

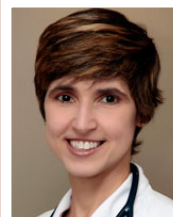
My Approach to Transseptal Mitral Valve-In-Valve

Como eu Faço Valve-in-Valve Mitral Via Transeptal

¹Dante Pazzanese Cardiology Institute; ²Institute of Cardiology and Transplantation of the Federal District; ³Fleury Group; ⁴Samaritano Hospital; ⁵Vila Nova Star; ⁶DF Star.



Andrea de Andrade Vilela^{1,3}



Maria Estefânia Bosco Otto^{2,6}



Antonio Tito Paladino Filho^{1,5}



Vanessa Andreoli Esmanhoto^{1,4}

Introduction

The percutaneous treatment of heart valve disease is a subject of great interest in cardiology. Percutaneous aortic valve implantation, first performed in 2002 by Alan Cribier,¹ paved the way for transcatheter treatment of the mitral valve.

The first valve-in-valve (VIV) procedures were performed to treat deteriorated bioprosthetic valves in the aortic position.^{2,3} In 2009, the group led by Dr. John Webb published the first successful case of mitral VIV.⁴ Since then, mitral VIV has been performed in numerous centers worldwide.

Mitral valve disease has a significant prevalence worldwide,⁵ particularly in Brazil. Its most frequent cause is rheumatic fever,⁶ implying more severe valve diseases at a younger age that require early and repeated surgical procedures.⁷ Knowing that bioprosthetic valve replacement is associated with high morbidity and mortality, VIV plays an extremely important role in avoiding or at least delaying surgery while improving patient quality of life.⁵

Keywords

Deart por Heart; Transthoracic Echocardiography; Treatment.

Mailing Address:

E-mail: andreadeandradevilela@gmail.com

Manuscript received 3/16/2022; revised 3/17/2022; accepted 3/31/2022.

DOI: 10.47593/2675-312X/20223502ecom24

Cardiovascular imaging multimodality is essential for transcatheter mitral valve interventions.⁸ Here we will describe the role of echocardiography and computed tomography (CT) angiography in the different stages of evaluating mitral VIV.

Preprocedural assessment

Mitral VIV is a complex procedure that should only be performed after a careful heart team assessment to obtain better results.

The indication for mitral VIV depends on a series of data necessary to ensure its feasibility. Knowing the type and size of the implanted prosthesis is very useful for assessing the true internal diameter of the prosthesis and choosing the ideal endoprosthesis.⁹ In the absence of information about surgical prosthesis type, fluoroscopy can provide important data for analyses of bioprosthetic valves.¹⁰

Role of echocardiography

Complete transthoracic echocardiography (TTE) followed by preprocedural transesophageal echocardiography (TEE) is essential, and the analysis main points include:

- Identify bioprosthesis failure mechanism and its quantification, including dysfunction type, degree, and, if possible, quantification;
- Rule out factors that contraindicate mitral VIV (Table 1)¹¹;

My Approach To

- Asses anatomical factors that predict left ventricular outflow tract (LVOT) obstruction (Table 2);
- Describe the characteristics of the interatrial septum, including the fact that the presence of extensive calcification, surgical patches, thrombus, aneurysm, and exuberant lipomatous infiltration may hinder or prevent transseptal puncture;
- Analyse the hemodynamic repercussion of prosthetic dysfunction by assessing biventricular function and estimating pulmonary hypertension in which pulmonary dysfunction and hypertension worsen the outcome after surgical and/or percutaneous mitral valve treatment.^{12,13}

Role of CT angiography

CT angiography is extremely important for analyzing the residual LVOT area after percutaneous prosthesis implantation

(Figure 1) and the internal diameter of the annulus (Figure 2), which determines the implanted prosthesis size.^{14,16}

The neo-LVOT area is calculated using an appropriate software that considers the LVOT measurement, the height of the percutaneous prosthesis, and the mitral-aortic angle, with the tolerated area to enable a VIV > 170 mm².¹⁶

As for the internal diameter of the prosthesis, the correct measurement is closely associated with the type of prosthesis implanted. In prostheses with internally sutured leaflets, the true diameter (true ID) of the annulus is 1 mm smaller than the measured value; prostheses with externally sutured leaflets have an internal diameter equal to that evaluated by CT angiography.^{10,14}

Another relevant use of CT angiography is analyzing the coronary arteries, aorta, and lungs, adjuvant factors in the short- and long-term success of mitral VIV.¹⁶

Table 1 – Mitral valve-in-valve contraindications.

