IMAGING DURING TRANSCATHETER INTERVENTIONS FOR VALVULAR HEART DISEASE

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Disclosure: No potential conflict of interest.
Received: 17.04.14 **Accepted:** 19.06.14
Citation: EMJ Cardiol. 2014;2:54-60.

ABSTRACT

Valvular heart disease is a growing field, and the number of new approaches for percutaneous treatment is increasing rapidly. These procedures usually cannot be performed with fluoroscopy alone; allowing echocardiography to be an essential role inside the Cath Lab. Three-dimensional echocardiography, and the introduction of a novel imaging modality that integrates live echocardiography and live fluoroscopy imaging, has potential in facilitating procedure guidance and increasing procedure efficiency.

Keywords: Valvular heart disease, transcatheter aortic valve implantation (TAVI), percutaneous mitral valve repair, paravalvular leakage, 3D echocardiography, EchoNavigator.

INTRODUCTION

The prevalence of valvular heart disease (VHD) is increasing with the ageing of the population. Transcatheter interventions have merged as an option for patients who, due to comorbidities or high surgical risk, would have otherwise suffered untreatable conditions. Nowadays we can perform heart valve interventions such as transcatheter aortic valve implantation (TAVI), percutaneous mitral valve (MV) repair, or percutaneous closure of paravalvular leakages (PVL). Catheter-based approaches for patients with regurgitant as well as stenotic valvular disease have shown excellent procedural success and clinical outcomes.[1-4]

Echocardiography plays an important role not only in identifying patients suitable for these interventions, but in providing intra-procedural monitoring. This is necessary because for VHD interventions continuous soft tissue imaging is required, which cannot be achieved with fluoroscopy alone. Moreover, echocardiography is a non-radiation, non-contrast, and real-time technique. These features have turned echocardiography into an essential tool inside the Cath Lab.

Transoesophageal echocardiography (TEE) provides more detailed images of anatomy and lesions than transthoracic echocardiography (TTE) and does not interfere with the procedure´s sterile field; therefore, it is the most commonly used technique. The use of only two-dimensional (2D) TEE is limited in that it only provides two spatial dimensions having to mentally reconstruct the anatomical setting and is limited in knowing the relation of the lesion to be treated, catheters, and wires with its surrounding structures. Nowadays, 3D echocardiography (3DE) complements 2D echocardiography (2DE).[5-7] With 3DE, an anatomical structure can be seen from different perspectives in real-time, providing a better understanding of morphology and spatial relation of intracardiac structures.[8,9]

During VHD interventions, fluoroscopy for catheter and device visualisation and echocardiography for anatomy and soft tissue imaging are most frequently used. Recently, a new navigation system (EchoNavigator, Philips Healthcare, Best, the Netherlands) has been introduced which synchronises echocardiography and fluoroscopy in real-time. The system places the two imaging modalities in the same co-ordinate system and is based on the localisation and tracking of the TEE probe. After synchronisation of TEE and fluoroscopy images, the system automatically tracks and follows the movements of the c-arm gantry.

When the c-arm is moved, echocardiography images will be updated and reconstructed with the same orientation as the c-arm.

It allows the visualisation on one screen of an X-ray view and up to three echocardiography views simultaneously and in real-time: an echocardiography image in the same orientation as the c-arm gantry, the standard TEE echocardiography view as on the echocardiographer's screen, and a free image that can be rotated or cropped. The system also allows the placing of markers in real-time on specific points of interest on echocardiography images; these markers will be automatically displayed on the fluoroscopy image in real-time and can be used for guidance during the procedure.[10,11]

In this review we will describe the role of imaging during transcatheter interventions on VHD in the Cath Lab, focusing on 3DE and the new navigation system that integrates live 3D and live fluoroscopy images.

