Editorial

Real-Time 3-Dimensional Transoesophageal Echocardiography: An Indispensable Resident in the Catheter Laboratory

Constantina Aggeli[1], Michael Bellamy[1], Nilesh Sutaria[1], Christodoulos Stefanadis[2], Petros Nihoyannopoulos[1]

[1]Department of Cardiology, Imperial College London, Hammersmith Hospital, London, UK; [2]First Department of Cardiology, Athens Medical School, Athens, Greece

Key words: **Three-dimensional transoesophageal echocardiography, haemodynamics laboratory.**

Manuscript received: September 11, 2011; *Accepted:* September 16, 2011.

Address:
Petros Nihoyannopoulos

Hammersmith Hospital
Du Cane Road
London W12 0NN, UK
e-mail: ***petros@imperial.ac.uk***

The variety and complexity of percutaneous catheter based procedures performed in the catheterisation laboratory has increased considerably over recent years. Echocardiography plays an essential role in identifying patients who are eligible for non-coronary interventions in the catheterisation laboratory and in providing intra-procedural monitoring and post-procedure follow up.[1] The echocardiographic assessment of patients undergoing transcatheter interventions places demands on echocardiographers that differ from those of a routine evaluation.

Transoesophageal echocardiography (TOE) has become one of the most exciting imaging modalities available today in modern clinical interventional cardiology. Current real-time three-dimensional transoesophageal echocardiography (RT 3D TOE) employs a dedicated novel matrix-array technology that allows the three-dimensional (3D) representation of cardiac structure and it comes as a valuable adjunct for diagnostic and therapeutic management in the clinical arena. In brief, modern transducers allow three distinct imaging modes, whose suitability depends on the study objectives: full-volume, live 3D (with or without zoom), and multiplane views.

The current use of RT 3D TOE in percutaneous procedures involves the following: atrial or ventricular septal defect closures, transcatheter aortic valve implantation, paravalvular leak occlusion including mitral repair with clips, balloon mitral valvuloplasty, and recently left atrial appendage occlusion. In this editorial, we will briefly discuss the clinical applications of RT3D TOE in evaluating patients who are eligible for interventions, before, during and after the completion of the procedure.[2,3]

Transcatheter aortic valve implantation (TAVI)

Recently developed systems that can deliver and deploy a prosthetic valve in the aortic position have been shown to be effective and life saving in selected patients (i.e. elderly frail patients with co-morbidities). Currently, two systems are in clinical use: the Edwards SAPIEN, and the Medtronic Core Valve.[4,5]

A complete understanding of the 3D anatomy of the aortic valve by interventionalists and imagers has become the foundation for the accurate placement of new transcatheter devices. 3D TOE conveys certain advantages over 2D TOE during TAVI. In the pre-procedural period during evaluation of the aortic valve, 3D TOE can be very useful in accurately sizing the annulus by allowing precise alignment of the short-axis view of the valve to present the true annulus. This is important in stent selection. Using computed tomography (CT) as the gold standard for aortic annulus size, 3D TOE was superior to 2D TEE, offering an improved estimation of annular size.[6]

In addition, for the implantation of the Edwards SAPIEN valve the annular-ostial distance is required.[4] Although 2D TOE is able to define the annular-ostial distance for the right coronary artery, measurement of the distance from the annulus to the left main coronary ostium requires 3D TOE, as the left main coronary artery ostium lies in the coronal plane, which cannot be acquired by standard 2D imaging. This measurement, though, is not necessary for the self-expanding prosthetic aortic valve. Live 3D may also be useful when positioning the transcatheter valve across the annulus. The 3D depth perspective makes it easier to visualise the position of the prosthesis on the balloon relative to the native valve annulus and surrounding structures. With the use of 3D TOE following valve deployment, the echocardiographer must rapidly and accurately assess the position and function of the valve, including identifying the presence/severity of aortic regurgitation (Figure 1). Significant regurgitation may be an indication for repeat balloon inflation to attempt maximal expansion of the valve. 3D colour Doppler volume sets obtained from deep gastric and/or mid-oesophageal views may allow direct planimetry of the regurgitant orifice(s).