Absolute contraindication	Relative contraindication
Infectious endocarditis	Narrow left ventricular outflow tract
Prosthesis dehiscence	Paraprosthesis regurgitation
Extensive prosthesis thrombosis	Thrombus in the atrial cavity
Atrial septum thrombus	Major prosthesis-patient mismatch
Inferior vena cava interruption	Surgical repair of previous atrial septum
	Previous transseptal mitral valve repair

Source: Harloff et al.¹¹

Table 2 – Anatomical factors predicting LVOT obstruction.

Echocardiography	Computed tomography
Basal septal hypertrophy	Estimated neo-outflow tract < 1.7 cm ²
Small LV (<48 mm)	Less obtuse mitral-aortic angle (<115°)
Reduced distance from the IV septum to the mitral annulus (unfavorable if <17.8 mm)	

IV, interventricular; LV, left ventricle; LVOT, left ventricular outflow tract.

Source: Pirelli et al.¹⁴ e Yoon et al.¹⁵

Intraprocedural assessment

Mitral VIV should be performed in a hybrid operating room with the patient under general anesthesia (Figure 3). TEE plays a fundamental role in all the steps of the procedure as follows:

Initial assessment

TEE must be used to confirm the findings described in the preprocedural “Role of Echocardiography” assessment and rule out contraindications (Table 1).

Transseptal puncture orientation

This is a critical moment. The ideal for an appropriate puncture is the posteroinferior region of the lamina of the fossa ovalis. The use of 3D-TEE resources such as multi-D or X-plane are extremely important, as they provide optimal spatial orientation to the interventional physician, avoiding accidentally perforation of the aorta or heart cavity (Figure 4).¹⁴



RLVO, residual left ventricular outflow. Source: Internal archives from cardiac tomography and magnetic resonance of Dante Pazzanese Cardiology Institute.

Figure 1 – Computed tomography image of estimated left ventricular outflow tract area with the implanted prosthesis chosen for the patient.

