

Evaluation of Paravalvular Leaks using Three-dimensional Transesophageal Echocardiography with Color Doppler

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Abstract

Background: Paravalvular leaks are a common complication after valve replacement surgery. Quantification of the severity, location and morphology of paravalvular leaks can be obtained by three-dimensional transesophageal echocardiography.

Objective: To evaluate the correlation between the severity of paravalvular regurgitation by vena contracta measurement using bidimensional echocardiography, and measurements derived from three-dimensional transesophageal echocardiography (length, width and area). To evaluate the therapeutic success of three-dimensional transesophageal echocardiography-guided paravalvular leaks occlusion and the correlation between three-dimensional transesophageal echocardiography measurements and dimensions of devices for percutaneous occlusion.

Method: Retrospective study of 11 patients consecutively submitted to percutaneous paravalvular leaks treatment between 2014 and 2015, using transthoracic echocardiography and between three-dimensional transesophageal echocardiography in the preoperative and intraoperative periods.

Results: Out of a total of 20 paravalvular leaks, 18 showed immediate technical success. There was no correlation between the measurements of the bidimensional vena contracta and the measures derived from the three-dimensional transesophageal echocardiography. There was a strong correlation between the defect length measured by the three-dimensional transesophageal echocardiography and the device for percutaneous occlusion length ($\rho = 0.929$; $p < 0.001$); and moderate between the defect area and the device for percutaneous occlusion area ($\rho = 0.682$, $p = 0.002$). There was no correlation between the device for percutaneous occlusion width and the defect width measured by three-dimensional transesophageal echocardiography ($\rho = 0.440$; $p = 0.067$).

Conclusion: There was no correlation between the measurement of the bidimensional vena contracta and the measures derived from the three-dimensional transesophageal echocardiography. The choice of devices for percutaneous occlusion based on three-dimensional transesophageal echocardiography measurements showed a high success rate, with an excellent correlation between defect length and devices for percutaneous occlusion length. The correlation between the areas was good, and there was no correlation between the widths. (Arq Bras Cardiol: Imagem cardiovasc. 2018;31(4):225-230)

Keywords: Heart Valves/surgery, Heart Valve Prosthesis; Prosthesis Failure; Echocardiography, Doppler, Color.

Introduction

Paravalvular leak (PVL) are common complications after valve replacement surgery. An incidence of 2 to 10% is estimated for prostheses in aortic position and 7 to 17% for mitral position.^{1,2} Most patients are asymptomatic, but about 1 to 5% of patients with PVL present clinical deterioration, symptoms of heart failure and hemolysis.³⁻⁵

Percutaneous closure of PVL is an important therapeutic strategy, especially in patients who are not candidates for surgical treatment.⁶ Three-dimensional transesophageal echocardiography (3DTEE) has been considered the best imaging test for the quantification of the severity, location and morphology of paravalvular regurgitation, allowing to choose Percutaneous Occlusion Device (POD) and interventionist support during the procedure.^{7,8} The use of colored flow mapping associated with three-dimensional scans was shown to be better than the images without color flow mapping in the selection of POD size and quantification of reflux degree.⁸

This study evaluated the correlation between the severity of paravalvular regurgitation evaluated by the two-dimensional measurement of vena contracta and the measurements derived from 3DTEE (length, width and area). Besides, it also attempted to evidence the correlation between 3DTEE measurements and POD measurements, and to determine the immediate technical success rate.

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Method

The study was a retrospective evaluation of 11 patients (20 PVL) consecutively undergoing percutaneous PVL therapy in a single tertiary cardiac center between 2014 and 2015. All patients were evaluated using 3DTEE both preoperatively and intraoperatively. The 3DTEE measurements (length, width and area of defects) were obtained using the software Echopac (GE Healthcare), version 112, and Qlab (Philips Medical Systems). Orthogonal three-plane reconstructions were made: two planes aligned parallel to the regurgitant jet and one transverse to its origin, on a plane corresponding to the effective leak orifice (plane of interest for the measurements). The PVL areas were estimated by the ellipse formula, according to their length and diameter, obtained using 3DTEE. The two-dimensional vena contracta was obtained by transesophageal echocardiography, in four-chamber (approximately zero degree) or three-chamber (approximately 130°) sections. If both measurements were taken, the arithmetic mean was used to calculate the final value.