Transcatheter occlusion of paravalvular leaks

Recently, devices specifically designed for the treatment of prosthetic valve paravalvular leaks have been developed.[2-4] RT 3D TOE is now considered the preferred imaging modality, as it is uniquely capable of demonstrating the irregular (frequently crescent) shape of the defects and is better able to identify multiple defects and provide accurate sizing. It is a major advance as regards confirming the location and severity of paravalvular regurgitation, facilitating guide wire and catheter positioning, and assessing the seating of the closure device (Figure 2). Furthermore, the location and orientation of the paravalvular regurgitant jets can be further delineated using 3D colour-flow imaging. Using the "*en face*" valve plane, the leak location can be described in terms of a clock face, with the percentage circumference reflecting severity.

Catheter based mitral valve repair for mitral regurgitation

This procedure constitutes the latest advance in the non-surgical repair of mitral regurgitation in selected patients. Using a catheter-based system, a clip can be delivered percutaneously to grab the tips of the mitral leaflets, creating an edge-to-edge repair.[2-4] This results in a double mitral orifice, with significant reduction in the total regurgitant orifice and improvement in the patient's symptoms and functional capacity. This technology has been used to treat hundreds of patients, with encouraging clinical results (EVEREST trial).[7] Real-time transoesophageal imaging is crucial to the procedure's success.

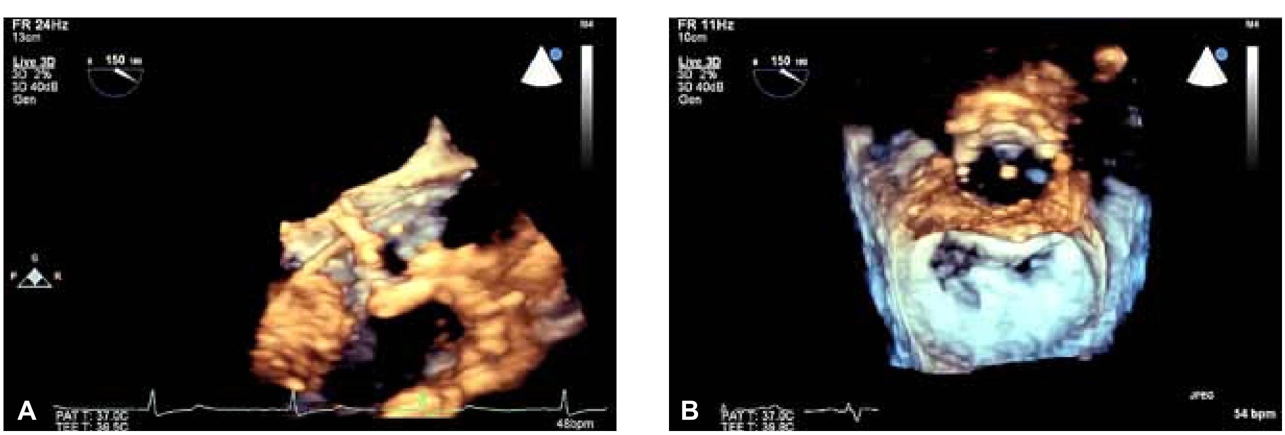

Figure 1. Real-time three-dimensional transoesophageal echocardiography in transcatheter aortic valve replacement. Proper position of the catheter through the calcified aortic valve (A) and an Edwards SAPIEN valve implanted successfully in a left atrial *en face* view (B).

