BRIEF REPORT

Intraoperative Monitoring With Transesophageal Real-Time Three-Dimensional Echocardiography During Transapical Prosthetic Aortic Valve Implantation

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Degenerative aortic stenosis is the most common valvulopathy in Europe. In symptomatic patients, aortic valve replacement with a prosthesis substantially improves prognosis. However, a high percentage of candidates for valve replacement surgery are rejected because of the high risk of serious complications. In recent years, percutaneous and minimally invasive surgical techniques have been developed for the transcatheter implantation of prosthetic aortic valves. These developments could lead to an increase in the number of interventions carried out in high-risk patients as the positive effect of treatment on prognosis would be retained while the complication rate would be reduced. We describe the use of transesophageal echocardiography (TEE) for intraoperative monitoring in 21 patients who underwent transcatheter aortic valve replacement using a transapical approach, and report morphologic findings, hemodynamic results, and complications observed. We propose a standard approach to imaging, in which real-time three-dimensional TEE is used to provide additional information during intraoperative monitoring of transapical transcatheter aortic valve replacement.

Key words: *Prosthetic valve. Echocardiography. Surgery.*

Supervisión con ecocardiografía 3D en tiempo real intraoperatoria de la implantación de prótesis valvular aórtica por vía transapical

La estenosis aórtica degenerativa es la valvulopatía más frecuente en Europa. En pacientes sintomáticos, la sustitución valvular aórtica por una prótesis mejora su pronóstico. Un elevado porcentaje de candidatos a cirugía de reemplazo valvular son desestimados por elevado riesgo de complicaciones graves. En los últimos años, se han desarrollado técnicas percutáneas o quirúrgicas mínimamente invasivas de implantación de prótesis valvular aórtica transcatéter (PATC), que persiguen elevar la tasa de intervención en pacientes de alto riesgo manteniendo los beneficios en el pronóstico y disminuyendo las complicaciones.

Describimos el protocolo de supervisión intraoperatoria con ecocardiografía transesofágica (ETE), hallazgos morfológicos, resultados hemodinámicos y complicaciones detectadas en 21 pacientes sometidos a la implantación de PATC por abordaje transapical. Proponemos una estandarización de la exploración, en la que la ETE tridimensional en tiempo real aportaría información adicional en la supervisión intraoperatoria de implantación por vía transapical de la PATC.

Palabras clave: *Prosthetic valve. Echocardiography. Surgery.*

INTRODUCTION

Degenerative aortic stenosis is the most common valvulopathy in Europe.[1,2] In symptomatic patients with severe aortic stenosis, substitution of the affected valve for a biological or metallic prosthesis significantly improves survival.[3] However, advanced age, coronary artery disease, and chronic kidney failure (among other conditions) significantly increase the risk of death during surgery,[4] limiting aortic valve surgery using the sternal approach and extracorporeal circulation. Balloon valvuloplasty is inefficient and does not change the natural course of the disease in adults.[5] In 2002, Cribier was the first to successfully achieve the transcatheter implantation of an aortic valve for the treatment of severe aortic stenosis.[6] Transcatheter aortic valve implantation

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Received August 28, 2008.
Accepted for publication June 18, 2009.

(TAVI), performed in a minimally invasive fashion either percutaneously or transapically, is a feasible therapeutic option. Irrespective of the approach chosen, the supervision of the procedure using transesophageal echocardiography would appear to be essential. Such monitoring provides important information to both interventional cardiologist and surgeon when selecting the size of the prosthetic valve to be used, as well as in its positioning, and can also positively influence the final results achieved.[1,6-8] The literature contains no reports on the possible additional supervisory advantages that might be afforded by real time three dimensional transesophageal echocardiography (3D-TEE), nor on the optimization of the protocol to be followed in the operating room.

METHODS

This study describes our initial experience in the intraoperative echocardiographic supervision of high surgical risk patients diagnosed with severe aortic stenosis. All patients were referred to our hospital for inclusion in the transcatheter aortic valve implantation (TAVI) program depending on the criterion of their attending physician. Valvulopathy was diagnosed by a conclusive hemodynamic study prior to intervention using 2-dimensional transthoracic echocardiography and either color Doppler or cardiac catheterization. All patients underwent coronary angiography in order to rule out severe atherosclerotic lesions and to determine the distance between the aortic ring and the coronary ostium. Three dimensional transesophageal echocardiography was performed using an iE33 apparatus and a transesophageal probe model X7-2t Live 3D with a matrix array containing 2500 elements (Philips Electronics, Eindhoven, The Netherlands). This model allows 2-dimensional conventional multiplane transesophageal, color Doppler and spectral Doppler explorations to be made. Its matrix architecture, which involves a panel of crystals, also allows one to obtain and process three dimensional images in real time (Live 3D®) (Figure 1), and in 2 orthogonal planes at 90º simultaneously (the Live xPlane® process or simply X-Plane) (Figure 2). Full volume acquisition was considered inappropriate given the need for post-processing, which is impossible in an intraoperative setting since immediate access to information is required.

