New innovations in interventional cardiac procedures - role of intraprocedural echocardiography

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The field of interventional cardiac procedures is rapidly growing. Since the "first in men" catheter-based implantation of a biological aortic valve by Cribier,[1] the number of transcatheter based aortic replacements (TAVR) exceeds several thousand implantations per year worldwide. Beside this percutaneous treatment of mitral regurgitation (MitraClip®), closure of the left atrial appendage, and closure of a patent foramen ovale have been developed. Whereas MitraClip® procedures require general anaesthesia,[2] percutaneous closure of the left atrial appendage as well as closure of a patent foramen ovale are usually performed without the help of anaesthesiologists and will therefore not be discussed furthermore.

The transapical NeoChord DS 1000 system (NeoChord Inc, USA) is a new treatment option for patients with severe mitral regurgitation and prolapse of the posterior mitral leaflet that can be done off-pump.[3]

Transcatheter aortic valve replacement

TAVR is an alternative treatment option in high risk patients with severe symptomatic aortic stenosis where the local "heart team" considers the patient as unsuitable for conventional aortic valve replacement.[4,5] The most common access routes for TAVR are transfemoral, transapical, and transaortic. Beside the Edwards SAPIEN and the Medtronic CoreValve, the most popular transcatheter valves, there are several other new valves currently under investigation like the Symetis Acurate valve (Symetis SA, Switzerland), JenaValve (JenaValve, Germany), the Engager Valve, the Sadra Lotus valve (Medtronic, USA), and the Direct Flow Medical (Direct Flow Medical , USA).[6]

The incidence of vascular injuries as one of the most frequent complications for the transfemoral approach could be decreased due to smaller device sizes.[7] Embolic protection devices like the Claret CE Pro system (Claret Medical Inc, USA) are designed to reduce the incidence of cerebrovascular events.[8] But this has to be proven in ongoing studies.

The transfemoral TAVR is performed under analgo-sedation in some centres. TEE is helpful for guiding the TAVR procedure in patients in whom the transapical or transaortal approach is used. These patients obtain general anaesthesia. After induction of anaesthesia the first step of guiding the TAVR procedure is sizing of the aortic annulus (Figure 1). Real time 3 dimensional transesophageal echocardiography (RT 3D TEE) adds additional information to 2D TEE.[9] Annulus sizing is performed with X-plane at the midesophageal long axis view (ME LAX) and the midesophageal aortic valve short axis view (ME SAX). Measuring is performed in systole with trailing edge to leading edge convention at the hinge points of the leaflets (Figure 1A). Accurate assessment is necessary to prevent under- or overestimation. A too small valve leads to poor haemodynamics, paravalvular regurgitation or valvular migration. A too large valve in comparison may lead to incomplete deployment and annular rupture. The second step is to determine the distance of the coronary ostia to the aortic annulus. A distance of less than 10 mm indicates high risk of obstruction of the coronary arteries after valve implantation.[10]

The next step is guidewire positioning in the aortic valve. It must be ensured that the guidewire goes through the aortic valve without compromising the mitral valve apparatus including papillary muscles and chords. Correct placement is approved with TEE in ME LAX and ME SAX. Consecutively, a balloon valvuloplasty of the native aortic valve is performed (Figure 1B). The balloon should be located in central position and dilatation should be effective. Valve positioning and deployment of the valve prosthesis are guided with X-plane of the aortic valve in LAX and SAX view (Figure 1C). Postoperative functional control is performed

directly after implanting of the valve to make sure that the valve is fully deployed, to assess possible residual regurgitation (Figure 1D), to exclude persistent aortic stenosis, and to evaluate ventricular function. Colour flow Doppler and continuous wave Doppler are used.

Percutaneous MitraClip® Procedures

The MitraClip® procedure is a percutaneous transcatheter device that allows treatment of severe mitral regurgitation without the use of cardiopulmonary bypass. The principle is similar to the well known Alfieri-repair in conventional surgical mitral valve repair.[11] The MitraClip® device is inserted through the femoral vein and via trans-septal puncture introduced into the left atrium.[12]

According to the guidelines of the European Society of Cardiology and the European Association for Cardio-Thoracic Surgery the percutaneous mitral clip procedures may be considered in patients with symptomatic severe secondary mitral regurgitation despite optimal medical therapy, who are judged inoperable or at high surgical risk by a team of cardiologists and cardiac surgeon, and who have a life expectancy greater than one year.[4] Echocardiographic guidance throughout the procedure is essential for the success of the procedure[13] for (I) confirming the pathology, (II) graduation of mitral regurgitation during general anaesthesia (III) defining the trans-septal puncture site, (IV) guidance of the Clip implantation, and (V) evaluation of the repair. Optimal mitral valve morphology for this procedure is a central pathology in segment 2, no leaflet calcification, a mitral valve opening area > 4 cm^2, mobile length of the posterior leaflet > 10 mm, coaptation depth < 11 mm, normal leaflet strength and mobility, and a flail-width < 15 mm.[2]