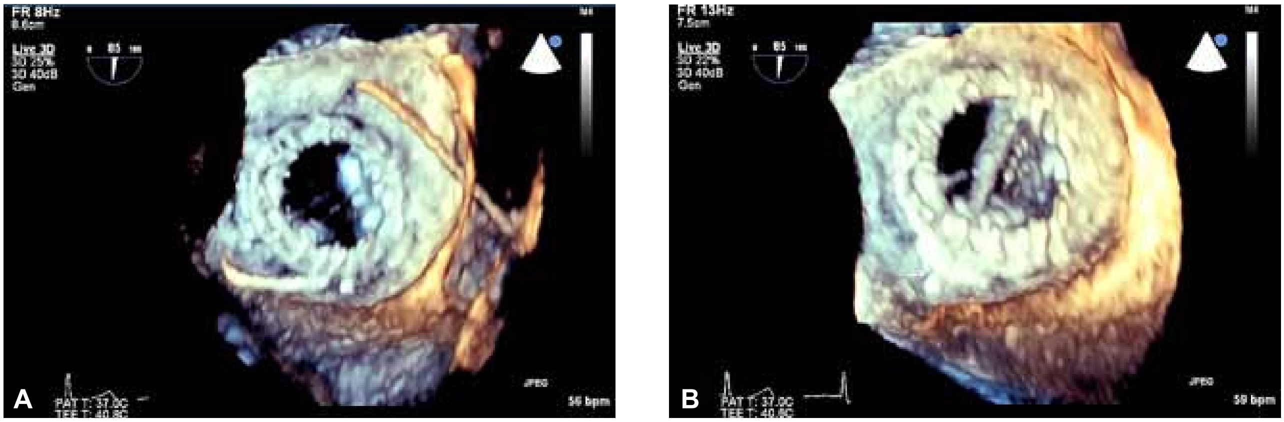

Figure 2. Real-time three-dimensional transoesophageal echocardiography in paravalvular leak. Zoom mode, left atrial perspective. The bi-leaflet mechanical mitral valve is seen. A transseptal catheter is guided to the inferior-posterior paravalvular dehiscence (A), where an AVP vascular plug is deployed (B).

Before the procedure, RT 3D TOE is used, in combination with conventional 2D TOE, to define the mitral valve anatomy, the mechanism of mitral regurgitation,[8-10] and suitability for the clip procedure. Optimal visualisation of all MV scallops with RT 3D TOE is possible in more than 90% of cases. Quantitative analysis of the mitral valve apparatus can be performed offline using dedicated quantification software (Q-Lab, Philips Medical Systems, Bothell, Washington, USA or TomTec, Munich, Germany). The contour of the mitral valve leaflets and annulus can be traced plane by plane and then reconstructed into a 3D representation for quantitative analysis. Reference values of the anatomical parameters for guiding surgical and percutaneous intervention will probably be defined in the next few years.

A patient is considered as a candidate for this procedure in cases where the mitral regurgitation is severe, and there is a regurgitant jet origin between scallops A2 and P2, a coaptation length of 2 mm or more, and a flail segment <10 mm. A large circumference of the mitral annulus and the presence of eccentric jets arising from the edge of the commissures represent unfavourable echocardiographic parameters for the procedure.

During the procedure, live 3D TOE is useful for guiding the catheter and the clip as they are advanced across the atrial septum into the left atrium and positioned just proximal to the centre of the mitral orifice. In our opinion this part of the procedure is the most difficult and time consuming. Under 2D and RT 3D TOE guidance, the clip arms are carefully aligned in a position perpendicular to the mitral closure line (Figure 3). The catheter with the clip crosses the valve, and the leaflets are grasped at the ventricular side of the valve. It is very important for 2D and 3D TOE images to confirm the position of the clip and evaluate the degree of residual regurgitation. Occasionally, particularly in cases with mitral valve prolapse and eccentric jets, placement of a second clip may be required.

