Journal of Surgery
Yang J, et al. J Surg 7: 1583
www.doi.org/10.29011/2575-9760.001583
www.gavinpublishers.com

OPEN ACCESS

GAVIN PUBLISHERS

Case Report

Transcatheter Mitral Valve-in-Valve Replacement Guided by 3-Dimensional Printing to Treat Patient Who Successively Underwent Mitral Valve Replacement, Tricuspid Valvuloplasty, and Transcatheter Aortic Valve Replacement

Yu Mao[1], Yang Liu[1], Yanyan Ma[1], Mengen Zhai[1], Lanlan Li[1], Ping Jin[1], Lifang Yang[2], Jian Yang[1*]

[1]Department of Cardiovascular Surgery, Xijing Hospital, Air Force Medical University, Xi'an, China

[2]Department of Anesthesiology, Xi'an Children Hospital, Xi'an, China

[*]**Corresponding author:** Jian Yang, Department of Cardiovascular Surgery, Xijing Hospital, Air Force Medical University, 127 Changle West Road, 710032 Shaanxi, China

Citation: Mao Y, Liu Y, Ma Y, Zhai M, Lanlan Li L, et al. (2022) Transcatheter Mitral Valve-in-Valve Replacement Guided by 3-Dimensional Printing to Treat Patient Who Successively Underwent Mitral Valve Replacement, Tricuspid Valvuloplasty, and Transcatheter Aortic Valve Replacement. J Surg 7: 1583. DOI: 10.29011/2575-9760.001583

Received Date: 21 September, 2022; **Accepted Date:** 06 October, 2022; **Published Date:** 10 October, 2022

Abstract

Objective: We describe a case of Transcatheter Mitral Valve-In-Valve Replacement (TMViVR) successfully performed under the guidance of 3-Dimensional (3D) printing.

Case presentation: A 76-year-old man presented with palpitations, shortness of breath, and chest tightness 2 months ago, and the symptoms continued to worsen. Transthoracic echocardiography showed mitral stenosis with bioprosthetic degeneration and New York Heart Association functional class III. The patient underwent mitral valve replacement 11 years ago for mitral stenosis, and he underwent tricuspid valvuloplasty 6 years ago because of tricuspid regurgitation after mitral valve replacement. One year ago, the patient developed clinical symptoms again. Transthoracic echocardiography showed aortic regurgitation combined with stenosis (PG_{max}=25 mmHg), and transcatheter aortic valve replacement was performed. In combination with his multiple operations, we used 3D printing for preoperative assessment and digital subtraction angiography for intraoperative guidance to complete the TMViVR. After the procedures, digital subtraction angiography showed that the bioprosthesis was in a good position and opened and closed normally. Furthermore, transesophageal echocardiography showed that the morphology and motion of the leaflets were good, the blood flow rate was normal, and there was no paravalvular leak. The 3D-printed model prepared after TMViVR showed the good position of the bioprosthesis and normal morphology.

Conclusion: Preoperative assessment and 3D printing guidance may play an auxiliary role when treating patients with high surgical risk undergoing TMViVR.

Keywords: Intervention; Mitral valve; Transcatheter; 3-Dimensional printing; Valve-in-valve

Abbreviations: 3D: 3-Dimensional; CTA: Computed Tomography Angiography; DSA: Digital Subtraction Angiography; NYHA: New York Heart Association; PG: Pressure Gradient; TEE: Transesophageal Echocardiography; TMViVR: Transcatheter Mitral Valve-In-Valve Replacement; TTE: Transthoracic Echocardiography