Real time 3D transesophageal Echocardiography helps for orientation, guidance of the interventionalist and decreases the time for intervention.[14] In the ACCESS trial the MitraClip® procedures has been effective with low rates of hospital mortality and adverse events.[15]

First step of guiding the MitraClip® procedures with 3D TEE is the graduation of the mitral regurgitation and to display the position of the regurgitant jet origin (Figure 2A). A catheter is introduced in the femoral vein and proceeded up through the inferior vena cava into the right atrium. X-plane imaging starting from a modified midesophageal aortic valve SAX view indicates anterior and posterior direction on the left side and superior and inferior direction on the right side to define the optimal puncture site (Figure 2B). In the midesophageal four chamber view, the distance from the puncture site to the coaptation of both mitral valve leaflets is measured (Figure 2C). After positioning of the guidewire into the left upper pulmonary vein, the guide is introduced into the left atrium (Figure 2D, red arrow). To avoid damage of the left atrial wall after introducing the Clipdevice through the guide, enough distance of the guide to the left atrial wall should be present (Figure 2D, yellow arrow).

The next important step is the alignment of the clip. The opened clip has to be oriented perpendicular to the free margin of the mitral valve leaflets to ensure optimal capture of both leaflets (Figure 3A). After introducing the clip into the left ventricle, it has to be positioned over the origin of the mitral regurgitant jet. At this time the echocardiograph

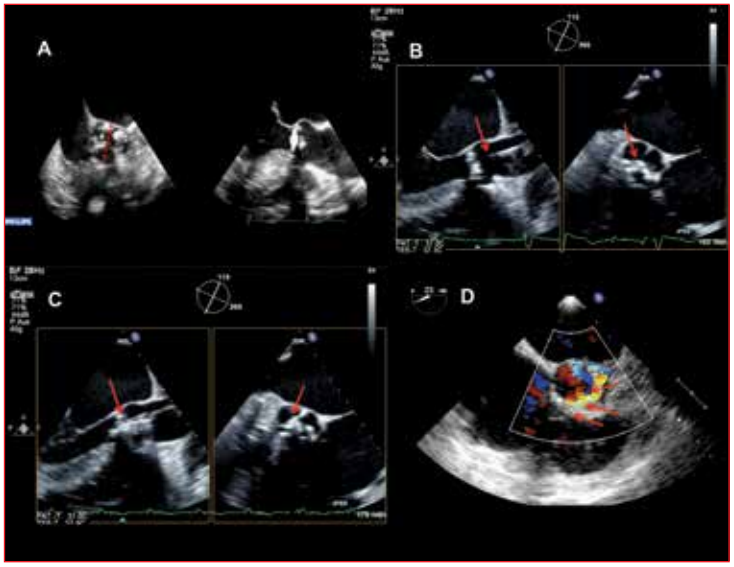

Figure 1: Important steps in TAVR: **A:** Annulus sizing using X-Plane, **B:** Central positioning of the guidewire, **C:** Positioning of the valve, **D:** Severe paravalular leackage after implantation

