Vitrea, Vital Images, USA) to examine the aortic root anatomy and initially suggested that it may not be possible to insert a TAVR valve safely due to insufficent space.

2.3 Computer Simulation

The ECG-gated cardiac CT images were imported into a dedicated work station with HeartNavigator III software (Philips Healthcare, Netherlands). The aortic root and relevant structures were then automatically segmented with manual correction if required. This 3D dataset was used to assess the potential relationships of implanted TAVR valves with the pre-existing Starr-Edwards prothesis.

3. Results

3.1 “Virtual” TAVR

Initial simulation revealed a 26mm balloon expandable Sapian S3 (Edwards Lifesciences, USA) would fit at its conventional implant depth (Figure 2A). However its delivery balloon would likely interact with the ball and cage apperatus of the Starr-Edwards prothesis. We then looked at implantation of a 29mm Portico aortic valve prothesis (Abbot Vascular, Illinois, USA) and found that this would not impinge on the Starr-Edwards prothesis at implant depths between 1mm (the minimum recommended implant depth for the valve) and 5mm (Figure 2B and 2C). A “virtual” deployment of the valve at the optimum implant depth (3mm) revealed a small but clear margin between the two valves (Figure 3A).

3.2 TAVR procedure

A Portico aortic prothesis (Abbot Vascular, Illinois, USA) was implanted percutaneously under fluroscopic guidance. Co-registration between the CT model of the aorta and fluroscopic images was performed, enabling live overlay of the outline of the aorta by the HeartNavigator III software (Philips Healthcare, Netherlands) facilitating precise deployment of the valve in the optimum position exactly matching the simulated “virtual” TAVR (Figure 3B). Trans-esophageal echocardiographic assessment post Portico valve implantation revealed no impingment on the function of the Starr-Edwards mitral prothesis and trivial paraprosthetic aortic regurgitation.

4. Discussion

With experience, TAVR in the presence of a mitral prosthesis has become feasible(4), although potential complications remain including both upward displacement of the aortic prostheses(5) and compromise of the function of the existing mitral prosthesis (6). Implanting TAVR under these circumstances is now performed with good success rates but almost all implants occurred in the presence of newer, low-profile mitral prosthesis(7). The Starr-Edwards prosthesis adds complexity as its large cage protrudes into the LVOT further increasing the chance of an interaction with either the aortic prosthesis or the deployment balloon of balloon expandable prostheses(8). In our case the patient had a small body habitus (Height 159cm, Weight 59kg) further minimising space in the LVOT.

HeartNavigator III (Philips Healthcare, Netherlands) is a proprietary, commercially available software program. It automatically identifies the cardiovascular landmarks simplifying and automating the process of assessing the annulus(9). The ability to superimpose TAVR valves of varying models and sizes into different implant positions and manipulate these in three dimensions (something not possible using standard software reconstructions) allows assessment of potential interaction with surrounding structures. This enabled the most suitable TAVR strategy in the presence of the Starr-Edwards mitral prothesis to be determined. We used the Portico aortic prosthesis (Abbot Vascular, Illinois, USA) as it does not need to be deployed low in the LVOT, there is no requirement for balloon expansion and its ability for partial recapture allow precise controlled deployment(10). The HeartNavigator III software (Philips Healthcare, Netherlands) also allows fusion of the CT-generated patient-specific computer simulation with live fluroscopy which may allow a reduction of contrast use during TAVR deployment(11). In this case the CT-Fluoroscopy co-registration was invaluable in guiding precise implantation of the TAVR valve required to maintain a clear margin between the two prostheses.

