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All that glitters is not gold: can videodensitometry replace echocardiography for the assessment of paravalvular aortic regurgitation?

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The clinical impact of paravalvular regurgitation (PVR) following surgical aortic valve replacement (SAVR) varies depending on the type of valve prosthesis, implant location, and means of delivery. In the aortic position, the incidence of prosthetic PVR is 2%-10%[1]. A meta-analysis of 12 clinical studies showed that a successful transcatheter closure of PVR (reduction of ≥1 grade) translated into lower cardiac mortality (odds ratio [OR] 0.08, confidence interval [CI]: 0.01-0.9) and greater improvement in New York Heart Association (NYHA) functional class or haemolysis (OR 9.95, CI: 2.1-66.7) with fewer repeat operations (OR 0.08, CI: 0.01-0.4)[2]. A random effects meta-analysis (including 604 patients from five observational studies) showed no significant difference between the two treatment strategies in terms of all-cause mortality (risk ratio 1.05, 95% CI: 0.63 to 1.76)[3]. Societal guidelines currently recommend transcatheter closure as an alternative to open surgery in patients with severe PVR at high risk for conventional surgery with anatomic features suitable for transcatheter therapy, after discussion with the Heart Team (class of recommendation IIa, level of evidence B)[4,5].

Conventional cineangiography with an aortic root injection of radiographic dye has long been used for intraprocedural determination of the severity of aortic regurgitation (AR)[6]. However, standard angiographic grading, while helpful in extremes, may not correlate well with quantitative assessment of AR severity, and cannot reliably distinguish central from paravalvular regurgitation. In the Interventional Flashlight case report by Teixeirense et al[7], the authors use quantitative videodensitometry (VD) to assess the severity of PVR before and after transcatheter closure of SAVR PVR. Although preprocedural assessment of SAVR PVR can be accomplished by computed tomography (CT), cardiac magnetic resonance (CMR) or echocardiography, intraprocedural guidance typically requires transoesophageal echocardiography (TEE)[1], as was used by Teixeirense et al, obviating the need for additional imaging modalities for this entity. In addition, TEE is typically also required to determine the type and size of the PVR closure device[1,8].

Article, see page 1260

Thus, although there seems little need for quantitative VD for SAVR PVR, transcatheter aortic valve implantation (TAVI)

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is frequently performed under conscious sedation where the assessment of PVR by echocardiography falls to transthoracic imaging[9], which may be limited by physical challenges (i.e., the supine position and access to optimal windows) as well as technical challenges (i.e., acoustic shadowing). Quantitative VD has been proposed as a more reproducible measure of AR following TAVI[10-12]. Unfortunately, the strict imaging protocol required (preprocedural determination of optimal projection angle [OPA], constant contrast infusion rate, optimal location of catheter tip, etc.) has previously limited the general applicability of this method. Using the aortic root as the reference region and using a limited region of the left ventricular outflow tract (LVOT) to reduce contrast overlap, a ratio of LVOT-to-aortic (LVOT:Ao) density ratio of >0.17 corresponded to >mild AR (defined by echocardiographic assessment); however, an average of four cycles improved accuracy[11]. Compared to regurgitant fraction by CMR, a VD LVOT:Ao ratio of ≥10% corresponded to >mild PVR, whereas a ratio of ≥25% corresponded to moderate-to-severe PVR[12].

Quantitative VD, however, has a number of limitations in the high surgical risk and TAVI population. The assessment requires additional intraprocedural time to determine the OPA, a specific injection protocol that necessarily increases the contrast burden in each case, and fails to discriminate transvalvular regurgitation from PVR – important in determining the appropriate intraprocedural treatment following TAVI (i.e., post-dilatation or valve-in-valve). Intraprocedural haemodynamics have also been used[13,14] but similarly suffer from the dependence on heart rate, an inability to distinguish central from paravalvular regurgitation and, in addition, significant overlap of mild and moderate PVR grades, the latter grade being associated with an increase in mortality post TAVI[15].