The TAVI procedure using the transapical approach was described by Lichtenstein et al.[7] Echocardiographic supervision consisted of marking the position of the apex of the left ventricle (LV) in the thorax using the apical transthoracic 4 and 2 chambers view. During left minithoracotomy at the

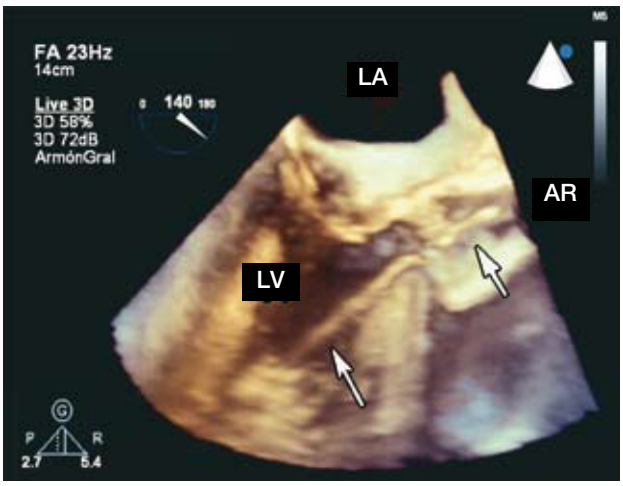

Figure 1. Three dimensional image (Live 3D® processing) of the left ventricular outflow tract, the valve and aortic root, during the positioning of an transcatheter aortic valve prosthesis (arrows). AR indicates aortic root; LA, left atrium; LV, left ventricle.

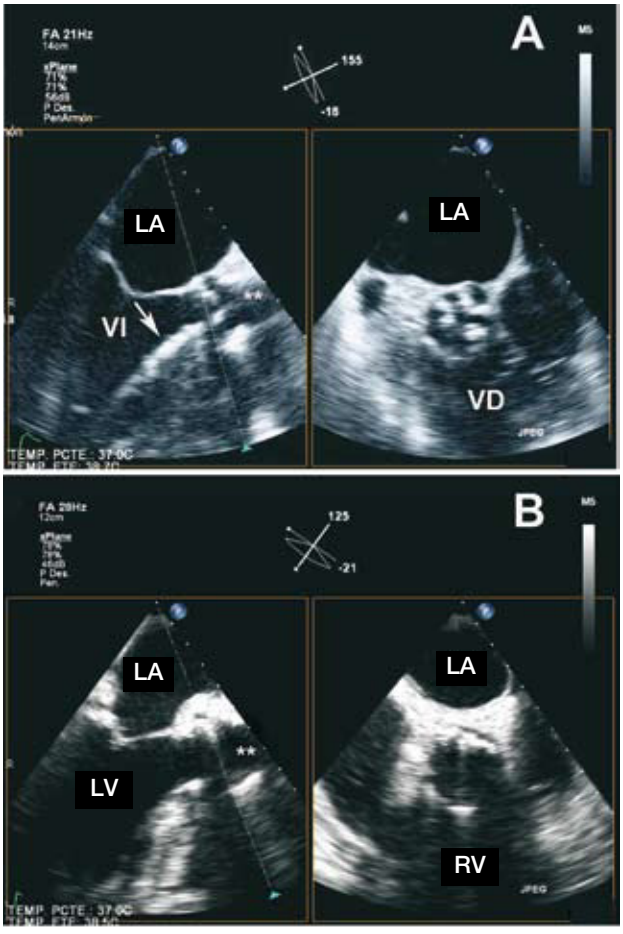

Figure 2. Three dimensional image obtained during the implantation of a transcatheter aortic valve prosthesis (X-Plane® processing); simultaneous visualization at 135° (left) and 45° (right). A: supervision of positioning of the valvuloplasty balloon (arrow) and of the prosthetic valve; B: final result of implantation. LA indicates left atrium; LV, left ventricle; RV, right ventricle. **: aortic root.