Figures

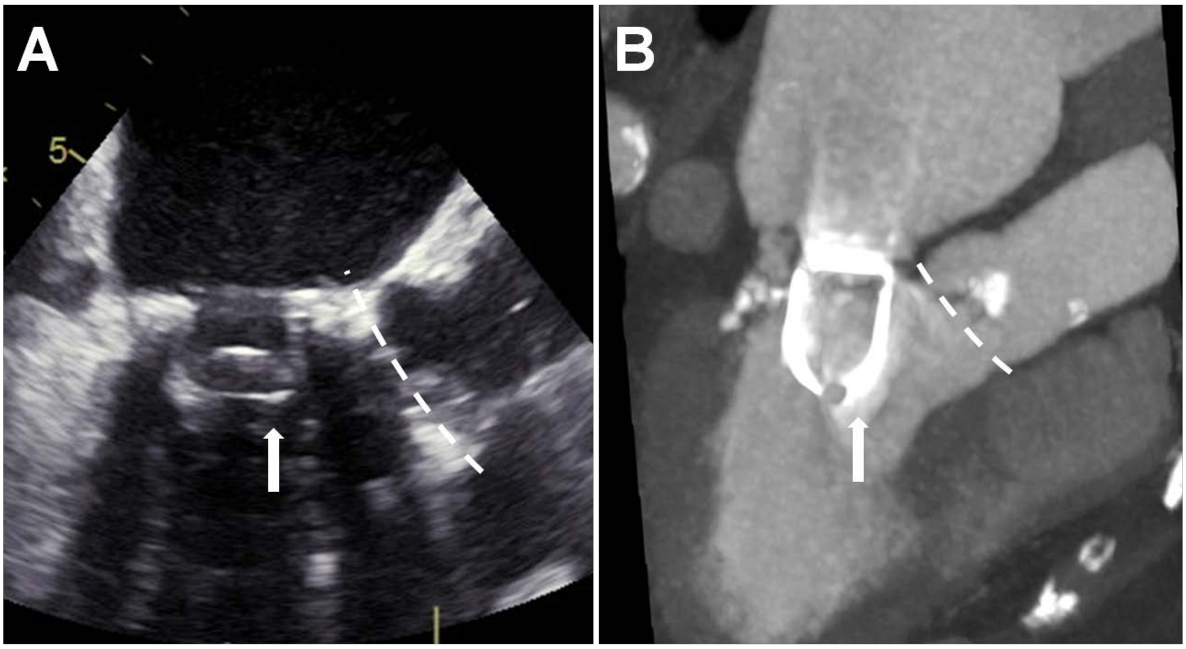

Figure 1. (A) Trans-esophageal and (B) Cardiac CT images depicting the close proximity of the aortic annulus (dashed line) and Starr-Edwards prosthesis (arrow).

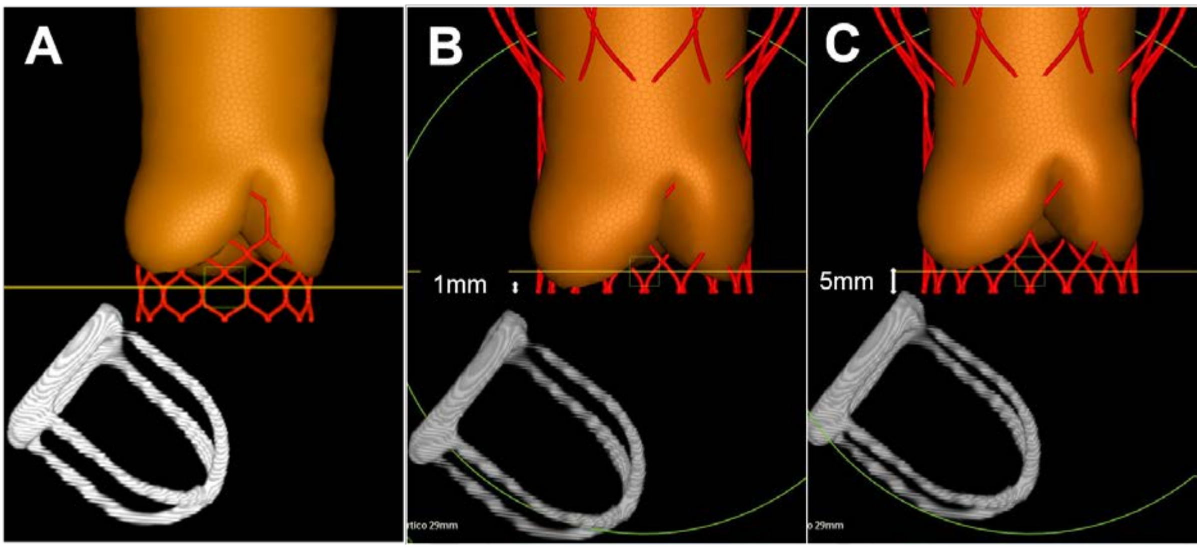

Figure 2. HeartNavigator CT model with simulated deployment of (A) 26mm Sapian S3 valve at optimal implant depth, (B) 29mm Portico valve at the

minimal depth (1mm) and (C)maximal implant depth (5mm) before aortic / mitral prosthesis interaction.