TAVI

The treatment of patients with aortic stenosis has been transformed after the introduction of TAVI, since it has shown to be an effective treatment for patients with severe aortic stenosis deemed high-risk for conventional surgery.[1] Detailed knowledge about the anatomy of the aortic root and its surrounding is crucial for a safe and precise procedure. Accurate pre-procedural aortic annular dimension measurements are important for the selection of an appropriate valve prosthesis size. Although 2DE seems to underestimate the size of the ellipsoid-shaped annulus,[12] 3D TEE has shown to be accurate in sizing the annulus, presenting the true annulus, and enabling assessment of its circularity and the measurement of its diameters.[13,14]

TEE imaging is useful for procedural guidance. During balloon valvuloplasty, TEE can guide positioning of the balloon relative to the aortic valve and confirm stable position during inflation, since the balloon may migrate during inflation, particularly in patients with significant septal hypertrophy. The behaviour of the calcified aortic cusps that are pushed into the sinuses and towards the coronary ostia during inflation may also be monitored using TEE. Visualisation of the guidewire into the left ventricle (LV) and around the MV subvalvular apparatus is facilitated with 3DE, reducing the likelihood of valvular disruption and regurgitation.

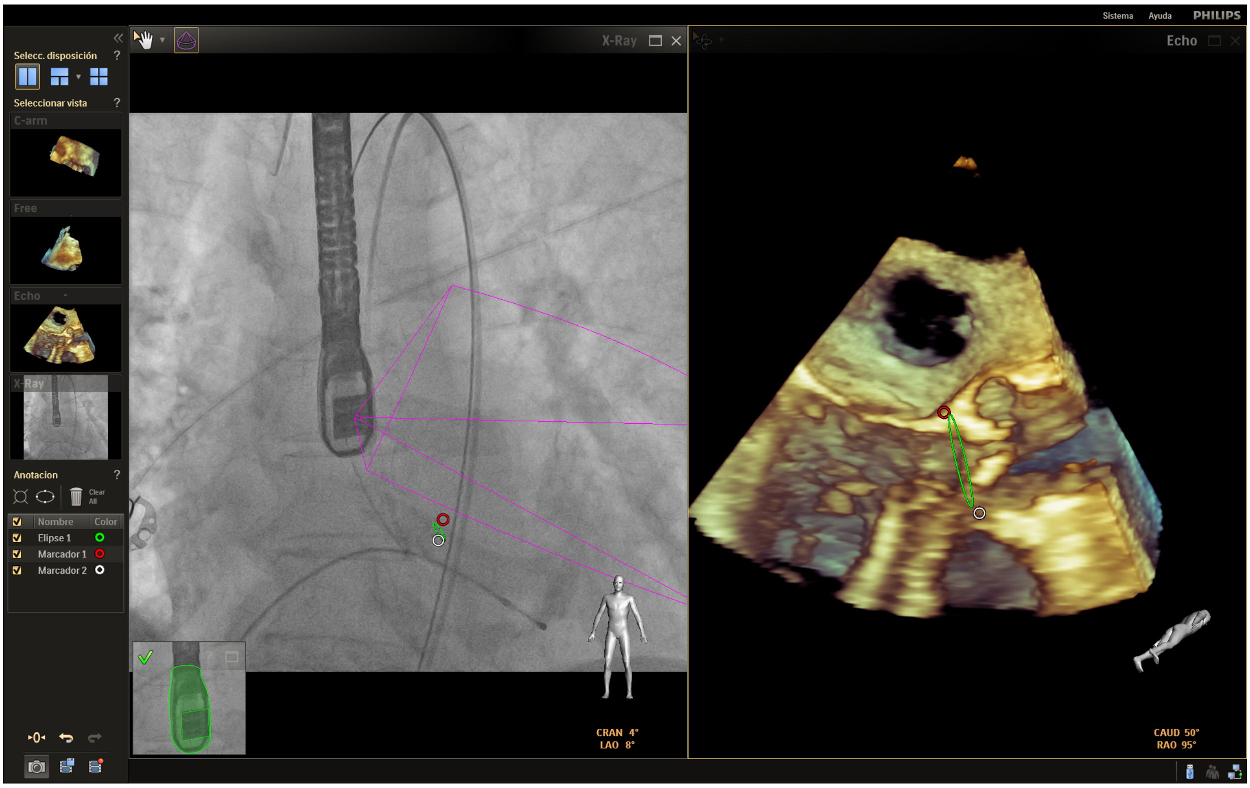

Figure 1: Transcatheter aortic valve implantation.
The level of the aortic annulus has been marked using EchoNavigator for procedure guidance.