Left atrial appendage device occlusion

Currently used percutaneous devices include the Watchman Left Atrial Appendage System and the Amplatzer Cardiac Plug III.[2,3] To determine the eligibility of patients and the size of device required, pre-procedural assessment includes the accurate measurement of the left atrial appendage orifice area and length. RT 3D TOE can perform these measurements in a single *en face* view (Figure 4), compared to the multiple view required with 2D TOE. The presence of an elongated oval ostium will make closure more challenging and this variant is more readily appreciated using 3-D compared with conventional 2-D imaging. During the percutaneous procedure, live 3D TOE can visualise the catheter tips and guide the interatrial septal puncture. Following left atrial appendage occluder placement, 3D TOE imaging is advantageous over 2D TOE in that off-angle device placement is more easily appreciated.

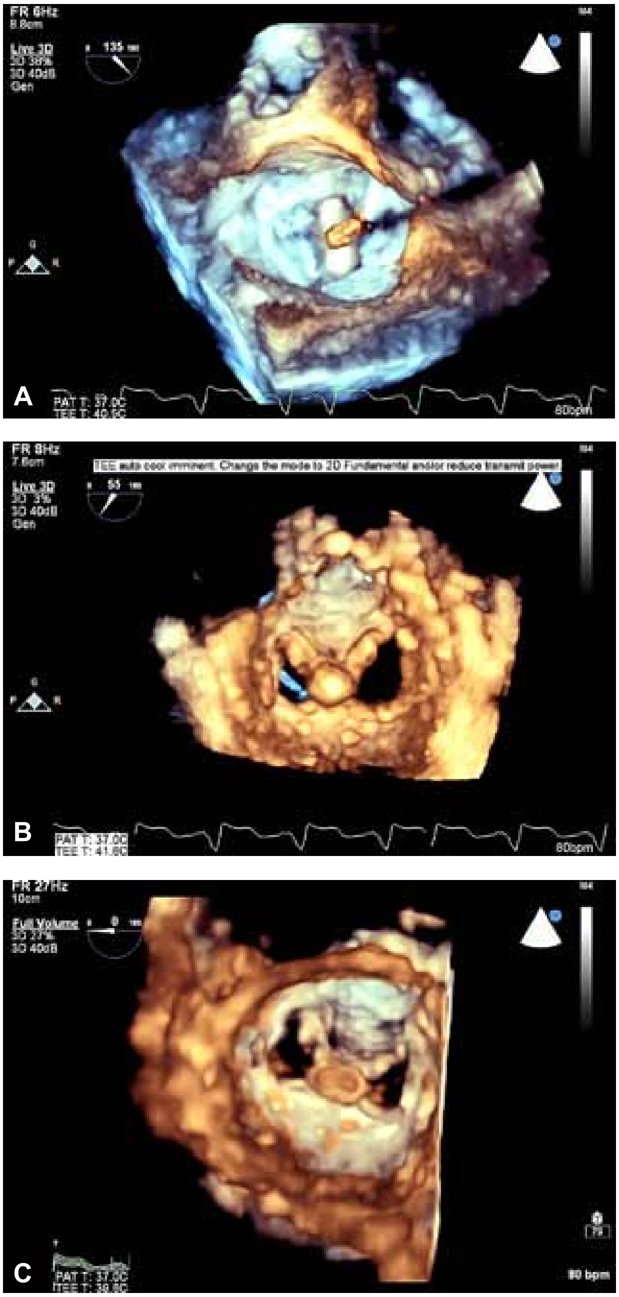

Figure 3. Real-time three-dimensional transoesophageal echocardiography in mitral valve clipping. Zoom mode, left atrial perspective. The clip arms are aligned in a position perpendicular to the mitral closure line (A). The first (B) and the second (C) MitralClip are deployed successfully, resulting in two mitral orifices.