Technical success was defined as the correct release of the occlusion device through the paravalvular leak, without significant residual regurgitation (grades III or IV) or a new valve prosthesis dysfunction.

All paravalvular leaks were occluded using the device Amplatzer™ Vascular Plug III (St. Jude Medical; Figure 1).

This study has been approved by the Research Ethics Committee of the institution.

Statistical analysis

The continuous variables were expressed as mean and standard deviation or median and interquartile range. The categorical variables were expressed in absolute numbers or percentages.

For the correlations between continuous variables, Spearman's correlation coefficient was used, considering a statistical significance of $p < 0.05$. To interpret the magnitude of the correlations, the following classification of correlation

coefficients (ρ) was adopted: 0.0 to 0.3 if negligible correlation; 0.3 to 0.5 if weak correlation; 0.5 to 0.7 if moderate correlation; 0.7 to 0.9 if strong correlation; 0.9 to 1.0 if very strong correlation.⁹

Results

The 11 individuals included in this study underwent percutaneous intervention of the paravalvular leaks in the late postoperative period of valve replacement surgery. Two patients had had three valve replacement surgeries, including one mitral commissurotomy and two subsequent valve replacements. Another patient had Ross surgery and surgical repair of aortic paravalvular leak. The other patients underwent only one valve replacement surgery.

Most of the valvular prostheses studied were located in the mitral position (7; 64%), of which three (43%) were reached by transapical surgical access and four (57%) by percutaneous access. All of the prostheses in the aortic position (4; 36%) were reached by percutaneous access (Figure 2).

The characteristics of the study population are found in Table 1.

The 11 individuals had 20 PVL. By analyzing those with prosthesis in mitral position ($n=8$), there were 14 PVLs: six located at the interatrial septum (43%), five adjacent to the lateral left atrial wall (36%), two posterior (14%) and one anterior (7%). As for the individuals with prosthesis in aortic position ($n = 4$), there were six PVLs equally distributed along the right (2), non-coronary (2) and left coronary (2) valves. All defects presented elliptical shape.

It was technically difficult to conduct the percutaneous treatment of two PVLs, both related to prostheses in the mitral position and located near the interatrial septum. In one case, the PVL was not closed due to its tortuous horizontalized path, relative to the plane of the valve prosthesis. Another PVL was closed with a small device due to mechanical interference with the valve prosthesis discs when attempting to implant a larger plug or two plugs. This case progressed to a moderate degree of leak.



Figure 1 – Amplatzer™ Vascular Plug III device (St. Jude Medical).