During deployment of the prosthesis, TEE is very helpful in confirming the correct position of the valve and is usually used in conjunction with fluoroscopy for this purpose. Especially in patients with less calcified valves, where visualising the aortic annulus in fluoroscopy may be more challenging, the EchoNavigator system seems especially useful as the level of the annulus can be marked in an echocardiography image. These markers will be automatically transposed and set in the fluoroscopy image, allowing the use of this reference for catheter guidance and evaluation of prosthesis implantation depth (Figure 1).

Following deployment, the echocardiographer must rapidly and accurately assess the position and function of the prosthesis. The 3DE depth perspective allows better visualisation of the position of the prosthesis relative to the native valve annulus and surrounding structures.[15] It is important to confirm adequate movement of prosthetic cusps and that the valve stent has assumed a circular configuration. The presence of immediate complications such as pericardial effusion or aortic regurgitation must be identified. 3DE can be useful in the detection and quantification of paravalvular aortic regurgitation.[16,17]

PERCUTANEOUS MV REPAIR

MV repair using a percutaneous approach is currently performed using the MitraClip system (Abbott Laboratories, Abbott Park, IL, USA). This technique is able to alter the MV morphology, and reduce mitral regurgitation (MR). This catheter-based technique is similar to the Alfieri technique since it implants a Clip that holds the free edges of the mid portions of the anterior and posterior mitral leaflets together, reducing the degree of MR.[18] The MitraClip procedure has shown to be a feasible and safe alternative for patients ineligible for surgery.[19]

Echocardiography is the essential imaging modality, not only for selection of patients, but also during the intervention. The procedure is technically demanding, and fluoroscopy alone is not enough to guide the procedure as the MV leaflets are not seen, and continuous echocardiography imaging is required. 3DE complements 2DE in different steps of the procedure, providing valuable additional information, and should be used when available.[20]

The transseptal puncture is the first of the main procedural steps for MitraClip implantation. It is one of the most important steps because a correct puncture site is crucial for the normal development of the rest of the procedure. The transseptal puncture must be performed in a specific site that allows manipulation of the system inside the left atrium (LA) and grasping of leaflets. It should be performed in a posterior and superior location in the interatrial septum and at a certain distance from the valvular plane. 2D TEE imaging planes using a short axis view at the base for anterior-posterior orientation (30-45°), a bicaval view for superior-inferior orientation (90-120°), and a four-chamber view to identify the height above the MV are used. A persistent foramen oval should be avoided for transseptal puncture as it is too anterior. 3DE is very convenient because it allows us to visualise the whole interatrial septum in one view, without needing to shift from one plane to another for localisation of the correct puncture site.

The EchoNavigator system that allows image integration of fluoroscopy and echocardiography in real-time can be used during the transseptal puncture. Since a specific puncture site is needed, this system allows marking on 2DE or 3DE of the exact puncture site. This marker will be automatically transposed to the fluoroscopy image and can be used as a guide for interventionalists, facilitating targeting (Figure 2).

After the puncture has been performed, the Steerable Guide Catheter with the dilator is introduced into the LA. Once placed in the LA, the dilator is retrieved and the Clip Delivery System is advanced into the LA. In both steps, continuous monitoring of the catheter is necessary to avoid injuring the free LA wall. We also have to ensure that the tip of the Steerable Guide Catheter remains across the interatrial septum. 3DE can be particularly helpful in this setting as it allows better definition of catheters and, therefore, evaluation of their distance to the LA wall.