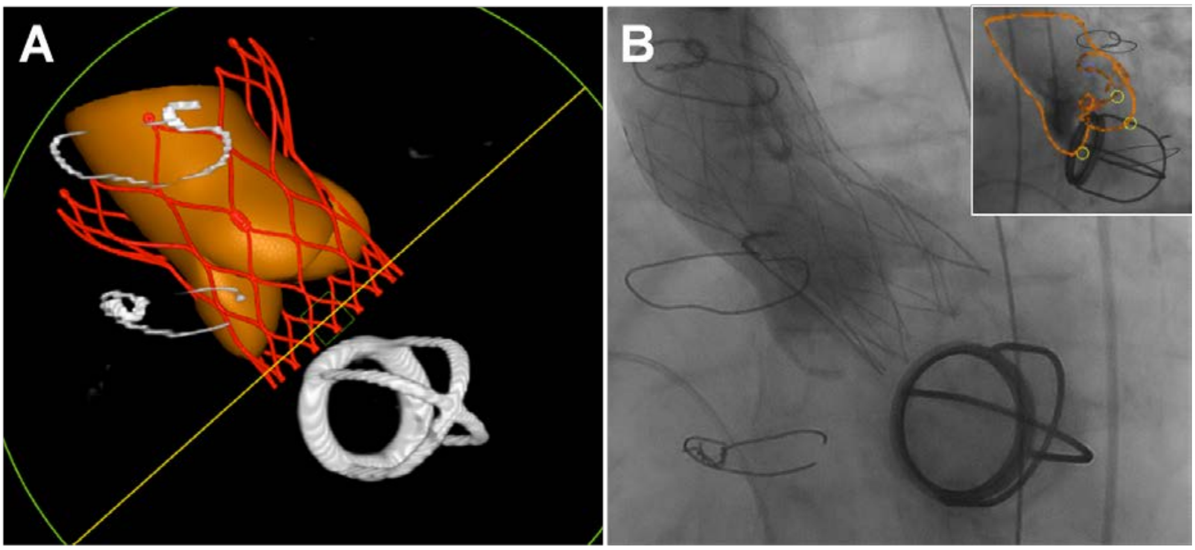

Figure 3. (A) Computer simulated deployment at ideal (3mm) depth demonstrating clear margin from Starr-Edwards prosthesis and (B) Fluoroscopic deployment of 29mm Portico aortic prosthesis exactly matching "virtual" TAVR with aid from CT – Fluoroscopy co-registration (inset panels).

References

1. Holmes DR, Jr., Mack MJ, Kaul S, Agnihotri A, Alexander KP, Bailey SR, et al. 2012 ACCF/AATS/SCAI/STS expert consensus document on transcatheter aortic valve replacement. J Am Coll Cardiol. 2012;59(13):1200-54.
2. Adams DH, Popma JJ, Reardon MJ, Yakubov SJ, Coselli JS, Deeb GM, et al. Transcatheter aortic-valve replacement with a self-expanding prosthesis. N Engl J Med. 2014;370(19):1790-8.
3. Smith CR, Leon MB, Mack MJ, Miller DC, Moses JW, Svensson LG, et al. Transcatheter versus surgical aortic-valve replacement in high-risk patients. N Engl J Med. 2011;364(23):2187-98.
4. Dumonteil N, Marcheix B, Berthoumieu P, Massabuau P, Dieye E, Decramer I, et al. Transfemoral aortic valve implantation with pre-existent mechanical mitral prosthesis: evidence of feasibility. JACC Cardiovasc Interv. 2009;2(9):897-8.
5. Maroto LC, Rodriguez JE, Cobiella J, Silva J. Delayed dislocation of a transapically implanted aortic bioprosthesis. Eur J Cardiothorac Surg. 2009;36(5):935-7.
6. Testa L, Gelpi G, Bedogni F. Transcatheter aortic valve implantation in a patient with mechanical mitral prosthesis: a lesson learned from an intraventricular clash. Catheter Cardiovasc Interv. 2013;82(4):E621-5.

7. Greason KL, Sandhu GS, Nkomo VT, King KS, Joyce DL, Williamson EE, et al. Transcatheter aortic valve insertion after previous mitral valve operation. J Thorac Cardiovasc Surg. 2017;154(3):810-5.
8. Rahman MS, Roy D, Brecker SJ. Transcatheter aortic valve implantation in a patient with previous Starr-Edwards mitral valve prosthesis. Heart. 2013;99(3):217-8.
9. Vaitkus PT, Wang DD, Greenbaum A, Guerrero M, O'Neill W. Assessment of a novel software tool in the selection of aortic valve prosthesis size for transcatheter aortic valve replacement. J Invasive Cardiol. 2014;26(7):328-32.
10. Willson AB, Rodes-Cabau J, Wood DA, Leipsic J, Cheung A, Toggweiler S, et al. Transcatheter aortic valve replacement with the St. Jude Medical Portico valve: first-in-human experience. J Am Coll Cardiol. 2012;60(7):581-6.
11. Madershahian N, Weber C, Majd P, Rudolph T, Kuhn E, Scherner M, et al. Feasibility and applicability of static vascular outline roadmapping during transcatheter aortic valve implantation. J Cardiovasc Surg (Torino). 2018;59(1):111-4.