Introduction

Various factors may lead to the degeneration of a bioprothesis, including Structural Valve Deterioration (SVD), which affects the durability of the bioprothesis and limits the quality of life and life expectancy of the patient [1]. When patients have a Mitral Valve (MV) that exhibits SVD, they usually need to undergo Mitral Valve Replacement (MVR) again, but a traditional thoracotomy is traumatic, especially for high-risk surgical patients [2]. Transcatheter Mitral Valve-In-Valve Replacement (TMViVR), as an alternative to traditional surgical procedures, may not only rapidly help patients to relieve but also significantly reduce the risk of bleeding and stroke [3]. However, patients undergoing TMViVR still face many challenges, such as postoperative left ventricular outflow tract obstruction, a Paravalvular Leak (PVL), and patient-prothesis mismatch [4]. In this case report, we describe how we printed a 3-Dimensional (3D) model of the anatomical characteristics of a high surgical risk patient before the procedures and conducted simulations to confirm the diagnosis and successfully complete the TMViVR.

Baseline Characteristics and Preoperative Imaging Evaluation

The patient underwent Mitral Valve Replacement (MVR) 11 years ago for mitral stenosis, and he underwent tricuspid valvuloplasty 6 years ago because of tricuspid regurgitation after the MVR. One year ago, the patient developed clinical symptoms again, and Transthoracic Echocardiography (TTE) showed aortic regurgitation combined with stenosis (PG_{max}=25 mmHg). A transcatheter aortic valve replacement was performed. Two months ago, the patient developed palpitations, shortness of breath, and chest tightness, and the symptoms continued to worsen. Physical examination showed that the Blood Pressure (BP) was 130/75 mmHg and that the was New York Heart Association (NYHA) functional class III; a systolic murmur occurred in the area of the MV osculation. In addition, the N-terminal pro-B-type natriuretic peptide level reached 574.7 pg/mL. Computed Tomography Angiography (CTA) and TTE showed an MV of SVD (anterior leaflet prolapse with incomplete closure); TTE displayed V_{max}=270 cm/s, PG_{max}=29 mmHg, PG_{mean}=9mmHg, Ejection Fraction (EF) = 57%, and massive regurgitation above MV (volume=29 mL) (Figure 1).

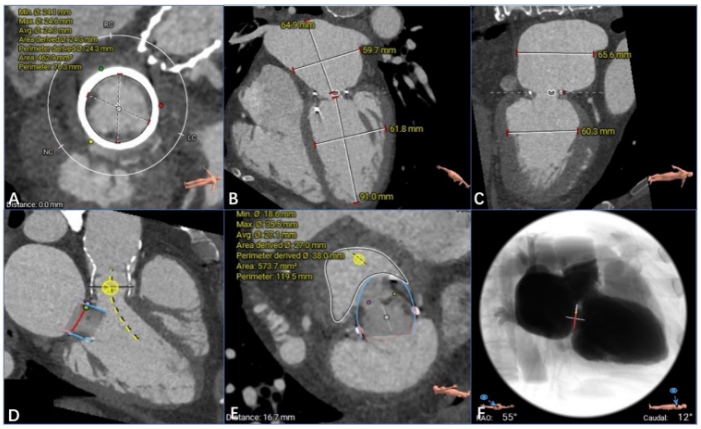

Figure 1: Assessment of computed tomography angiography before the procedure using Circle Cardiovascular Imaging CVI42 software (Calgary, AB, Canada). **(A)** The annular area of the prosthetic mitral valve was 462.9 mm^2. **(B)** The left ventricle was 91.0 mm in the long axis and 61.8 mm in the short axis, and the left atrium was 64.9 mm in the long axis and 59.7 mm in the short axis. **(C)** The left and right axes of the left ventricle and left atrium were 60.3 mm and 65.6 mm, respectively. **(D)** By simulating a 26-mm valve, the relationship between the stent and the neo-left ventricular outflow tract could be observed. **(E)** The area of the neo-left ventricular outflow tract was 573.7 mm^2 after simulating the process of implanting the valve. **(F)** The projection angle of the released valve implanted by trans-septal access is RAO55, CAU12.