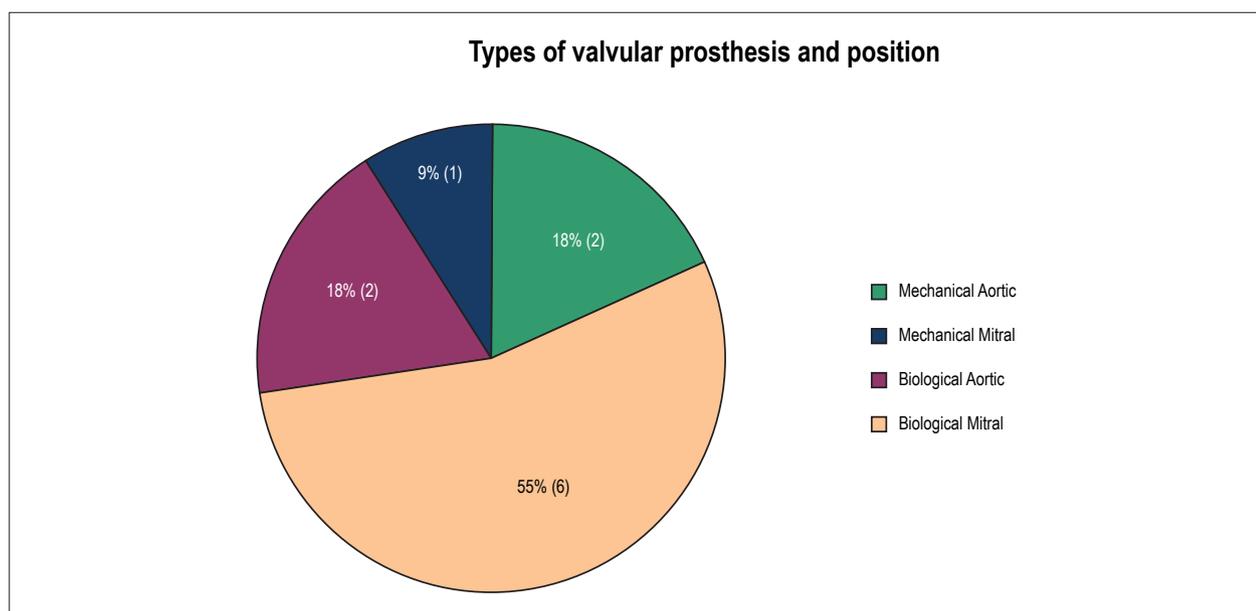


Figure 2 – Types of valve prosthesis and implant position.

Table 1 – Clinical characteristics of the population studied

Population characteristics	Data
Individuals, n	11
Leaks, n	20
POD, mean per patient	23 (2.3)
Age, mean ± SD	54.18 ± 14.39
Male (%)	54.50
STS* mortality, median (IR), %	1.76 (1.33 - 3.33)
STS morbidity and mortality, median (IR), %	19.43 (14.27 - 30.40)
Euroscore II, median (IR), %	3.00 (1.50 - 3.99)
Functional Class NYHA III-IV, %	36.35
Hemolysis, %	63.60
Leak degree (III-IV), %	90.90

POD: Percutaneous occlusion device; SD: standard deviation; IR: Interquartile range; STS: Society of Thoracic Surgeons Score; NYHA: New York Heart Association.

There was no correlation between the two-dimensional vena contracta measurements and the 3DTEE measurements (length, width and area of the defects): $\rho = 0.241$ ($p = 0.305$); $\rho = 0.129$ ($p = 0.589$); $\rho = 0.182$ ($p = 0.443$), respectively. Removing the two PVLs with technical difficulties, the other 18 PVLs showed immediate technical success. For these 18 cases, there was a very strong correlation between the defect length using 3DTEE and the POD length ($\rho = 0.929$, $p < 0.001$), and a moderate correlation between the defect area and the POD area ($\rho = 0.682$; $p = 0.002$). There was no correlation between the POD width and the defect width as measured by 3DTEE ($\rho = 0.44$; $p = 0.067$).

Figures 3 and 4 show an example of the location and scaling of two PVLs using 3DTEE and echocardiographic appearance, after releasing the devices.

Discussion

PVLs can lead to heart failure and hemolysis. In cases of refractoriness to clinical treatment and high surgical risk, percutaneous closure is a therapeutic strategy aimed at reducing the leak and avoiding the deterioration of ventricular function.¹⁰

For the evaluation of PVL, transesophageal echocardiography is very important to avoid acoustic shadow artifacts, particularly for prostheses in mitral position. Three-dimensional technology more accurately reveals the location, size, and severity of PVL.¹⁰ In this series, the measures obtained by 3DTEE guided the interventionists' choice of the size of the PVL closure devices and, consequently, determined the treatment success.

The techniques based on the PVL anatomical planimetry measure the anechoic areas corresponding to the echo dropout without the aid of color flow mapping. However, they present limitations related to gain, compression and resolution of the images, besides being more technically laborious. The concomitant evaluation of three-dimensional images with color flow mapping has shown to be a more accurate and feasible technique in the evaluation of PVLs, determining the effective leak orifice.⁸

To date, there are no PODs specifically designed and approved for percutaneous closure of PVL. In this study, the Amplatzer™ Vascular Plug III was used. It has an oval shape, with good adaptation to the PVL, as these defects usually present a growing shape. The choice of the device should be based on the morphology of PVL, always looking for dimensions that are a little larger than the anatomical defects, without mechanical interference with the valvular prostheses.