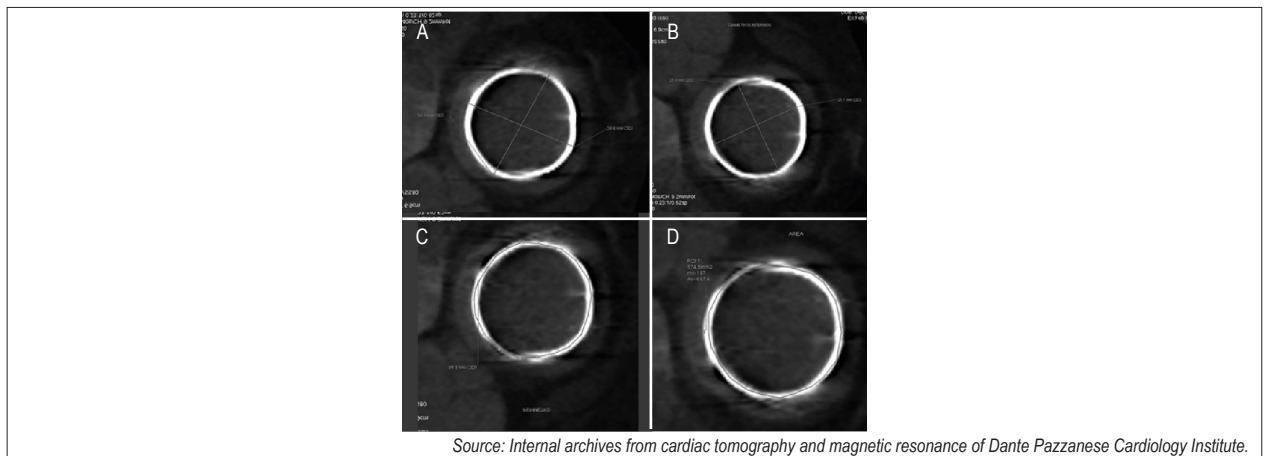


Figure 2 – Tomography. (A) Measurement of the prosthesis' annulus. (B) Measurement of the prosthesis' internal diameter. (C) Measurement of the prosthesis' perimeter. (D) Measurement of the prosthesis' area.

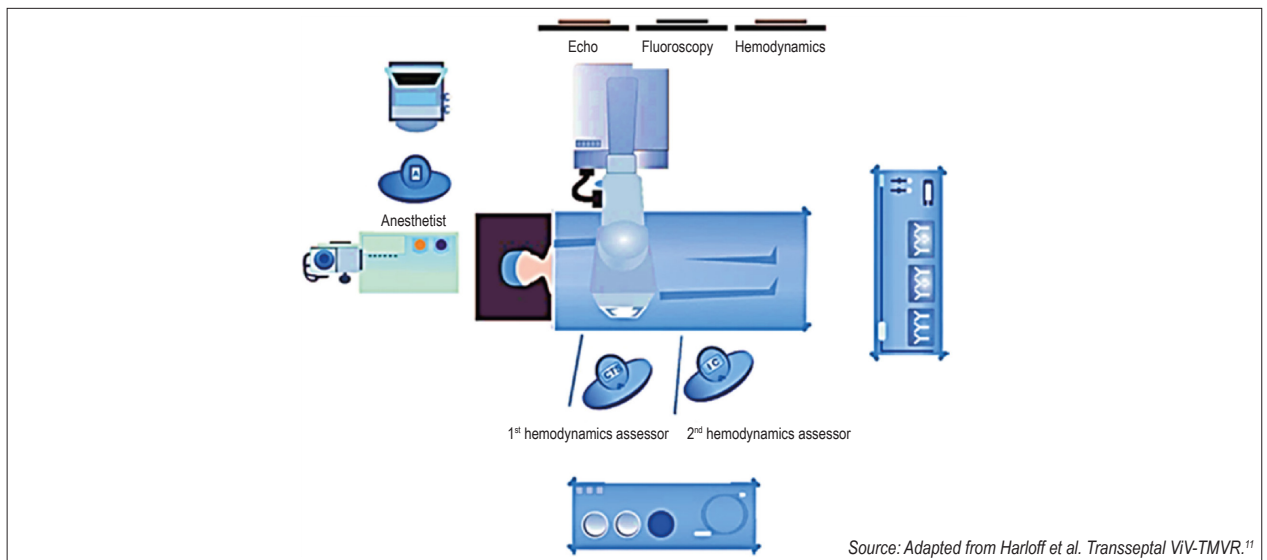


Figure 3 – hybrid operating room.

Device position

The sequence of device positioning and release is detailed in Figure 5. The height of the percutaneous prosthesis implant is calculated by neo-LVOT on CT angiography.^{14,16} The largest area usually occurs with 20% of the prosthesis in the atrial position and 80% in the ventricular position^{14,16}; and postprocedural assessment must be performed systematically to ensure the absence of complications and to confirm the proper functioning of the new prosthesis.¹⁶

- Mitral endoprosthesis assessments are performed using 2D echocardiography (ECHO), 3D ECHO, and color flow mapping. The objective is to analyze whether the endoprosthesis is adequately expanded (circular shape, mobility, and adequate opening of leaflets) and identify the flow pattern (laminar or turbulent) in addition to the presence of central and/or paraprosthetic regurgitation and