3-Dimensional Printing and Preoperative Simulation

The Digital Imaging and Communication of Medicine format of the patient's CTA data was imported into Materialise Mimics version 21.0 (Leven, Belgium) software, and the 3D reconstructed MV model was segmented by the threshold segmentation function. Using Materialise 3-Matic (Leven, Belgium) software, the 3D reconstructed model was digitally processed, including shell extraction, cutting, smoothing, and repair, and the anatomical structures were completely restored (Figure 2A). Finally, the digital model was exported to Standard Tessellation Language format, and the files were imported into the Polyjet 850 multimaterial full-color 3D printer (Stratasys, Inc., Eden Prairie, MN, USA) for printing. The 3D printed MV model was obtained by editing and printing different tissues made from different materials (Figure 2B). When working with the 3D printed MV model, surgeons may intuitively and fully understand the specific anatomical structures of the MV and the adjacent tissues and use the model and the Prizvalve balloon-expandable valve (Newmed Medical Co., LTD.,

Shanghai, China) to simulate the transatrial septal approach when performing the bench test, which may show the influence of the bioprosthetic coaxiality on the different puncture locations on the atrial septum (Figure 2C-F). In addition, the process of releasing the balloon-expanded bioprothesis can be simulated to formulate the surgical strategy more accurately and effectively, so that the procedures may be carried out smoothly and successfully.

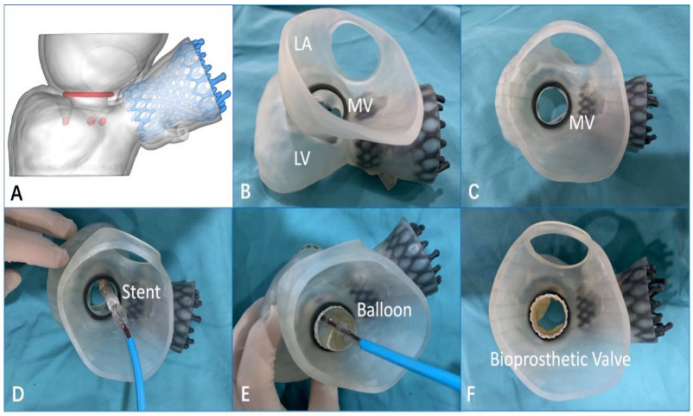

Figure 2: A 3-dimensional printed model was used to simulate the procedure during the bench test. **(A)** 3-Dimensional reconstructed model in the lateral view. **(B-C)** The 3-dimensional printed model in the lateral view and the left atrium view. **(D-E)** TMViVR procedures were simulated: the catheter went through the left atrium and released the balloon-expandable valve successfully. **(F)** Released valve from the plane of the left atrium. LA: left atrium; LV: left ventricle; MV: mitral valve.

Procedural Steps

The left femoral artery of the patient was taken as the puncture point, and 2 mL of 2% lidocaine was used for local anesthesia. After a successful puncture, a 6F arterial sheath was placed, and 3000 U of heparin was injected intravenously. Transesophageal echocardiography performed before the procedures showed severe paravalvular regurgitation in the MV (Figure 3A). Afterwards, a 6F sheath was placed through the right jugular vein to deliver the pacing lead into the right ventricle. The 6F femoral sheath was inserted into the right femoral vein, and the 9F Cook sheath was replaced. After successfully puncturing the atrial septum, a J wire was inserted into the left atrium, and the puncture site of the atrial septum was dilated with a balloon. The 8F adjustable bendable sheath was inserted into the left atrium to guide the MPA2 catheter, and the loach guide wire was guided to the left ventricle. A Lunderquist guide wire was placed into the left ventricle, and a 26F GORE sheath (W.L. Gore, Newark, DE, USA) was inserted into the femoral vein along the supporting guide wire. According to the preoperative imaging assessment and 3D printing model simulation results, a 26-mm Newmed interventional valve system (NewMed Medical Co., Ltd., Shanghai, China) was selected. Heparin 2000 U was added during the procedures, and the delivery system was sent to the MV along the Lunderquist guide wire (Figure 3B). When the stent coincided with the tangent position of the MV, the pacing was performed 180 times/min to release the stent and deploy the bioprosthesis (Figure 3C, D). After the implant was completed, a DSA scan showed the good position of the bioprosthesis (Figure 3E). Transesophageal echocardiography showed that the MV leaflet opened and closed normally, the blood flow rate was normal, and no PVLs were noted (Figure 3F). The whole procedure went smoothly, ending with 40 mL of intraoperative blood and 35 mL of contrast agent.

