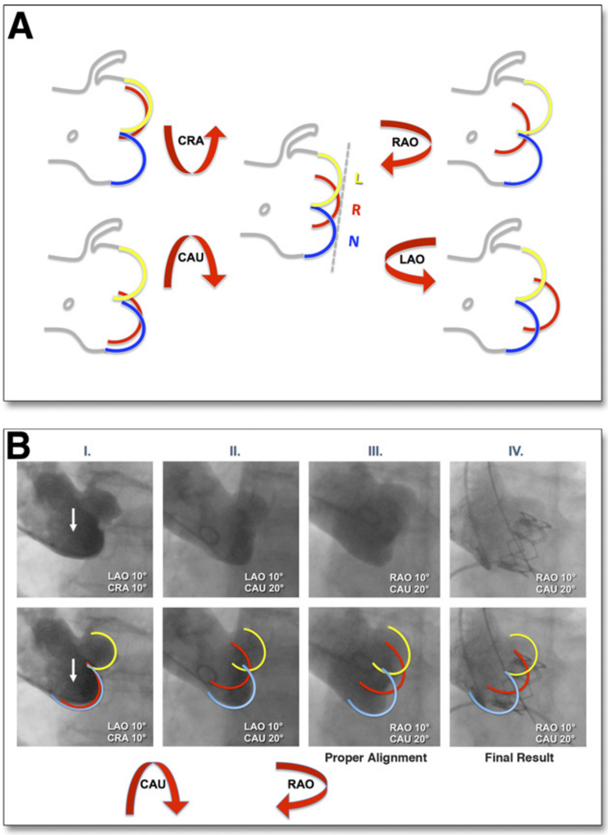

Figure 2. Suggested Scheme and Real-World Application of the Rule in Horizontal Aortic Root Anatomy

(A) Schematic illustration of the "follow the right cusp" rule pointing to the proper alignment in the case of "horizontal" aortic root anatomy. **(B)** Example of horizontal aortic root anatomy: images are provided without **(upper images)** and with **(lower images)** a schematic overlay. The **white arrow** indicates the pigtail catheter. Panels I through IV are as described in Figure 1B. Abbreviations as in Figure 1.

moved in a CAU direction in order to follow the right cusp (Fig. 2B, panel II). According to fluoroscopy, the right cusp will appear in the middle, but higher than the other cusps. Once again, follow the right cusp by turning the C-arm counterclockwise in the RAO projection (Fig. 2B, panel III). After alignment is obtained, successful TAVR can be performed with the 3 leaflets in line (Fig. 2B, panel IV).

A fluoroscopy-guided approach to TAVR may have several potential advantages as compared with other imaging techniques that are currently under consideration. First, it allows precise valve positioning without the limitations of calcium-related or device-related artifacts, as with TEE (4). On the contrary, fluoroscopy may rely on severe aortic valve calcifications as anatomic references for exact bioprostheses deployment (5) and for measurement of the distance of the surrounding structures with respect to the valve plane. Second, fluoroscopy reduces the contrast medium and total radiation load with respect to intraoperative CT scans (2). Finally, no general anesthesia or rapid pacing is necessary, as in the case of TEE and intraprocedural CT, respectively (1).

The follow the right cusp rule is intended as a useful tool that allows proper fluoroscopy-guided aortic root alignment. This permits simplification of TAVR procedures. Fluoroscopy-guided TAVR may overcome clinical and procedural caveats associated with an ultrasound-based approach (5) and without the expense of higher radiation and contrast load as in the case of intraoperative CT (2).

Trials evaluating the merits and pitfalls of fluoroscopy-guided TAVR in comparison with other intraoperative imaging techniques will help to define an evidence-based paradigm for TAVR procedures.

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http:dx.doi.org/10.1016/j.jcmg.2012.06.014

Please note: Dr. Kasel is a proctor for Edwards Lifesciences. Dr. Leber has received research funding and lecture fees from Edwards Lifesciences and Medtronic. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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Determination of the Aortic Annulus Plane in CT Imaging—A Step-by-Step Approach

Transcatheter aortic valve replacement (TAVR) is increasingly used to treat severe aortic stenosis in patients with high operative mortality. Accurate determination of aortic annulus dimensions is necessary in order to appropriately select prosthesis size, or to exclude patients from the procedure if no suitable prosthesis is available. While echocardiography is the most commonly used

JACC: CARDIOVASCULAR IMAGING, VOL. 6, NO. 2, 2013
FEBRUARY 2013:274–80

imaging modality to determine aortic annulus size, it has recently been recognized that computed tomography (CT) may provide more accurate measurements of aortic annulus dimensions, especially given the fact that the so-called "basal ring," formed by the lowest insertion sites of the 3 aortic cusps, is typically not circular but oval in shape (1). CT-based determination of the aortic annulus has, in fact, been shown to be a better predictor of post-implantation aortic regurgitation than echocardiography, which also suggests that the use of CT to determine prosthesis size may be advantageous (2). Furthermore, CT allows measurement of