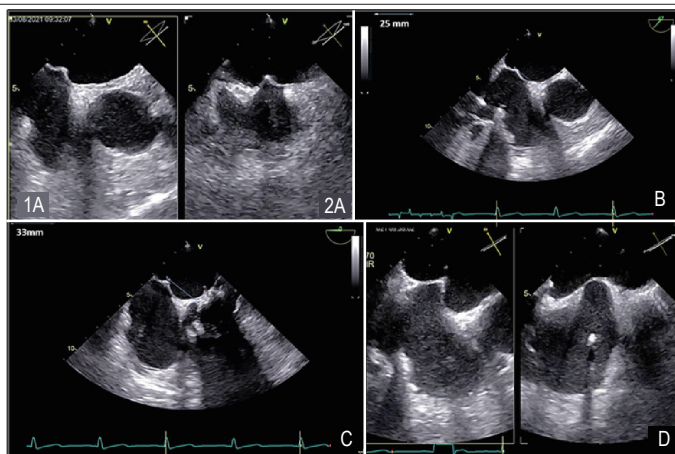
its quantification. The maximum and mean gradients of the endoprosthesis are recorded using continuous Doppler, while its area is defined using the continuity equation or 3D planimetry (figures 5 and 6 and video 1).

- LVOT assessment by color flow mapping and pulsed Doppler to detect high gradients. The technique of choice is deep transgastric view TEE at 0° or 5°, or even TTE (if flow alignment by TEE is inadequate). LVOT obstruction should be suspected in cases of hemodynamic deterioration immediately after endoprosthesis release and in the presence of turbulent outflow. These cases present an increase of ≥ 10 mmHg in mean LVOT gradient compared to the preprocedural assessment.¹⁷

- Ruling out the onset of pericardial effusion or changed left ventricular segmental contraction.

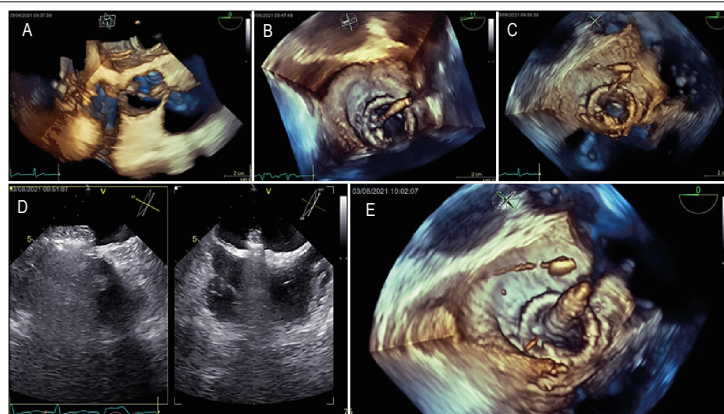
- Assessment of the atrial septum orifice status after puncture to determine its dimensions (orthogonal diameters and area,

My Approach To



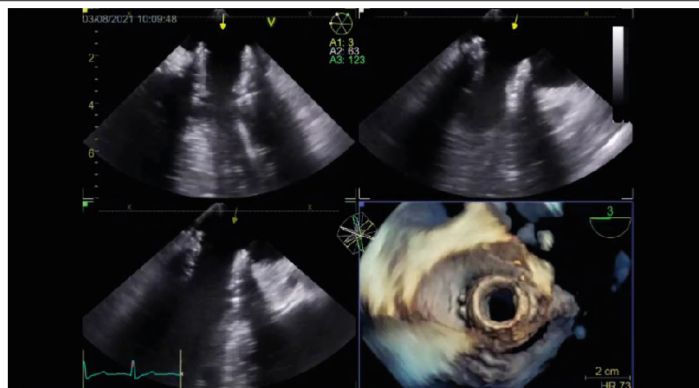
Source: Internal archive from Echocardiography division of Dante Pazzanese Institute of Cardiology.

