Web supplement:

Echocardiographic analysis of the aortic valve in the context of valve repair surgery

In addition to the precise analysis of the valve, a complete TEE examination (1) should be performed before surgical incision and the findings reviewed in detail with the surgeon.

Table S1 (see Supplemental Digital Content 1, http://links.lww.com/AA/A125) lists the useful TEE planes that are to be combined for a complete assessment of aortic valve morphology and for analysis of the regurgitation mechanism. **Video clips 1** (see Supplemental Digital Content 2**,** http://links.lww.com/AA/A126), **2** (see Supplemental Digital Content 3**,** http://links.lww.com/AA/A127), and **3** (see Supplemental Digital Content 4**,** http://links.lww.com/AA/A128) show echocardiographic analysis of normal and regurgitant aortic valves (see video clip captions below).

We propose in **Fig S1** (see Supplemental Digital Content 5, http://links.lww.com/AA/A129) an algorithm for the echocardiographic analysis of a regurgitant aortic valve in the context of possible AV repair. Beginning in the midesophageal aortic valve short-axis (ME AV SAX) view at about 30° to 60° allows for the analysis of the symmetry and the number of the cusps. The observation of bicuspid aortic valves may explain the aortic regurgitation mechanistically due to the frequent presence of a raphé, asymmetric cusps with associated prolapse, and aortic root dilation. Application of color-flow Doppler permits location of the origin of a regurgitant jet at one commissure, along a coaptation line, or in the middle of one cusp, but it is important to not cut through the valve obliquely. .

The midesophageal aortic valve long-axis (ME AV LAX) view allows for diameter measurements made at end diastole at the level of (1) the aortic annulus, (2) the widest cross-section at the sinuses of Valsalva, (3) the sinotubular junction (STJ), and (4) the ascending aorta 1 cm beyond the STJ (2,3) **(Video clip 1, http://links.lww.com/AA/A126) (Fig. 2a)**. Normal values for these diameters are related to age and body surface area and measured diameters can be plotted on available published nomograms (2,4). Accepted values are: aortic annulus: 1.9±0.2 cm (limits 1.4-2.6 cm), sinuses of Valsalva: 2.8±0.3 cm (limits 2.1-3.5 cm), STJ: 2.4±0.4 cm (limits 1.7-3.4 cm), Ascending aorta: 2.6±0.3 cm (limits 2.1-3.4 cm) (5). In case of distal dilation, a measurement of the most dilated part of the ascending aorta should also be performed.

The cusp coaptation length also can be measured at end-diastole and corresponds to the length from the base to the tip of apposition of the anteriorly located right coronary cusp with its posteriorly located counterpart, either the non- or the left coronary cusp depending on the position and alignment of the probe. The normal value is between 4 and 10 mm.

In this view, color-flow imaging enables not only the analysis of the origin but also importantly, the orientation of any regurgitant aortic jet, central or eccentric, depending on the presence of a cusp prolapse. (6,7).

Both the transgastric (TG LAX) and deep transgastric long-axis (deep TG LAX) views enable the visualization of the aortic root and allow a regurgitant flow analysis across the valve **(Video clip 3, http://links.lww.com/AA/A128)**. Rotation of the transducer from 0° to 160° may be required depending on the heart's position in the chest. However, with the aortic valve in the far field, a detailed anatomic assessment is not precise, and the intensity of the jet may be underappreciated.

Evaluation of the severity of the aortic insufficiency (AI) should be based on a combination of specific and supportive indices along with quantitative parameters as defined in the American Society of Echocardiography (ASE) guidelines (8) **(Table 1, Fig S2** [see Supplemental Digital Content 6, http://links.lww.com/AA/A130] and **video clips 2 [**http://links.lww.com/AA/A127] and **3 [**http://links.lww.com/AA/A128]**)**. In central jets, the measurement of the proximal jet width and its ratio to the LVOT is recommended, associated if possible with the measurement of the vena contracta that provides an estimate of the size of the effective regurgitant orifice area (9). The jet width / LVOT width ratio method tends to underestimate the severity of eccentric jets. The rate of deceleration of the diastolic regurgitant jet and the derived pressure half-time (PHT) is easily measured with continuous wave (CW) Doppler if a view can been obtained with the jet direction parallel to the ultrasound beam to allow recording of diastolic velocities of the regurgitant jet. A value > 500 ms is usually compatible with mild AI, while a value < 200 ms is consistent with severe AI (8,10). This value is, however, affected by many factors such as diastolic compliance of the left ventricle (LV) and LV and aortic diastolic pressures and should therefore be used with caution in anesthetized patients (8,11,12). Recently, the principle of proximal isovelocity surface area (PISA) has been applied to central and eccentric AI jets, allowing measurement of quantitative parameters such as the effective regurgitant orifice area, the regurgitant volume, and regurgitant fraction (13-15).

Post-Repair TEE: General Principles.

Following weaning from CPB, a complete evaluation of the surgical procedure is performed **(Table S2,** see Supplemental Digital Content 7, http://links.lww.com/AA/A131**).** In order to evaluate the adequacy of AV repair, three important parameters need to be analyzed: the level and the length of the aortic cusps coaptation and the presence of a residual AI. This analysis is described in the main text.

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Fig S1: **Proposed algorithm for echocardiographic analysis of a tricuspid regurgitant aortic valve in the context of valve repair surgery.**

Examination should begin in the ME AV SAX view determining the origin of the regurgitant jet. Then, the ME AV LAX view helps to analyze the direction of the jet and allows for root measurements. The use of a classification helps to determine the repairability of the lesion and guides the surgical procedure. It is important to keep in mind that lesions can be combined.