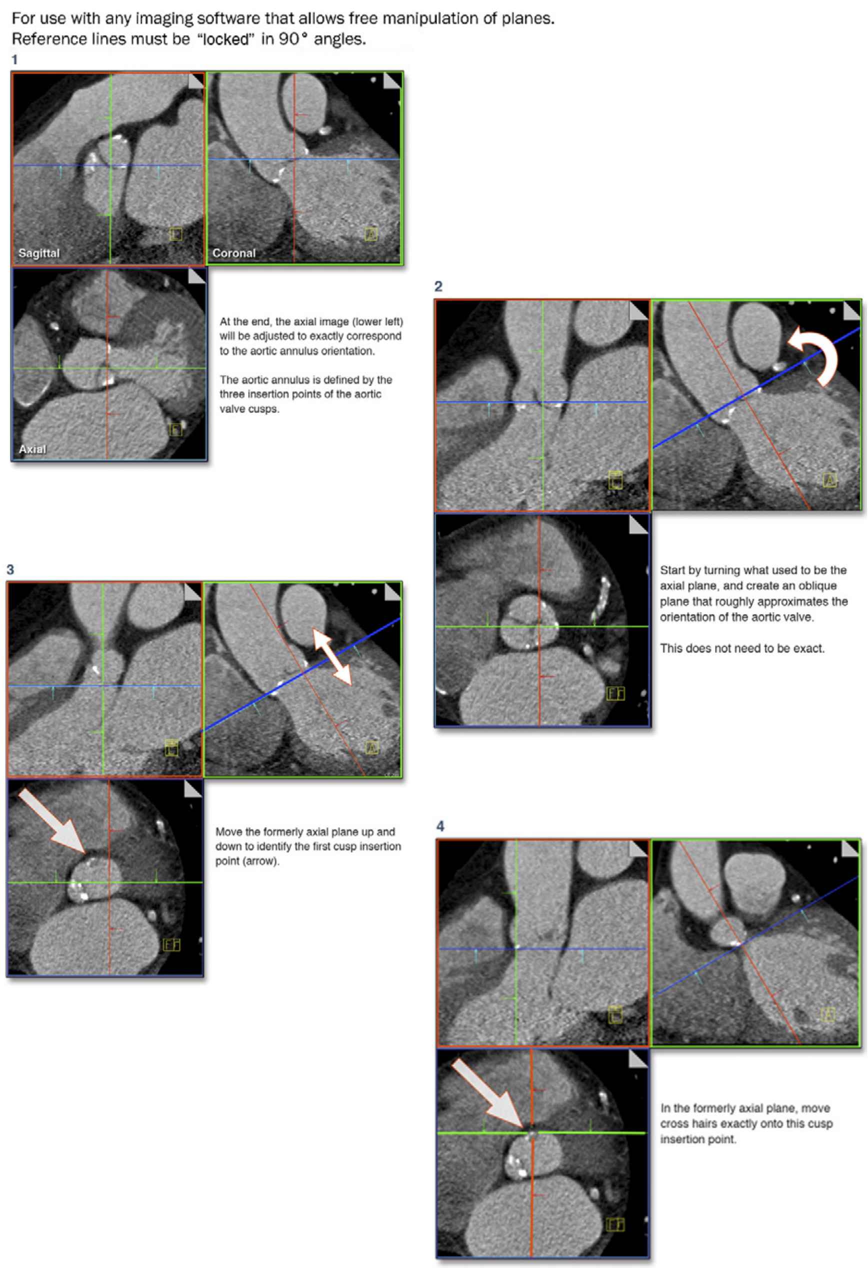

Figure 1. A Method to Create the Aortic Annulus Plane in CT

For use with any imaging software that allows free manipulation of planes. Reference lines must be "locked" in 90 degree angles. **(Panel 1)** At the end, the axial image **(lower left)** will be adjusted to exactly correspond to the aortic annulus orientation. The aortic annulus is defined by the 3 insertion points of the aortic valve cusps. **(Panel 2)** Start by turning what used to be the axial plane, and create an oblique plane that roughly approximates the orientation of the aortic valve. This does not need to be exact. **(Panel 3)** Move the formerly axial plane up and down to identify the first cusp insertion point **(arrows)**. **(Panel 4)** In the formerly axial plane, move cross hairs exactly onto this cusp insertion point.

the distance of the coronary ostia from the aortic annulus, and CT can be used to identify suitable angulations for fluoroscopy, which will provide orthogonal views of the aortic valve plane during the implantation procedure (4,5).