The MitraClip system should be placed above the MV in its mid portion, and perpendicular to the line of coaptation, directed towards the largest proximal isovelocity surface area (PISA). Instead of changing from 2D midoesophageal intercommissural view to midoesophageal long axis view for alignment, a 3DE en face view of the MV from the LA perspective allows visualisation in one image of the whole MV for precise and correct orientation (Figure 3). With the use of EchoNavigator, the origin of the largest PISA can be marked on echocardiography, and the device targeted towards this marker in the fluoroscopy images.

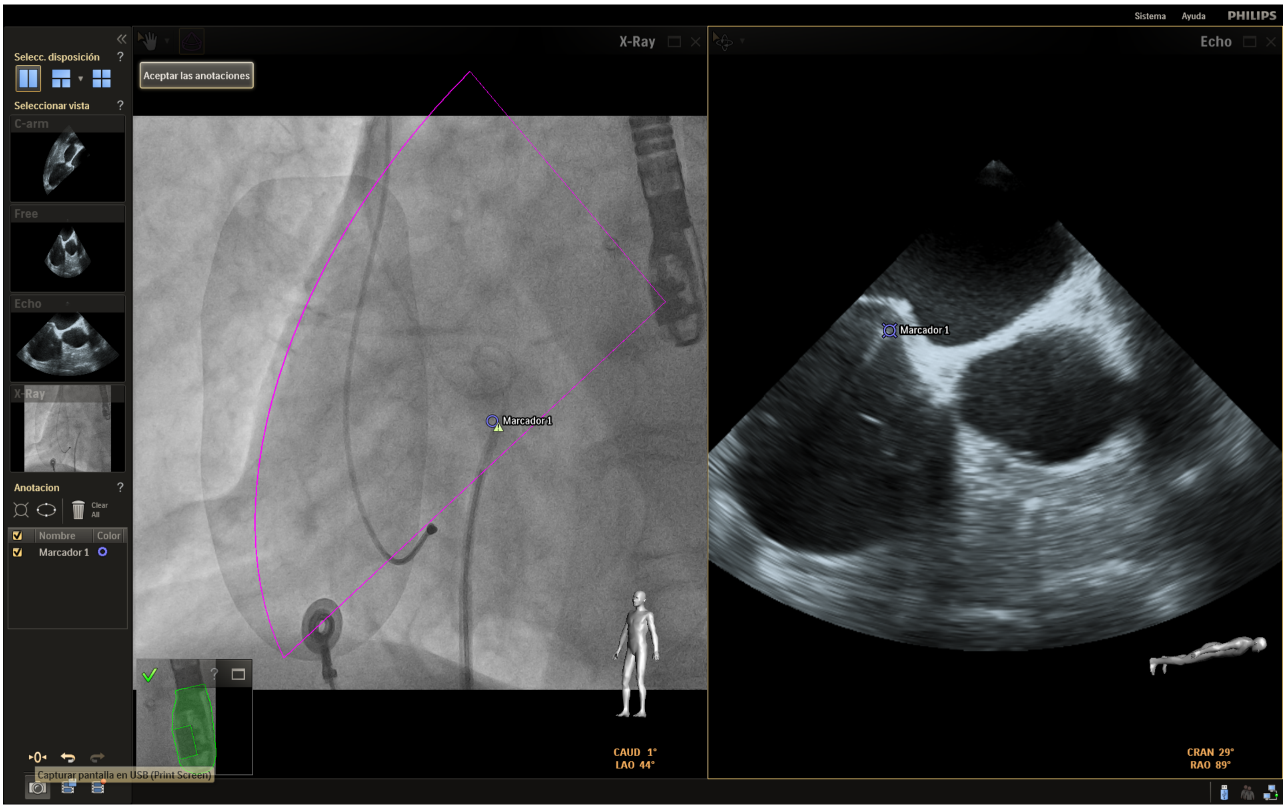

Figure 2: Transseptal puncture site has been marked using EchoNavigator system at the beginning of a MitraClip implant procedure to ensure correct location of the puncture.

Figure 3: A 3DE en face view of the MV from the LA perspective allows visualisation in one image of the whole MV for precise and correct orientation of the MitraClip device.
3DE: 3D echocardiography; MV: mitral valve; LA: left atrium.