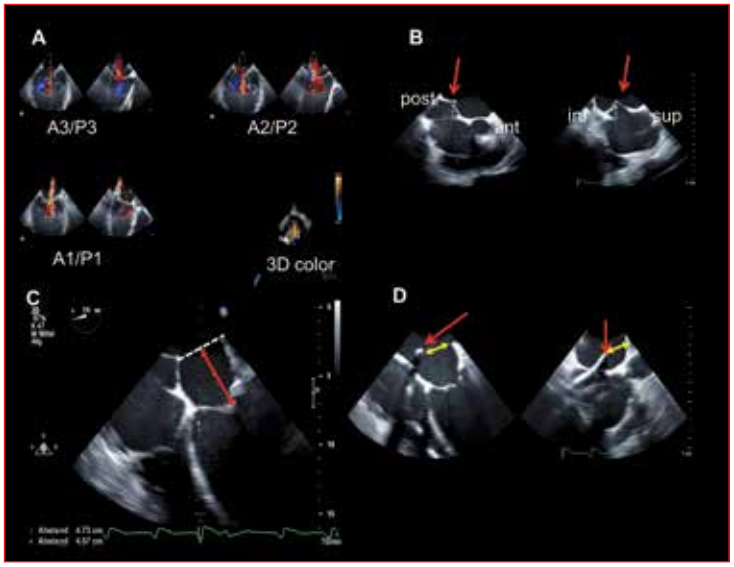

Figure 2: Echoguidance during MitraClip® procedure. **A:** localisation of the origin of the mitral regurgitation using X- plane Color Doppler imaging starting from the midesophageal mitral commissural position. **B:** Guidance of the transseptal puncture using X-plane starting from a modified midesophageal Aortic Valve SAX view. On the left picture the anterior (ant) and posterior (post) part of the right atrium is displayed, on the right picture the superior (sup) and inferior (inf) part. **C:** Measurement of the distance between transseptal puncture and coaptation of the mitral valve leaflets in the midesophageal four chamber view. A distance of 4.5 ± 0.5 cm should be achieved. **D:** Visualisation of the guide in the left atrium with enough distance to the left atrial wall.

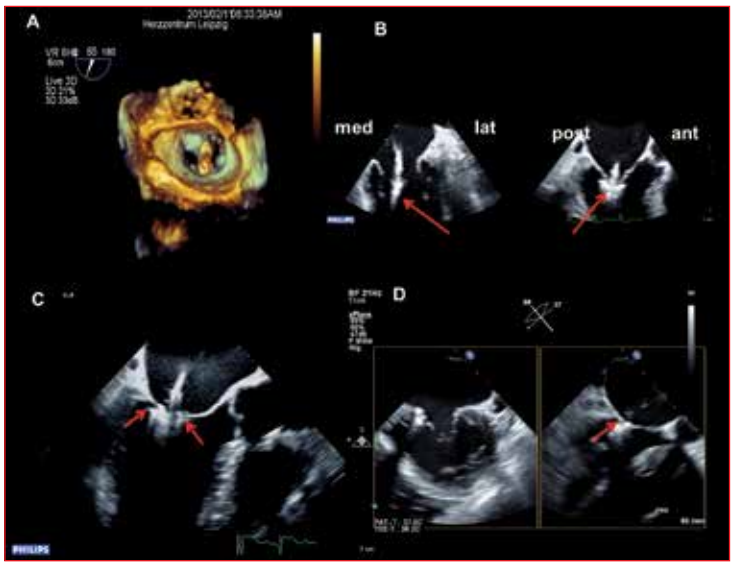

Figure 3: Echoguidance during MitraClip® procedure. **A:** Correct alignment of the clip in Real Time 3 D wide sector mode. **B:** Orientation for correct positioning of the clip in X-plane starting from midesophageal mitral commissural view with medial (med) and lateral (lat) part of the mitral valve on the left picture and posterior (post) and anterior (ant) part on the right picture. **C:** "Gripper down" in the midesophageal long axis view. Both leaflets can be seen in- between the grippers (arrows). **D:** Control of leaflet insertion after grasping the leaflets to ensure that enough tissue was catched (arrow).

and the interventionalist have to work precisely. The echocardiographer guides the interventionalist to get the optimal position of the clip. For this step again X- plane imaging is very helpful starting from a midesophageal mitral commissural view (Figure 3B). If the optimal position was found then the midesophageal long axis is required to see if the gripper grasp the tips of the anterior and posterior mitral leaflet (Figure 3C). Leaflet insertion has to be controlled to ensure that both leaflets were grasped securely before the Clip is released (Figure 3D). Optimal outcome is achieved if the regurgitant jet is two grade smaller than prior the procedure and the resulting transmitral mean pressure gradient is < 6 mm.

NeoChord® Implantation

The NeoChord® DS1000 system (NeoChord Inc, USA) allows implantation of artificial neochordae to fix a well defined prolapse of the mitral valve leaflet without the use of a cardiopulmonary bypass.[3] In this procedure RT 3D TEE is also crucial to guide the intervention and to control the success of the procedure. With a left lateral minithoracotomy the NeoChord® system gets introduced to the apex of the heart. The NeoChord® DS 1000 System is inserted through the apex of the heart into the left ventricle. From this position the mitral valve leaflets can be reached and fixed with the NeoChord® system. The prolapsing leaflet is grasped with the device guided by TEE. If the leaflet has been captured appropriately, a suture is attached to the leaflet. With the use of TEE the length of the suture is determined by observing the improvement of mitral valve regurgitation. After confirmation with TEE of reduction of the prolapse of the mitral valve leaflet the suture is fixed at the apex.

It has been shown that offpump transapical implantation of artificial chordae to correct mitral regurgitation is technically safe and feasible, however, it yields further potential for improvement of efficacy.[16]

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