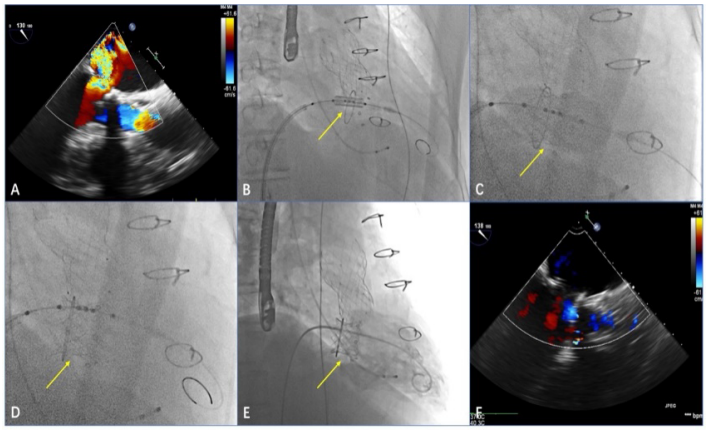

Figure 3: Transesophageal echocardiography and digital subtraction angiography images showed that the procedure achieved good results. **(A)** Preprocedural transesophageal echocardiography displayed a large amount of colorful blood flow at the mitral valve. **(B)** The delivery system was positioned in relation to the mitral valve (arrow shows the delivery system). **(C)** After adjusting the position and the coaxiality, the balloon-expandable valve was inflated (arrow indicates the balloon). **(D)** After expansion, the stent was fully unfolded (arrow indicates the stent). **(E)** When the guide wire was withdrawn, digital subtraction angiography showed that the position and shape of the mitral valve were ideal and that the stent fitted closely to the valve (arrow indicates the stent). **(F)** Postprocedural transesophageal echocardiography showed that the balloon-expandable valve was properly closed, with no paravalvular regurgitation.

Follow-Up

The patient was followed up on the 30th day after the procedures. The examination results showed that the heart rate was 55 beats/min, the BP was 128/72 mm Hg, and the NYHA functional class was I. CTA displayed a good stent position and a bioprosthesis that opened and closed normally. TTE showed normal subvalvular flow velocity with no PVLs and normal left ventricular systolic function with an EF of 55%.

Discussion

MV disease is a common heart valve disease, especially after the onset of symptoms combined with cardiac insufficiency. MVR or MV repair is the main treatment for MV disease [5]. At present, SVD is the main challenge after MVR. Once the patient has severe SVD, it may lead to severe mitral regurgitation or stenosis of the degenerated valve, which often requires reoperation of the MVR [6]. Although re-MVR is the gold standard for the treatment of SVD, at least half of the patients cannot tolerate the operation [7]. In 2009, Cheung et al. first reported a ViV intervention to treat the degenerated bioprothesis after MVR [8]. In 2014, Bapat and colleagues successfully completed 3 Fortis device implants (Edwards Lifesciences, Irvine, CA, USA) for the first time, with good hemodynamics after the implant procedure, an event that marked the arrival of the TMViVR era [9]. However, TMViVR is not suitable for all patients with SVD, and the procedure still presents significant technical challenges. In particular, TMViVR has a higher rate of PVLs than the re-MVR [10]. In addition, there is still more room for development in terms of dealing with long-term complications such as bioprosthetic persistence, thrombosis, and reduced cardiac function.