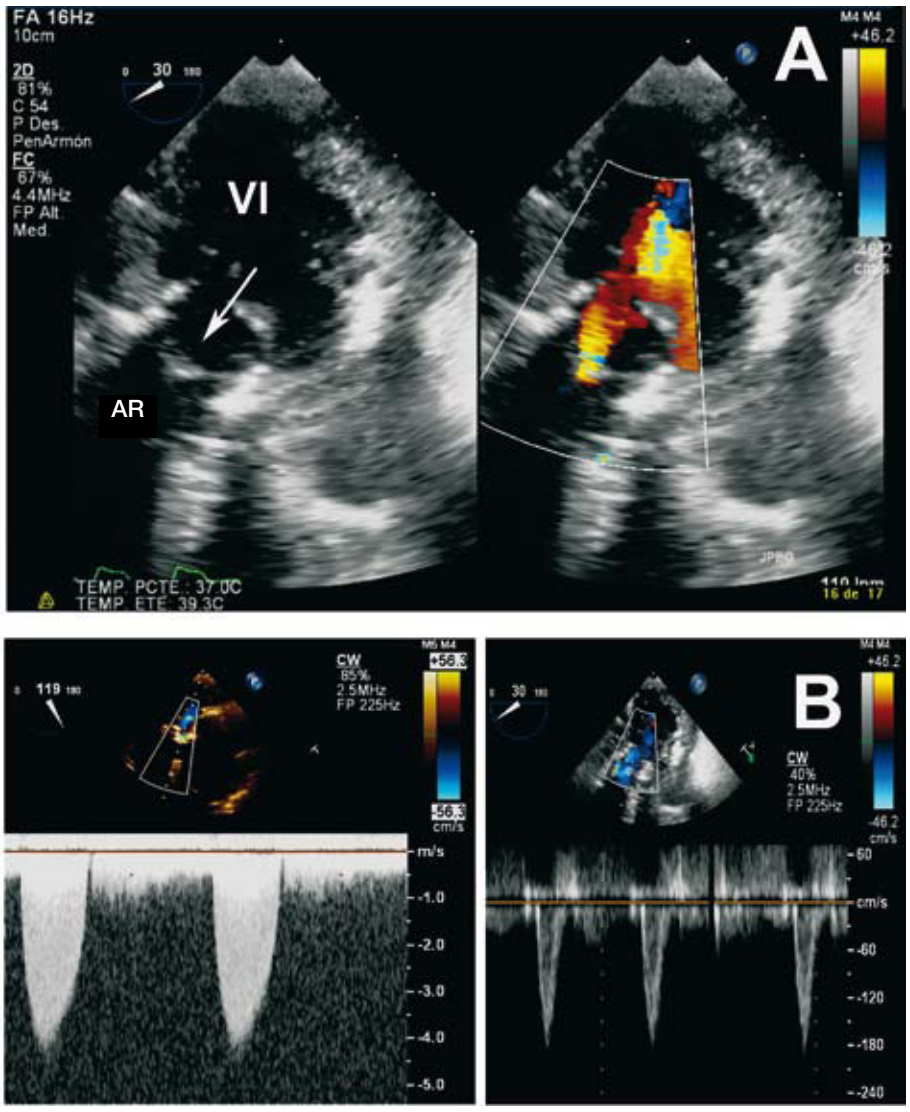

Figure 3. Aortic valve hemodynamic assessment before and after transthoracic implantation of the aortic valve prosthesis. A: two dimensional deep transgastric transesophageal view (left) and color Doppler (right); the prosthesis is well positioned, the leaflets show coaptation, and there is mild central regurgitation. B: spectral Doppler data obtained continuously during intraoperative transesophageal echocardiography before (left) and after (right) transthoracic implantation of the aortic valve prosthesis; note the normalization of the transvalvular flow velocity. AR indicates aortic root; LV, left ventricle.

indicated point and the exteriorization and punction of the LV, 3D-TEE was used to provide data on the hemodynamics of the aortic valve (maximum aortic transvalvular velocity and effective aortic valve area, monitoring the presence and degree of aortic regurgitation) and mitral valve (monitoring presence and degree of aortic regurgitation). In order to choose the size of the prosthesis (Edwards Sapien® 23 or 26 mm transcatheter valve, using the Ascendra® implantation system [Edwards Lifesciences, Horw, Switzerland]) 3D-TEE X-Plane images of the left ventricular outflow tract diameter (LVOTD), the aortic ring, the aortic valve, and the aortic root were examined. The diameter of the aortic ring was taken from the insertion of the non-coronary leaflet to the insertion of the right coronary leaflet with a 135º viewing angle. The 2 orthogonal diameters of the aortic root at the level of the sinus of Valsalva (45º) were also measured in a plane immediately above the outflow of the coronary arteries. Other data of interest gathered included the preferential location of calcification (leaflets and commisures), and the relationship between the coronary ostia and the degree of septal hypertrophy, both of which appear to increase the risk of later complications.[8]