For these potential applications of CT in the context of TAVR, it is of utmost importance to create double-oblique multiplanar reconstructions which are exactly aligned with the aortic annulus. The orientations of such reconstructions vary from patient to

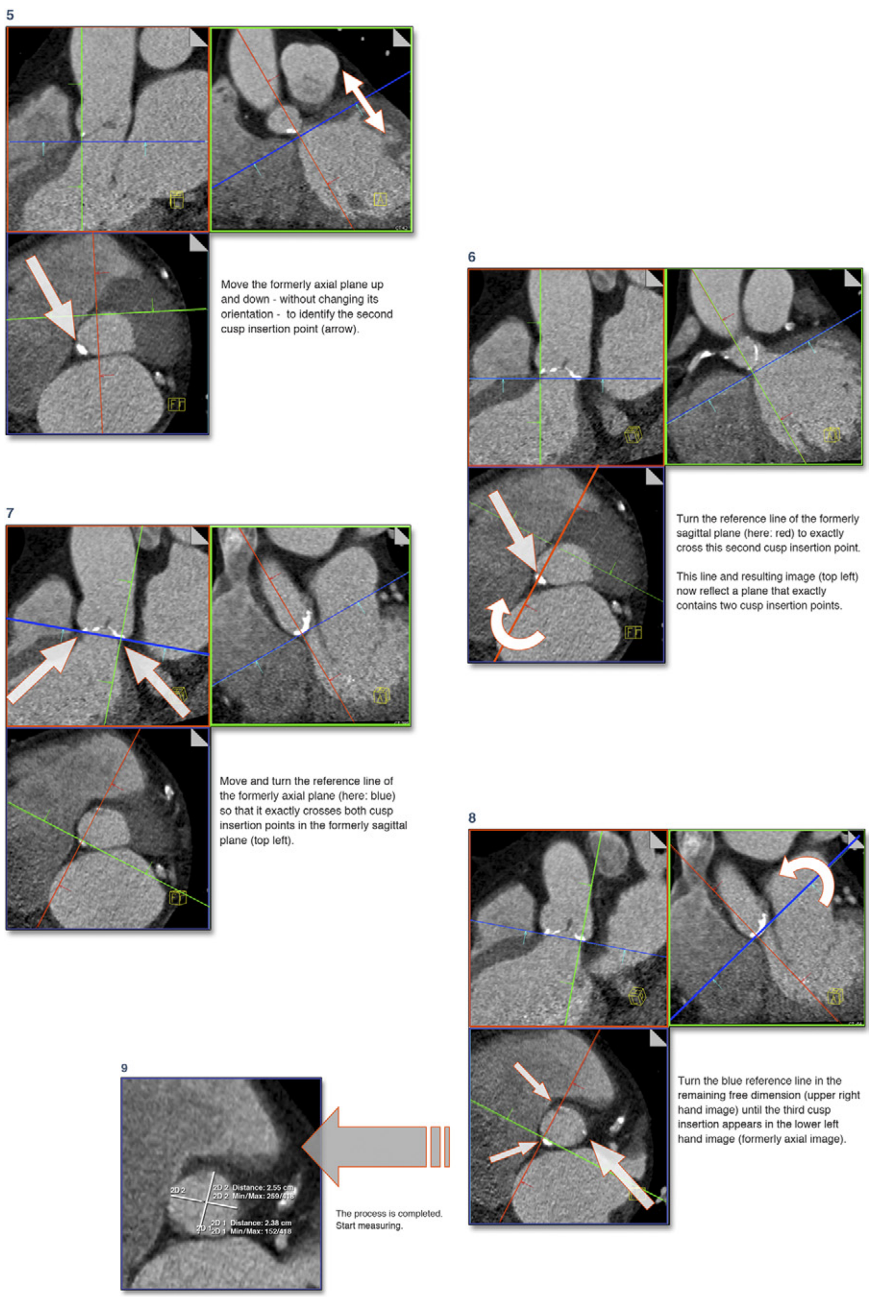

Figure 1. Continued

(Panel 5) Move the formerly axial plane up and down without changing its orientation- to identify the second cusp insertion point **(arrow)**. **(Panel 6)** Turn the reference line of the formerly sagittal plane **(red)** to exactly cross this second cusp insertion point. This line and the resulting image **(top left)** now reflect a plane that exactly contains 2 cusp insertion points. **(Panel 7)** Move and turn the reference line of the formerly axial plane **(blue)** so that it exactly crosses both cusp insertion points in the formerly sagittal plane **(top left)**. **(Panel 8)** Turn the blue reference line in the remaining free dimension **(upper right-hand image)** until the third cusp insertion appears in the lower left-hand image **(formerly the axial image)**. **(Panel 9)** The process is completed. Start measuring.