After crossing the MV, the orientation of the Clip and the delivery system should be confirmed, since the Clip may rotate during translation into the LV. 3DE allows a rapid check from the LV perspective to confirm that the arms of the MitraClip device are still perpendicular to the line of coaptation; alternatively 2DE transgastric short-axis view may be used. Once the MitraClip is satisfactorily positioned, grasping of the mitral leaflets between the Clip arms and the grippers is monitored using LV outflow tract view (where the insertion of the posterior leaflet is commonly best seen), four-chamber view (where the insertion of the anterior leaflet is best seen), and intercommissural view (60-70°), adding information in the evaluation of chordae tendineae. Once grasping has been achieved, 3D TEE helps confirm correct bridging between the valves and the Clip.

Before release, assessment of residual MR with Colour Doppler should be performed. It is also essential to exclude mitral stenosis. This can be accomplished by measuring the transvalvular gradient with continuous-wave Doppler and planimetering the two orifices using 3DE. It is important to ensure that all periprocedural measurements of MR are made under similar haemodynamic conditions since these influence MR severity. There are currently no consensus guidelines on how to evaluate the degree of MR in the presence of a double orifice, and a multi-modal analysis is recommended. 3DE can also be used for quantification of MR. Direct measurements of vena contracta area using 3DE have potential for the quantification of MR with irregular vena contracta areas.[21] In the absence of aortic regurgitation and ventricular septal defects, using 3D acquisition of LV volumes, the regurgitant volume can be calculated.

MV gradient should be evaluated before Clip release; a mean gradient of up to 5 mmHg is considered acceptable. Using 3D TEE, if the sum of the planimetered orifices gives an area of <1.5 cm^2 it is considered criteria for significant mitral stenosis.[18]