To supervise the undertaking of the aortic valvuloplasty and TAVI, real time 3D-TEE X-Plane and color Doppler (in 2 orthogonal planes at 135° and 45°) images were used (Figure 2A and B). During the anterograde insertion and positioning of the guidewire, the catheter and the 24 French introducer, checks were made for catheter or sheath entrapments and for damage to the mitral valve apparatus and intraventricular septum. The correct positioning of the valvuloplasty balloon and the prosthesis at the aortic ring was ensured. Before inflating, and using 3D-TEE X-Plane and color Doppler images, it was ensured that there was no aortic transvalvular flow during the brief interruption of the circulation controlled by rapid ventricular

stimulation via the electrostimulation catheter. After inflating and expanding the prosthesis, its optimum circular expansion was qualitatively checked, along with the eccentric positing of the native leaflets, and the correct movement of the aortic leaflets. Careful checks were made to rule out periprosthetic and transprosthetic regurgitation, as well as aortic wall damage or occlusion of the coronary ostium. The introducer and guidewire were then withdrawn for final assessment using 2D X-Plane and color Doppler images, along with conventional 2D images and spectral Doppler data (deep transgastric view) (Figure 3A and B).

RESULTS

Between June 2008 and March 2009, 21 patients underwent TAVI. The median age of these patients was 81 [74-84] years; 11 (52%) patients were men. The median logistic EuroSCORE value was 11 (range, 6-15). Four patients had a logistic EuroSCORE of ≤5; TAVI was deemed particularly indicated in these patients, among whom 1 had a porcelain aorta, 1 had a metallic mitral prostheses, 1 had end-stage kidney disease, and 2 had chronic obstructive pulmonary disease. In 6 patients (29%) the transapical approach was followed owing to severe aortoiliac involvement. In all cases intraoperative 3D-TEE X-Plane, color Doppler and real time sectorial 3D imaging was performed without problems, providing adequate visualization during the implantation and expansion of the prosthesis. Table shows the main echocardiographic findings. In all patients a significant reduction was seen in the maximum aortic transvalvular velocity and mean aortic pressure gradient, resulting in an increase in the effective aortic valve area.

No fatal intraoperative complications were encountered. 3D-TEE detected 4 complications. In 2 patients this involved rocking of the prosthesis and in 1 patient anterograde displacement, with migration to the LVOTD and a rotation of 90°. The appearance of severe aortic regurgitation in 2 of these 3 patients required the use of a conventional biological prosthesis. Finally, in 1 patient with marked septal hypertrophy (20 mm), 3D-TEE detected a small erosion and lifting of the endocardium due to trauma caused by the 24 French introducer; no alteration of the flow was seen after repositioning the introducer.

TABLE . **Morphofunctional Echocardiographic Characteristics of the Present Patients**

	Before Implantation	After Implantation
EDDLV, mm	46 [43-49]	–
LVEF, %	55 [48-60]	–
LVOTD, mm	19 [18-22]	–
Wall thickness, mm	15 [13-18]	–
Mitral regurgitation > grade 2	2 (10)	1 (10)
V_{max} m/s	4.3 [4-4.6]	2.1 [1.7-2.5]
Maximum transaortic pressure gradient, mm Hg	76 [67-85]	17 [12-25]
Mean transaortic pressure gradient, mm Hg	49 [41-53]	9 [5-13]
TVI Ao/TVI LVOTD	0.16 [0.14-0.19]	0.45 [0.31-0.49]
EAVA, cm^2	0.5 [0.4-1]	1.5 [0.95-2]
Calcification[a]		
Left coronary leaflet	12 (60)	–
Right coronary leaflet	10 (50)	–
Non-coronary leaflet	18 (90)	–
Commisure		
Posterior right	16 (80)	–
Posterior left	15 (75)	–
Anterior	16 (80)	–
Aortic regurgitation >grade 2	–	2 (10)
Central	–	0
Periprosthetic	–	2 (10)

EAVA indicates effective aortic valve area (continuity equation); EDDLV, end-diastolic diameter of the left ventricle (long parasternal axis); LVEF, left ventricular ejection fraction; LVOTD, left ventricular outflow tract diameter, intraoperative transesophageal view at 135° guided by X-Plane; TVI, time velocity integral; V_{max}, maximum aortic transvalvular velocity.
[a]Data for 20 patients. Continuous variables are expressed as medians [interquartile ranges] and discrete variables are expressed as n (%).