JACC: CARDIOVASCULAR IMAGING, VOL. 6, NO. 2, 2013
FEBRUARY 2013:274–80

patient, and they are not obtained intuitively. We present a step-by-step approach that can be used to create double-oblique multiplanar reconstructions which are exactly aligned with the lowest insertion points of the 3 coronary cusps (Fig. 1). This approach is not limited to a specific software product and can be used with any software package which allows generation of double-oblique multiplanar reconstructions from contrast-enhanced CT data sets.

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http:dx.doi.org/10.1016/j.jcmg.2012.06.015

Please note: Dr. Min has served on the medical advisory board for GE Healthcare and Arineta, has received research support from GE Healthcare, Philips Healthcare, and Vital Images, has served on the Speaker's Bureau for GE Healthcare, and holds equity interest in TC3 and MDDX. Dr. Leipsic has a relationship with Edwards Lifesciences. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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Stenosis of a Mechanical Mitral Valve Prosthesis by Eccentric Paraprosthetic Aortic Regurgitation

Compared with 2-dimensional (2D) transesophageal echocardiography (TEE), 3-dimensional (3D) TEE, providing realistic visualization of the valve prosthesis in the context of the surrounding anatomy, promises to provide even more accurate evaluation of prosthetic valve malfunction.

This will be exemplified by the following case of a 57-year-old man who was referred to our hospital with progressive shortness of breath. He had an extensive cardiac history, including 3 aortic valve replacements after aortic valve endocarditis ending with a mechanical bileaflet aortic valve prosthesis (AVP) (25 mm, St. Jude Medical Master HP, St. Paul, Minnesota) 14 years ago. In addition, he received a mechanical bileaflet mitral valve prosthesis (MVP) (31 mm, St. Jude Medical) 12 years ago. All cardiac surgery was performed in institutions elsewhere.

Transthoracic echocardiographic (TTE) measurements suggested relevant MVP obstruction with a mean pressure gradient (PG) of 9.2 mm Hg and a maximum PG of 29.8 mm Hg (Vmax: 273 cm/s) using the simplified Bernoulli equation. Pressure half time was increased with 163 ms. There was no obvious reason for MVP stenosis like thrombosis or pannus formation. However, in the presence of unrestricted opening motion of both MVP leaflets, there was suspicion of an asynchronous motion pattern of the 2 leaflets. At the AVP, we found moderate to severe paraprosthetic aortic regurgitation (ppAR) with a very eccentric jet directed straight toward the MVP. Beside these findings, systolic PG over tricuspid valve was 57.9 mm Hg, and 6-min walk test was limited with only 124 m.

TEE measurements and leaflet motion confirmed dynamic MVP obstruction with a mean PG of 9.3 mm Hg (Vmax: 246 cm/s) and an increased pressure half time of 229 ms. Detailed visualization of MVP revealed premature closure of the posterior leaflet of MVP (Fig. 1). Color Doppler imaging clearly showed the eccentric ppAR jet striking the 2 MVP leaflets, forcing the posterior disk to close prematurely, whereas the anterior disk stayed wide open until the end of diastole. 3D imaging clearly visualized the MVP in a realistic en face perspective with the asynchronous disk closure demonstrated in direct comparison to fluoroscopy (Fig. 1).

Importantly, 3D-TEE demonstrated the MVP implanted in an antianatomic orientation with a 45° counterclockwise rotation from the anatomic orientation toward the left atrial appendage (Fig. 1), with the consequence that the ppAR jet did not strike the anterior leaflet in a frontal direction but from the side with a relevant portion of the ppAR jet impinging directly on the posterior leaflet (streamline of jet flow with asterisk). Although the phenomenon of diastolic leaflet oscillation caused by aortic regurgitation that impinges on the anterior or posterior mitral leaflet and impedes its normal opening pattern has been discussed (1), such a mechanism was never considered before to appear also in mechanical bileaflet MVP.

Because a surgical intervention would have been the fifth open-chest heart surgery and based on the hypothesis that mitral stenosis was not a primary MVP dysfunction, but a secondary malfunction caused by the ppAR jet, we decided to close the paraprosthetic AVP leak by percutaneous occluder implantation. In a catheter intervention via a femoral arterial access, 2 occluder devices (Amplatzer Vascular Plug III 12 × 5 mm and 10 × 5 mm) were successfully implanted into a slitlike paraprosthetic AVP leak (Fig. 2).

After device closure, TTE revealed a significantly reduced mean PG over the MVP of 5.0 mm Hg. Maximum PG was decreased to 14 mm Hg (Vmax: 160 cm/s) and pressure half time was also significantly reduced to 77 ms. Both TTE and TEE demonstrated residual mild-to-moderate ppAR, but with the direction of the regurgitant jet changed in a way not impinging on the MVP leaflets