Figure 4 – Proper transseptal puncture sequence. Orthogonal multi-D three-dimensional transesophageal echocardiography images of the interatrial septum, its anterior (1A) and posterior (1B) portions with the image of a “tent” formed by the puncture needle. (B) The distance from the aortic puncture site should be assessed at 45°. (C) The puncture site must be a maximum of 35 mm away from the mitral annulus plane (performed at 0°). (D) Atrial septal transfixation by the puncture needle.



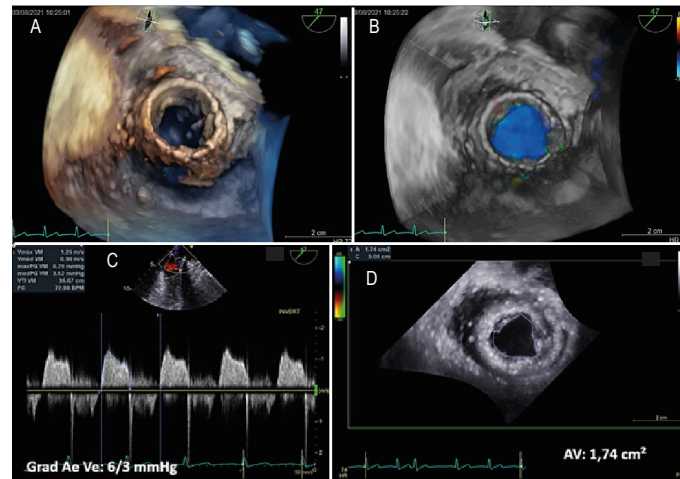
Source: Internal archive from Echocardiography division of Dante Pazzanese Institute of Cardiology.

Figure 5 – Intraprocedural device positioning. (A) Passage of the catheter through the atrial septum. (B) Progression of the guide wire to the mitral prosthesis, passing into the left ventricle. (C) A rigid wire is passed to support release of the endoprosthesis. (D) At this time, the septal puncture orifice is usually dilated (to allow passage of the device delivery equipment). (E) Device position is evaluated (as central as possible to the bioprosthetic valve). Some degree of eccentricity is normally corrected with balloon inflation, which tends to naturally reposition the device in the center of the dysfunctional prosthesis.



Source: Internal archive from Echocardiography division of Dante Pazzanese Institute of Cardiology.

Video 1 – Endoprosthesis evaluation immediately after liberation.



Source: Internal archive from Echocardiography division of Dante Pazzanese Institute of Cardiology.

Figure 6 – Assessment after endoprosthesis release. (A) Three-dimensional echocardiogram (3D-ECHO) showing the endoprosthesis annulus inside the prosthetic annulus in diastole. (B) 3D-ECHO showing laminar flow delimiting the effective endoprosthesis orifice. (C) Left atrium-left ventricle gradient by continuous Doppler. (D) 3D planimetry used to estimate the endoprosthesis area.

preferably by 3D ECHO) and the shunt direction through the orifice.

- Assessment of right ventricular function and tricuspid regurgitation and estimation of pulmonary artery systolic pressure.

Postprocedural assessment

Numbers of published cases and follow-up times remain small and limited. Simonato et al.¹⁸ compiled a range of relevant information through a multicenter VIV and valve-in-ring registry (surgical ring endoprosthesis) in 90 different centers with 1,079 patients analyzed from 2006 to 2020, which can help the proper determination of long-term follow-up.¹⁸ The results of this study are of great interest in the field of interventional cardiology and will be briefly summarized in this document. The long-term follow-up currently used at the Dante Pazzanese Cardiology Institute (*Instituto Dante Pazzanese de Cardiologia* - IDPC) is described in Table 3.

Key VIV registry findings:¹⁸

- Prosthesis stenosis was the most frequent failure in procedure success, occurring in 8.2% of VIV cases.
- The mean gradient of the analyzed prostheses was 5.7 mmHg; 61% of the patients had mean gradients above 5 mmHg, mainly when smaller devices were used or in patients with a larger body surface area. Considering that the Mitral Valve Academic Research Consortium (mitral-VARC)¹⁶ definition of stenosis is a mean gradient above 5 mmHg.
- The implications of these findings relate to suboptimal hemodynamic performance in mitral VIV prostheses, with a higher frequency of prosthesis-patient mismatch reported in 24.5% of cases and possible shorter durability.