DISCUSSION

The present results highlight the importance of intraoperative TEE in the monitoring of TAVI when using the transapical approach. Since the introduction of TEE in the operating room its effectiveness as a monitoring system during hemodynamic management and the assessment of myocardial and valve function in patients with cardiovascular disease has become well established. Indeed, it has had an undeniable impact on surgery and the results achieved.[9] Vahanian et al[1] indicate the usefulness of TEE during the transcatheter implantation of prostheses, as a means of guaranteeing correct positioning and diagnosing complications. The greatest experience in TAVI has been gained employing the retrograde iliac route; the transapical route has been used much less often. Precise measurements made using TEE is vital in the selection of the size of the prosthesis, only then can the migration of the latter be avoided, optimum hemodynamics be guaranteed, and perivalvular regurgitations minimized. The use of this system also ensures the correct positioning of the prosthesis, helps avoid complications, and, following implantation, allows the checking of adequate functioning via the determination of the transprosthetic pressure gradient the valve area, and absence of regurgitation.

Assessment using a 3D probe in real time, employing the X-Plane process, allows for better viewing of the prosthesis in 2 orthogonal planes simultaneously (longitudinal axis at 135° and short axis at 45° to the aortic valve); this is of great importance in the delicate positioning of the advancing device system during the implantation of the prosthesis at the aortic ring.

This paper describes a small, single center study; the findings, although promising, are therefore preliminary and the same clinical results cannot be guaranteed everywhere. However, they would appear to show that intraoperative TEE, when used as part of an optimum protocol, can provide 3D images in real time of great use in the monitoring of TAVI in patients with severe aortic stenosis.

REFERENCES

1. Vahanian A, Alfieri O, Al-Attar N, Antunes M, Bax J. Transcatheter valve implantation for patients with aortic stenosis: a position statement from the European Association of Cardio-Thoracic Surgery (EACTS) and the European Society of Cardiology (ESC), in collaboration with the European Association of Percutaneous Cardiovascular Interventions (EAPCI). Eur Heart J. 2008;29:1463-70.
2. Lung B, Baron G, Butchart E, Delahaye F. A prospective survey of patients with valvular heart disease in Europe: The Euro Heart Survey on Valvular Heart Disease. Eur Heart J. 2003;24:1231-43.
3. Schwarz F, Baumann P, Manthey J, Hoffman M, Schuler G, Mehmel HC, et al. The effect of aortic valve replacement on survival. Circulation. 1982;66:1105-10.
4. Bloomstein LZ, Gielchinsky I, Bernstein AD, Parsonnet V, Saunders C, Karanam R, et al. Aortic valve replacement in geriatric patients: determinants of in-hospital mortality. Ann Thorac Surg. 2001;71:597-600.
5. Vahanian A, Palacios IF. Percutaneous approaches to valvular disease. Circulation. 2004;109:1572-9.
6. Cribier A, Eltchaninoff H, Tron C, Bauer F, Agatiello C, Sebagh L, et al. Early experience with percutaneous transcatheter implantation of heart valve prosthesis for the treatment of end-stage inoperable patients with calcific aortic stenosis. J Am Coll Cardiol. 2004;43:698-703.
7. Lichtenstein S, Cheung A, Ye J, Thompson C, Carere R, Pasupati S, et al. Transapical transcatheter aortic valve implantation in humans: Initial clinical experience. Circulation. 2006;114:590-6.
8. Hanzel GS, O'Neill WW. Complications of percutaneous aortic valve replacement: experience with the Cribier-Edward percutaneous heart valve. Eurointervention. 2006; Suppl 1:A3-8 [cited August 21, 2008]. Available from: http://www.europcronline.com/eurointervention/A_issue/A3/
9. Shapira Y, Vaturi M, Weisenberg DE, Raanani E, Sahar G, Snir E, et al. Impact of intraoperative transesophageal echocardiography in patients undergoing valve replacement. Ann Thorac Surg. 2004;78:579-83.