With the continuous development of cardiovascular 3D printing technology, surgeons can use 3D printed models to perform simulated evaluation before the procedures, which plays an important role in assisting and guiding the accurate formulation of a surgical plan and improving the success rate of the procedures [11]. Before performing the procedures, the CT data of the specific patient were evaluated in detail, and the 3D reconstruction and 3D model printing were performed using the CT data. Under the guidance of 3D printing, TMViVR was performed successfully. The shape and position of the bioprosthesis were ideal, and no perivalvular regurgitation occurred. During follow-up, the patient recovered well without complications. In addition, it is believed that with the progress of minimally invasive interventional technology for structural heart disease, more optimized surgical design is bound to emerge, which will result in more satisfactory treatment plans for the individual patients.

Conclusion

Overall, on the basis of accurate measurements by various medical imaging methods before the procedures are performed, the 3D printed model is used to simulate the preoperative conditions in order to formulate patient-specific surgical plans. For patients with high surgical risk, cardiovascular 3D printing technology may play an important guiding role in the perioperative period. With the continuous development of material science and imaging technology, 3D printing will be gradually mature to show the anatomical structures of individual lesions accurately and intuitively. Furthermore, the models can be used to simulate procedures during the bench test to improve the success rate and efficiency of the procedures performed in real time.

References

1. Barbera MD, Pettenazzo E, Livi U, Mangino D, Gerosa G, et al. (2023) Structural valve deterioration and mode of failure of stentless bioprosthetic valves. Cardiocasc Pathol 51:107301.
2. Mehaffey HJ, Hawkins RB, Schubert S, Fonner C, Yarboro LT, et al. (2018) Contemporary outcomes in reoperative mitral valve surgery. Heart 104: 652-656.
3. Harloff MT, Chowdhury M, Hirji SA, Percy ED,Yazdchi F, et al. (2021) A step-by-step guide to transseptal valve-in-valve transcatheter mitral valve replacement. Ann Cardiothorac Surg 10: 113-121.
4. Yoon SH, Bleiziffer S, Latib A, Eschenbach L, Ancona M, et al. (2019) Predictors of left ventricular outflow tract obstruction after transcatheter mitral valve replacement. JACC Cardiovasc Interv 12: 182-193.
5. Gara PT, Graybum PA, Badhwar V, Afonso LC, Carroll JD, et al. (2017) 2017 ACC expert consensus decision pathway on the management of mitral regurgitation: a report of the American College of Cardiology Task Force on expert consensus decision pathways. J Am Coll Cardiol 70: 2421-2449.
6. Goldstone AB, Chiu P, Baiocchi M, Lingala B, Patrick WL, et al. (2017) Mechanical or biologic prostheses for aortic-valve and mitral-valve replacement. N Engl J Med 377: 1847-1857.
7. Mehaffey HJ, Hawkins RB, Schubert S, Fonner C, Yarboro LT, et al. (2018) Contemporary outcomes in reoperative mitral valve surgery. Heart 104: 652-656.
8. Cheung A, Webb JG, Barbanti M, Freeman M, Binder RK, et al. (2013) 5-year experience with transcatheter transapical mitral valve in valve implantation for bioprosthetic valve dysfunction. J Am Coll Cardiol 61: 1759-1766.
9. Bapat V, Buellesfeld L, Peterson MD (2014) Transcatheter mitral valve implantation (TMVI) using the Edwards FORTIS device. Eurointervention 10: U120-U128.
10. Nalluri N, Atti V, Munia AB, Karam B, Patel NJ, et al. (2018) Valve in Valve Transcatheter Aortic Valve Implantation (ViV TAVI) Versus Redo-Surgical Aortic Valve Replacement (redo SAVR): a systematic review and meta-analysis. J Interv Cardiol 31: 661-671.
11. Mao Y, Liu Y, Ma YY, Jin P, Li L, et al. (2022) Mitral valve-in-valve implant of a balloon-expandable valve guided by 3-dimensional printing. Front Cardiovasc Med 9: 894160.