Table 3 – Suggested IDPC valve-in-valve follow-up.

Follow-up steps
1. Register prosthesis type and size in the first follow-up report.
2. Pre-discharge: TTE with anatomical description, mean and maximum gradients, and effective orifice area.
3. Repeat follow-up at 3, 6, and 12 months with TTE and TEE.
4. What to evaluate on TTE: anatomy, maximum and mean gradients, and area by continuity equation.
5. What to evaluate on TEE: anatomy and presence of thrombi on the ventricular or atrial face of the valve, size and flow pattern in the ASD (normal being left to right).
6. Warning signs:
↑ Mean gradient > 5 mmHg
↓ Effective orifice comparison
↑ PASP
ASD shunt changed direction (right to left)

ASD, atrial septal defect; IDPC, Instituto Dante Pazzanese de Cardiologia; PASP, pulmonary artery systolic pressure; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography. Source: Follow up protocol described for randomized mitral VIV study on going SurVIV (NCT04402931).

Acknowledgment

Dr. Ibrahim Masciarelli for cardiac tomography images and Dr. Dmitry Alexandre Alvim de Siqueira for performing the VIV procedures

Authors' contribution

Writing, preparing figures and videos and revisions:
Vilela AA, Otto MEB, Paladino AT, Esmanhoto VA

Conflict of interest

The authors have declared that they have no conflict of interest.