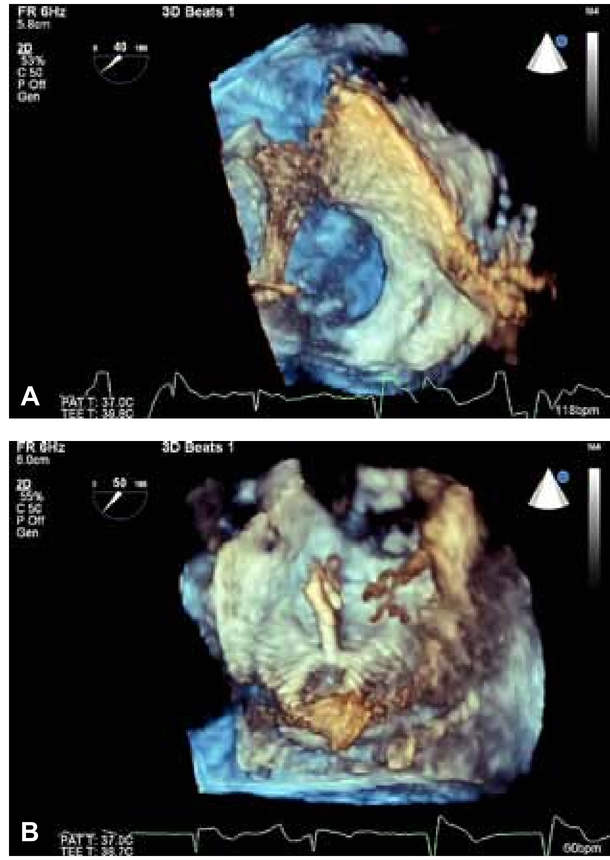

Figure 4. Real-time three-dimensional transoesophageal echocardiography in left atrial appendage occlusion. *En face* view of the oval single-lobe appendage before (A) and after (B) the device is deployed successfully.

Device closure of atrial septal defects and patent *foramen ovale*

In pre-procedural assessment by live 3D TOE, the use of non-traditional *en face* views allows the true size and morphology of the defect to be assessed and frequently confirms that the atrial defects are not perfectly round. The use of RT 3D TOE provides information about complicated defects, such as fenestrated atrial septal defect or those with a partial membrane in the defect, which can be useful for case planning.[1-3] In addition, it permits accurate measurement of defect size and provides information on the adequacy of tissue rims.[11] During the procedure, live 3D TOE allows continuous visualisation of the tip of the guiding catheter as well as guiding the deployment of the pre-expanded device. Therefore, verification of their location before, during, and after deployment, is feasible, minimising the risk of complications (Figure 5).

Post-procedure, full volume and live 3D TOE can visualise the left and right atrial sides of the occluder device as well as the tissue rim nested between the two device plates. If the device is misaligned, RT 3D TOE can be used to reposition or remove the device.