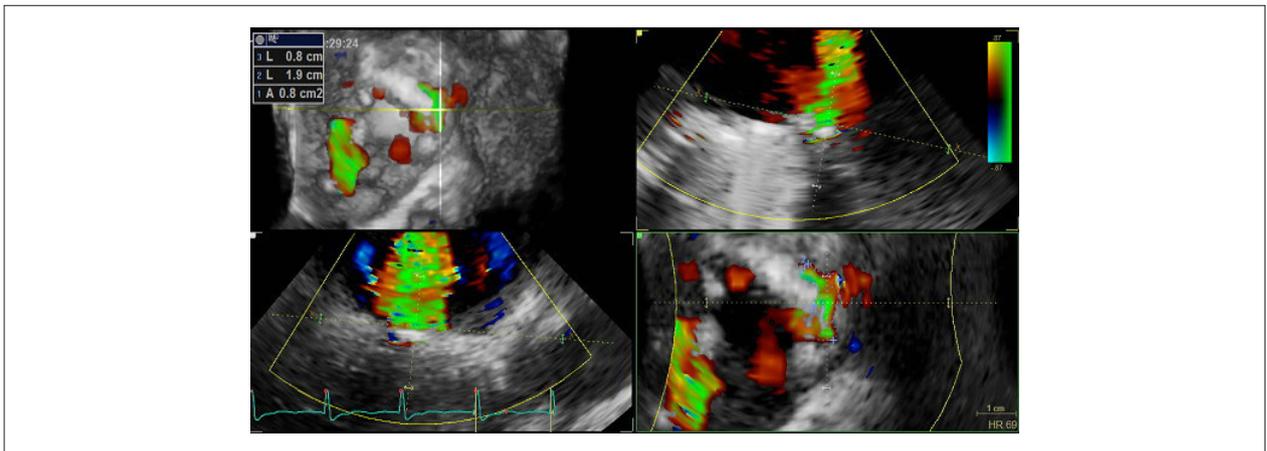


Figure 3 – Three-dimensional transesophageal echocardiography demonstrating orthogonal three-plane reconstructions: two planes aligned parallel to the regurgitant jet and one transverse to its origin on a plane corresponding to the effective leak orifice to measure the diameters and the area. In this case, two paravalvular leaks and the planimetry of one of them are observed.