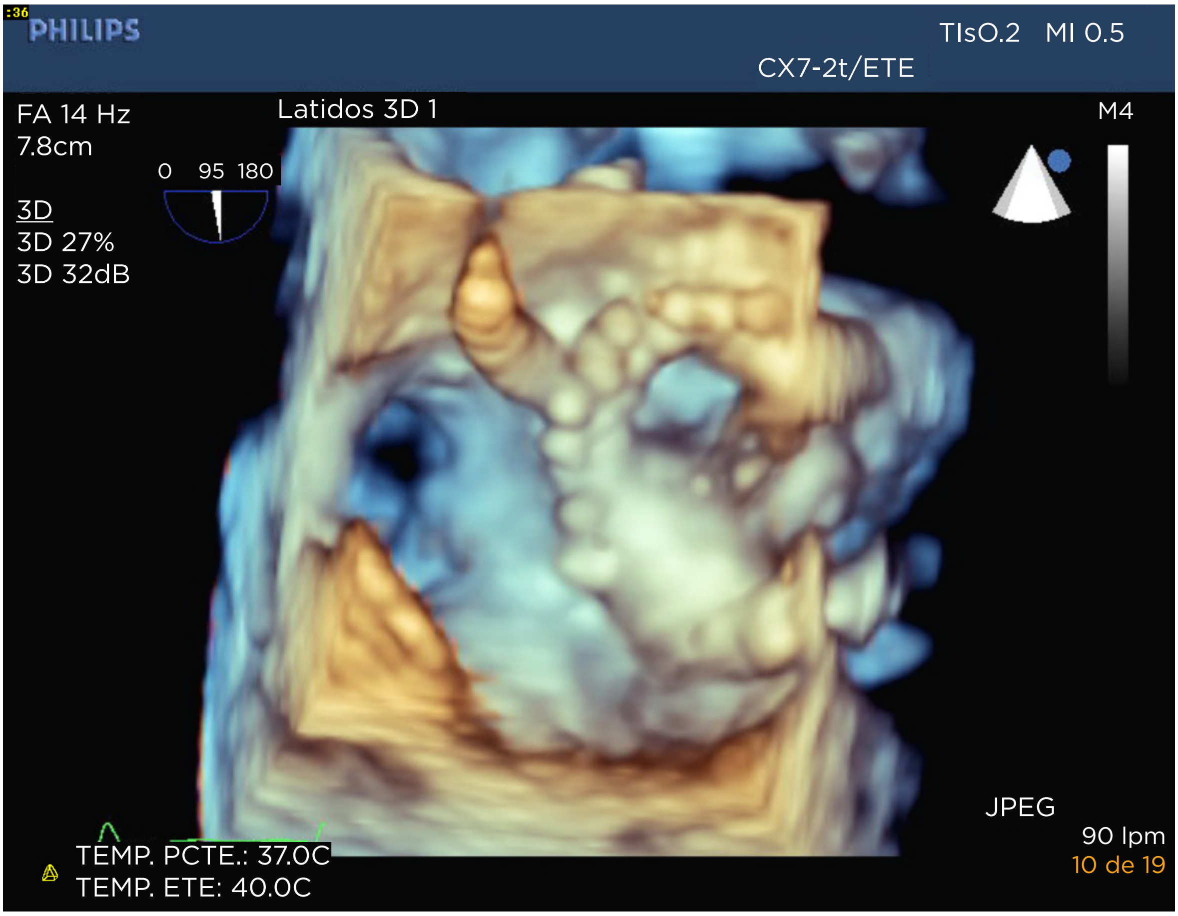

Figure 4: MV prosthesis paravalvular leak closure.
Real-time 3D TEE allows assessment during catheter navigation, determining whether it is located through the defect as seen in the figure or through the prosthetic valve leaflets.
MV: mitral valve; TEE: transoesophageal echocardiography.

In cases of unsatisfactory MR reduction, repositioning of the Clip or the implant of a second Clip may be considered. After deployment, the residual degree of MR should be reassessed.[22]

PERCUTANEOUS CLOSURE OF PVLS

Prosthetic PVLs are a potential complication of surgical valve replacements that can have significant clinical consequences, such as haemolytic anaemia or congestive heart failure. In cases where a second surgery is deemed high-risk, percutaneous treatment of this disorder is advisable if possible, having shown good clinical results and rates of procedural success.[23]

Percutaneous closure of a PVL is a challenging and time-consuming intervention, usually leading to long procedure times with high levels of ionising radiation. The optimal technique for planning the intervention is 3D TEE because 2DE shows limitations due to acoustic shadowing and difficulties in orientation. Real-time 3DE provides an en face view of the mitral prosthesis, allowing accurate assessment of the number, localisation, size, and shape of the paravalvular dehiscence. The location and orientation of the jets can be delineated using 3D Colour Doppler. A prosthesis in an aortic position is usually less optimally imaged than the mitral prosthesis due to its more anterior position, making it further away from the TEE probe and the fact that a proper short axis en face view may be difficult to obtain.[24]

Due to the difficulties in location and intubation of the defect in a 2D image-like fluoroscopy, EchoNavigator is very helpful in cases of PVL closure; since the defect can be marked in the echocardiography image, this marker is transposed to the fluoroscopy image and can be used to facilitate targeting of the lesion. Real-time 3D TEE allows assessment during catheter navigation, determining whether it is located through the defect or through the prosthetic valve leaflets (Figure 4). After device positioning and before deployment, 3D TEE can confirm adequate positioning and absence of interaction between the occluder and the prosthesis as well as residual paravalvular regurgitation. Repositioning or implantation of another device can be performed, but results are not considered optimal.

CONCLUSIONS

VHD is a growing field, with a significant increase in the number of patients that can be treated percutaneously. However, percutaneous treatment of these diseases is challenging and fluoroscopy alone is usually not enough, having turned echo cardiography into an essential tool inside the Cath Lab. 3DE has given access to high resolution images in real-time, allowing continuous and detailed imaging of anatomy and surrounding. Moreover, the actual integration of different imaging modalities, such as live echocardiography and live X-ray, and future fusion has added value, increasing anatomical awareness and confidence during procedure guidance.

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