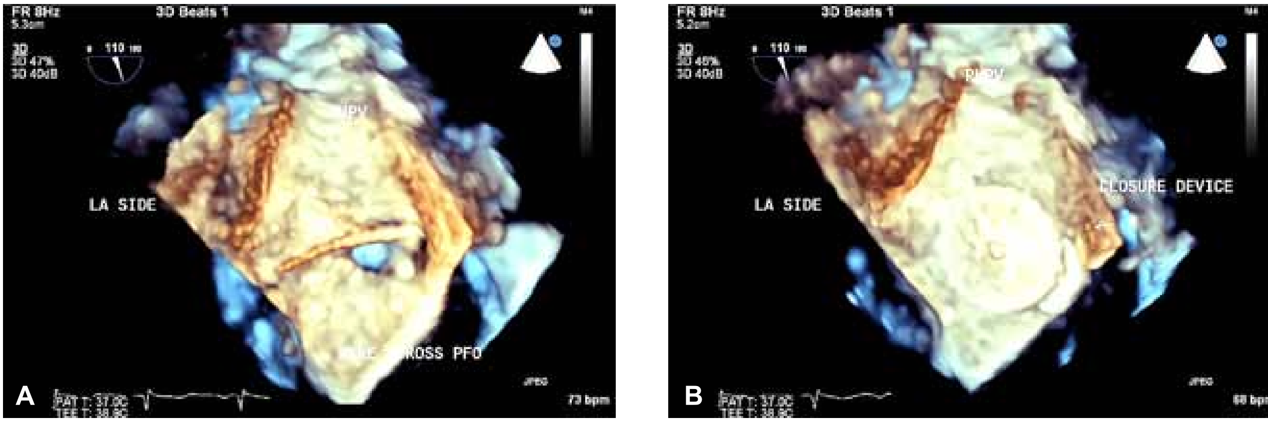

Figure 5. Real-time three-dimensional transoesophageal echocardiography in patent *foramen ovale* (PFO) device closure. Views from the left atrium. The catheter passes through the PFO (A), where a 25 mm PFO occluder device is deployed (B).

Conclusions

RT 3D TOE is a now a regular resident in the catheter laboratory, as it is applicable to a wide range of interventions. The interventional echocardiographer must be aware of the different implantation techniques before attempting to guide a procedure. RT 3D TOE has been shown to provide additional insight into the anatomical, morphological and haemodynamic assessment of structural heart disease. It has become the imaging modality of choice of many interventionalists, and in many cases it serves as the operator's "eyes" to evaluate, guide, and assess the results of procedures in the catheterisation laboratory. The unique structural information obtained by RT 3D TOE offers the potential for shorter and safer interventional procedures, with a higher rate of technical success, thus improving patient outcomes.

References

1. Nihoyannopoulos P, Kisslo J. Echocardiography. Springer-Verlag, 2009.
2. Lee AP, Lam YY, Yip GW, Lang RM, Zhang Q, Yu CM. Role of real time three-dimensional transesophageal echocardiography in guidance of interventional procedures in cardiology. Heart. 2010; 96: 1485-1493.
3. Brochet E, Vahanian A. Echocardiography in the catheterisation laboratory. Heart. 2010; 96: 1409-1417.
4. Zamorano J, Badano L, Bruce C, et al. EAE/ASE recommendations for the use of echocardiography in new transcatheter interventions for valvular heart disease. Eur Heart J. 2011; 32: 2189-2214.
5. Vavuranakis M, Voudris V, Vrachatis DA, et al. Transcatheter aortic valve implantation, patient selection process and procedure: two centres' experience of the intervention without general anaesthesia. Hellenic J Cardiol. 2010; 51: 492-500.
6. Ng AC, Delgado V, van der Kley F, et al. Comparison of aortic root dimensions and geometries before and after transcatheter aortic valve implantation by 2- and 3-dimensional transesoephageal echocardiography and multislice computed tomography. Circ Cardiovasc Imaging. 2010; 3: 94-102.
7. George J, Varghese V, Dangas G, Feldman T. Percutaneous mitral valve repair. Lessons from the EVEREST II (Endovascular Valve Edge-to Edge Repair Study) and Beyond. JACC: Cardiov Interv. 2011; 7: 825-827.
8. García-Orta R, Moreno E, Vidal M, et al. Three-dimensional versus two-dimensional transesophageal echocardiography in mitral valve repair. J Am Soc Echocardiogr. 2007; 20: 4-12.
9. Grewal J, Mankad S, Freeman WK, et al. Real-time three-dimensional transesophageal echocardiography in the intraoperative assessment of mitral valve disease. J Am Soc Echocardiogr. 2009; 22: 34-41.
10. van Gorselen E, Nihoyannopoulos P, Verhorst P, von Birgelen C, Prendergast B, Bellamy M. Severe regurgitation due to perforation of the mitral-aortic intervalvular fibrosa 3 years after aortic valve replacement. Eur J Echocardiogr. 2011; 12: E30.
11. Dardas PS, Ninios VN, Mezilis NE, Tsikaderis DD, Thanopoulos VD. Percutaneous closure of atrial septal defects: immediate and mid-term results. Hellenic J Cardiol. 2010; 51: 104-112.