References

1. Cribier A, Eltchaninoff H, Bash A, Borenstein N, Tron C, Bauer F, et al. Percutaneous Transcatheter Implantation of an Aortic Valve Prosthesis for Calcific Aortic Stenosis. *Circulation*. 2002;106(24):3006-8. doi: <https://doi.org/10.1161/01.cir.0000047200.36165.b8>.
2. Cribier A. The development of transcatheter aortic valve replacement (TAVR). *Global Cardiology Science and Practice*. 2017;2016(4). doi: <https://doi.org/10.21542/gcsp.2016.32>
3. Barbanti M, Webb J, Gilard M, Capodanno D, Tamburino C. Transcatheter aortic valve implantation in 2017: state of the art. *EuroIntervention*. 2017;13(AA):AA11-21. 10.4244/EIJ-D-17-00567
4. Cheung A, Webb JG, Wong DR, Ye J, Masson JB, Carere RG, et al. Transapical transcatheter mitral valve-in-valve implantation in a human. *The Annals of Thoracic Surgery*. 2009;87(3):e18-20. doi: <https://doi.org/10.1016/j.athoracsurg.2008.10.016>
5. Otto CM, Nishimura RA, Bonow RO, Carabello BA, Erwin JP 3rd, Gentile F, et al. 2020 ACC/AHA Guideline for the Management of Patients With Valvular Heart Disease: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. *Circulation*. 2021;143(5):e72-e227. doi: <https://doi.org/10.1161/CIR.0000000000000923>. Erratum in: *Circulation*. 2021;143(5):e229
6. Tarasoutchi F, Montera MW, Ramos AI, Sampaio RO, Rosa VE, Accorsi TA, et al. Update of the Brazilian Guidelines for Valvular Heart Disease - 2020. *Arq Bras Cardiol*. 2020;115(4):720-775. doi: <https://doi.org/10.36660/abc.20201047>
7. Chan V, Malas T, Lapierre H, Boodhwani M, Lam BK, Rubens FD, et al. Reoperation of left heart valve bioprostheses according to age at implantation. *Circulation*. 2011;124(11_suppl_1). doi: <https://doi.org/10.1161/CIRCULATIONAHA.110.011973>
8. Blanke P, Naoum C, Webb J, Dvir D, Hahn RT, Grayburn P, et al. Multimodality Imaging in the Context of Transcatheter Mitral Valve Replacement. *JACC: Cardiovascular Imaging*. 2015;8(10):1191-208. doi: <https://doi.org/10.1016/j.jcmg.2015.08.004>.
9. Bapat VN, Attia R, Thomas M. Effect of valve design on the stent internal diameter of a bioprosthetic valve: a concept of true internal diameter and its implications for the valve-in-valve procedure. *JACC Cardiovasc Interv*. 2014;7(2):115-127. doi: <https://doi.org/10.1016/j.jcin.2013.10.012>.
10. Bapat V, Mydin I, Chadalavada S, Tehrani H, Attia R, Thomas M. A guide to fluoroscopic identification and design of bioprosthetic valves: A reference for valve-in-valve procedure. *Catheterization and Cardiovascular Interventions*. 2013;81(5):853-61. doi: <https://doi.org/10.1002/ccd.24419>.
11. Harloff MT, Chowdhury M, Hirji SA, Percy ED, Yazdchi F, Shim H, et al. A step-by-step guide to transseptal valve-in-valve transcatheter mitral valve replacement. *Ann Cardiothorac Surg*. 2021;10(1):113-121. doi: <https://doi.org/10.21037/acs-2020-mv-104>
12. Sengupta A, Yazdchi F, Alexis SL, Percy E, Premkumar A, Hirji S, et al. Reoperative mitral surgery versus transcatheter mitral valve replacement: a systematic review. *J Am Heart Assoc*. 2021;10(6):e019854. doi: <https://doi.org/10.1161/JAHA.120.019854>
13. Yucel E, Al-Bawardy R, Bertrand PB. Pulmonary Hypertension in Patients Eligible for Transcatheter Mitral Valve Repair: Prognostic Impact and Clinical Implications. *Curr Treat Options Cardiovasc Med*. 2019;21(10):60. doi: <https://doi.org/10.1007/s11936-019-0768-6>
14. Pirelli L, Hong E, Steffen R, Vahl TP, Kodali SK, Bapat V. Mitral valve-in-valve and valve-in-ring: tips, tricks, and outcomes. *Ann Cardiothorac Surg*. 2021;10(1):96-112. doi: <https://doi.org/10.21037/acs-2019-mv-169>.
15. Yoon SH, Bleiziffer S, Latib A, Eschenbach L, Ancona M, Vincent F, et al. Predictors of Left Ventricular Outflow Tract Obstruction After Transcatheter Mitral Valve Replacement. *JACC Cardiovasc Interv*. 2019;12(2):182-193. doi: <https://doi.org/10.1016/j.jcin.2018.12.001>
16. Little SH, Bapat V, Blanke P, Guerrero M, Rajagopal V, Siegel R. Imaging Guidance for Transcatheter Mitral Valve Intervention on Prosthetic Valves, Rings, and Annular Calcification. *JACC Cardiovasc Imaging*. 2021;14(1):22-40. doi: <https://doi.org/10.1016/j.jcmg.2019.10.027>.
17. Stone GW, Adams DH, Abraham WT, Kappetein AP, Généreux P, Vranckx P, et al.; Mitral Valve Academic Research Consortium (MVARC). Clinical Trial Design Principles and Endpoint Definitions for Transcatheter Mitral Valve Repair and Replacement: Part 2: Endpoint Definitions: A Consensus Document From the Mitral Valve Academic Research Consortium. *J Am Coll Cardiol*. 2015;66(3):308-321. doi: <https://doi.org/10.1016/j.jacc.2015.05.049>
18. Simonato M, Whisenant B, Ribeiro HB, Webb JG, Kornowski R, Guerrero M, et al. Transcatheter Mitral Valve Replacement After Surgical Repair or Replacement: Comprehensive Midterm Evaluation of Valve-in-Valve and Valve-in-Ring Implantation From the VIVID Registry. *Circulation*. 2021;143(2):104-116. doi: <https://doi.org/10.1161/CIRCULATIONAHA.120.049088>