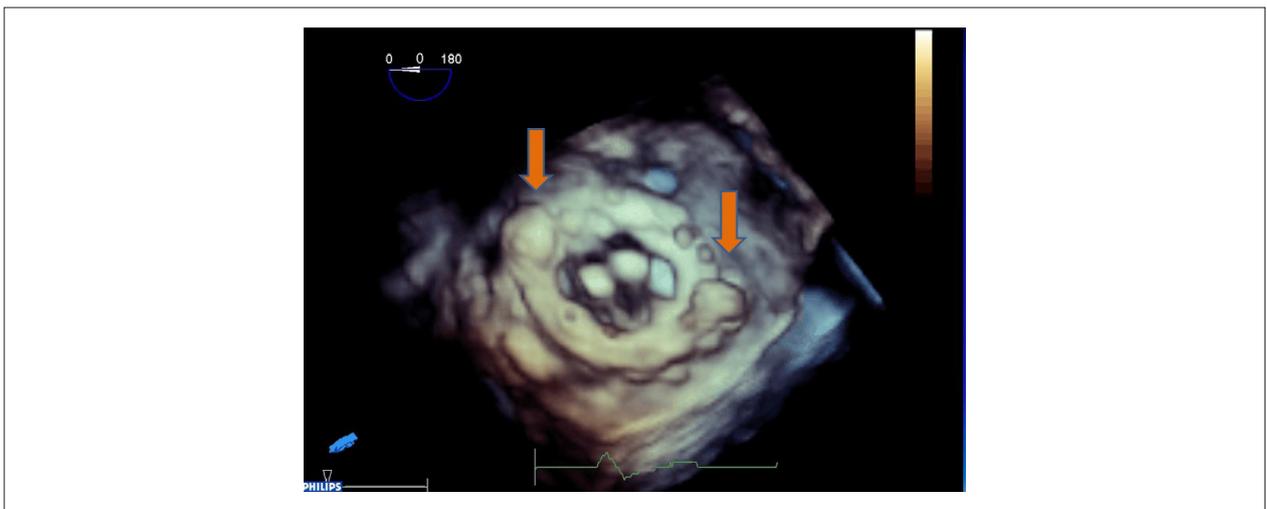


Figure 4 – Echocardiographic aspect of mechanical prosthesis in the mitral position after the release of two devices for percutaneous occlusion (see arrows; it is the same patient as in Figure 3). There was no significant paravalvular leak after the procedure.

When using round devices, a plausible strategy is the use of multiple smaller devices.¹⁰

Sorajja et al.¹¹ published the largest cohort of percutaneous treatment performed at the Mayo Clinic. Out of 126 patients undergoing the procedure, immediate technical success was achieved in 75%, 15.9% required subsequent surgical correction, and 30-day mortality was 2.4%.¹¹ Some authors recommend, according to the experience of each institution, to adopt percutaneous treatment as the first therapeutic strategy in most cases, before surgery.¹²

Franco et al.⁸ demonstrated that, in the choice of PODs, the undersizing of their lengths was associated with failure at percutaneous closure.⁸ Similarly, in our study, the best correlations were found between the defect length using 3DTEE and the POD length.

In this study, we considered to be of critical importance to confirm the statistics of correlation between the POD dimensions and the anatomical defects measured by 3DTEE. We believe that this strong correlation was predictable, since the interventionist usually considers, in order to choose the number and size of PODs, the information given by the echocardiographer. However, we consider that it is important to prove the mathematics of this correlation and, mainly, to prove that such strategy, based on 3DTEE, was associated to high success rates in the interventions.

Another important point of this study was the demonstration that the two-dimensional vena contracta measurements are not associated with the 3DTEE measurements. This probably occurred because of the growing shape of these defects. Probably, the two-dimensional measurement reflects more the smaller defect diameters, rather than its largest diameter.

Finally, our data suggest that, among the information provided by the 3DTEE, the length and area of the defect should be especially valued, since these measurements were the ones that were best associated with the POD size in this success case series. Our study corroborated the idea that it is necessary to respect the measurements obtained by echocardiography, which probably justified the high rate of immediate technical success also in this case series.

Study limitations

This observational study retrospectively evaluated a small number of patients in a single tertiary center. There was no long-term clinical follow-up, therefore, it is not possible to estimate long-term success.

Conclusions

The choice of percutaneous occlusion devices based on the measurements of three-dimensional transesophageal echocardiography showed an immediately high success rate, with an excellent correlation between the length of the defects and the length of the devices. The correlation between the areas was good and there was no correlation between the widths.

The vena contracta measurement obtained by two-dimensional echocardiography did not correlate with the

defect measurements using three-dimensional transesophageal echocardiography.

Authors' contributions

Research creation and design: Giffoni RT, Le Bihan DCS, Barretto RBM, Siqueira D, Arrais M, Assef JE, Pedra CAC, Abizaid A; Data acquisition: Giffoni RT, Nishida G, GBG Silva, Le Bihan DCS, Barretto RBM, Siqueira D, Arrais M, Pedra CAC, Abizaid A; Data analysis and interpretation: Giffoni RT, Le Bihan DCS, Barretto RBM; Statistical analysis: Giffoni RT, Le Bihan DCS; Manuscript writing: Giffoni RT, Le Bihan DCS, Barretto RBM; Critical revision of the manuscript as for important intellectual content: Giffoni RT, Le Bihan DCS, Barretto RBM.

Potential Conflicts of Interest

There are no relevant conflicts of interest.

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Academic Association

This study is not associated with any graduate programs.

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