AML: anterior mitral leaflet; AVJ: aortoventricular junction; IVS: interventricular septum; ME AV LAX: midesophageal aortic valve long axis; ME AV SAX: midesophageal aortic valve short axis; LCC: left coronary cusp; NCC: non-coronary cusp; RCC: right coronary cusp; STJ: sinotubular junction.

Figure S2

Continuous wave Doppler (CWD) and color flow Doppler recordings of the regurgitant jet in examples of mild and severe aortic insufficiency (AI).

In case of severe aortic insufficiency (AI), the deceleration rate of AI velocity is steeper and the pressure half-time (PHT) is shorter, the vena contracta is larger and both the effective regurgitant orifice area (EROA) and the regurgitant volume (RV) calculated by PISA are larger compared to the same parameters in mild AI.

Video Clip # 1

Analysis of the aortic valve

A. ME AV SAX view.

Left. Midesophageal aortic valve short-axis view of a normal aortic valve. The three cusps are identified.

Right. Color flow Doppler shows no aortic insufficiency during diastole.

B. ME AV LAX view.

Left. Midesophageal aortic valve long-axis view of a normal aortic root. The shape of the root is normal and the sinotubular junction is well depicted.

Right. Color flow Doppler shows no aortic regurgitation during diastole.

C. Still frame. ME AV LAX view.

Normal aortic root in the midesophageal aortic valve long-axis view at end diastole. Measurements are made at four levels: A: the aortic annulus , B:the widest cross-section at the sinuses of Valsalva , C: the sinotubular junction, D: the ascending aorta 1cm beyond the sinotubular junction.

D. Still frame. ME AV LAX view.

The cusp coaptation is depicted (blinking bar) and its highest part reaches the mid-portion of the sinuses of Valsalva (line B).

Ao = ascending aorta, LA = left atrium, LV = left ventricle, LVOT = left ventricular outflow tract, NCC = non-coronary cusp , LCC = left coronary cusp, RCC = right coronary cusp, PV = pulmonary valve, RA = right atrium, RV = right ventricle.

Video Clip # 2

Aortic insufficiency (AI) analysis and quantification in the ME AV LAX view.

All the following loops and still frames correspond to the same patient with aortic insufficiency.

A. Still frame.

Measurement of the vena contracta in the ME AV LAX view.

The vena contracta is measured at the narrowest portion of the jet which is usually at the level of the aortic valve, immediately below the flow convergence region.

B. Still frame.

Measurement of the AI jet / LVOT width ratio in the ME AV LAX view, color M-mode.

This mode of assessment of AI severity is based on the ratio of the maximal proximal jet width to the left ventricular outflow tract diameter immediately below the aortic valve, within 1 cm of the valve. The measurements should be done at the same point of time and this method tends to underestimate the severity of eccentric jets.

Video Clip # 3

Aortic insufficiency (AI) analysis and quantification in the transgastric (TG) views.

Two TG views can help to analyze the aortic valve and to help in aortic insufficiency quantification.

A. Deep TG LAX view

Left. Obtained at zero degrees by TG approach, this view similar to the apical four-chamber view obtained by transthoracic echo permits vertical alignment of the left ventricular outflow tract, the aortic valve and the aortic root. A detailed anatomic assessment of the valve is difficult but sometimes feasible allowing analysis of the cusp coaptation (see also video clip 6).

Right. Good alignment with color flow Doppler allows for analysis of the flow across the aortic valve both during systole and diastole. However the intensity of the regurgitant jet may be underappreciated.

B. TG LAX view

Obtained by rotation of the transducer from 0 to 160 degrees, this view also sometimes permits flow analysis across the aortic valve.

Gradient measurement

It is often feasible to align the continuous wave (CW) Doppler beam with the aortic outflow in one of the two TG views described above. This allows one to measure peak and mean velocities through the aortic valve and hence to calculate peak and mean gradients.

C. Still frames TG LAX view

In this case of pure aortic insufficiency, parallel alignment of the Doppler beam permitted measurement of a systolic mean velocity of 102 cm/sec and peak velocity of 150 cm/sec corresponding respectively to mean and peak gradients of 4.8 mmHg and 8.9 mmHg.

D. Still frames: Pressure Half-time (PHT) measurement

PHT corresponds to the rate of deceleration of the diastolic regurgitant jet and reflects the rate of equalization of aortic and left ventricular pressures. In this case PHT is measured at 498 msec corresponding to a moderate aortic insufficiency.

PISA measurements

E. TG LAX view

After a TG long-axis view has been obtained, zoom is applied to the aortic valve and the Nyquist limit of the aliasing velocity is shifted towards the direction of flow (in this case at 39 cm/sec). The radius of the hemispheric shell of the aliased velocity is then measured.

F. Still frame

CW Doppler is applied to the regurgitant jet and an envelope is traced.

Peak AI velocity and the velocity time integral (TVI) are so measured and allow calculation of both the effective regurgitant area (EROA) and the regurgitant volume.

Ao = ascending aorta, AoV = aortic valve, EROA = effective regurgitant orifice area, LA = left atrium, LV = left ventricle, Mi V = mitral valve, PISA = Proximal Isovelocity Surface Area, RV = right ventricle, TVI = time velocity integral,