Echocardiography thus remains the preferred method for assessing PVR, since this imaging modality can identify the location (including central versus paravalvular), number and size of the PVR jets, and provide a multi-parametric assessment in a continuous, physiologic manner. Although a 5-grade scheme has been proposed for research protocols[16], this scheme can be reduced to the typical 3-grade scale advocated by the guidelines **(Table 1)**. Whereas grading of surgical or transcatheter AR is similarly multi-window and multi-parametric, grading of PVR following TAVI has important caveats[9]:

1. Circumferential extent should be assessed as the sum of the individual small jets and not the arc that includes non-regurgitant spaces due to the stent frame or calcific leaflets. To assess the jet number and regurgitant orifice location and size accurately, meticulous scanning is required to identify the origin of the jets and confirm their path into the LVOT.
2. Given the frequent presence of ventricular and aortic compliance abnormalities in this patient population, mitral E:A ratio, pressure half-time and holodiastolic reversal of flow in the descending aorta should be used with caution in isolation but may have utility when comparing a baseline to a post-TAVI flow pattern.
3. Jet length or jet area should not be used to assess the severity of AR following TAVI since these jets are frequently eccentrically directed, constrained by the LVOT, or entrained within the LVOT, leading to rapid jet broadening.
4. Both quantitative Doppler and three-dimensional colour Doppler may be used to assess regurgitant orifice area and regurgitant volume, with the caveat that, in the acute setting, lower regurgitant volumes may be associated with haemodynamically severe PVR.

In summary, although quantitative VD is feasible, the overlap of AR grades, inability to localise the PVR jet or distinguish paravalvular from central regurgitation, and increased contrast use relegate it (along with haemodynamic measures) to an adjunctive tool, with echocardiography being the diagnostic test of choice in all guidelines. The echocardiographic quantitation of PVR is however nuanced, and a multi-window, multi-parametric assessment should be performed.

Conflict of interest statement

R. Hahn reports speaker fees from Boston Scientific Corporation and Baylis Medical; consulting for Abbott Structural, Edwards Lifesciences, Gore & Associates, Medtronic, NaviGate, Philips Healthcare and Siemens Healthcare; non-financial support from 3mensio and GE Healthcare. She is Chief Scientific Officer for the Echocardiography Core Laboratory at the Cardiovascular Research Foundation for multiple industry-sponsored trials, for which she receives no direct industry compensation.

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Table 1. Evaluation of severity of prosthetic aortic regurgitation after SAVR or TAVI.

Echocardiography: TTE and/or TEE		PVR severity		
		Mild	Moderate	Severe
Structural parameters				
Surgical valve structure and motion		Usually normal	Variable*	Variable*
Transcatheter valve position		Usually normal	Variable*	Frequently abnormal
Transcatheter valve shape and leaflet morphology		Usually normal	Variable*	Frequently abnormal
Doppler parameters				
Qualitative (jet features)				
Proximal flow convergence (CD)		Absent	May be present	Often present
Jet density (CWD)		Incomplete or faint	Dense	Dense
Diastolic flow reversal (PWD)**	Proximal descending aorta †	Brief, early diastolic only	May be holodiastolic	Holodiastolic (end-diastolic velocity ≥20 cm/s)
	Abdominal aorta	Absent	Absent	Present
Semi-quantitative parameters				
Vena contracta width (cm) (CD)		<0.3	0.3-0.6	>0.6
Vena contracta area (cm^2)‡ (2D/3D CD)		<0.10	0.10–0.29	≥0.30
Jet width: LVOT diameter (%)		<30	30-65	>65
Circumferential extent of PVR ¶ (%) (CD)		<10	10-29	≥30
Jet deceleration rate (PHT, ms) ∂ (CWD)		Variable Usually >500	Variable 500-200	Steep Usually <200**
Quantitative parameters ø				
EROA, cm^2		<0.10	0.10-0.29#	≥0.30#
Regurgitant volume (mL)		<30	30-59#	>60#
Regurgitant fraction (%)		<30	30-49	≥50

* The likelihood of structural or motion abnormalities depends on whether regurgitation is central or paravalvular. **May not be specific for severe aortic regurgitation in the setting of abnormal aortic or ventricular compliance. † Influenced by LV and aortic compliance, particularly in this population. ‡ The vena contracta area is measured by planimetry of the vena contracta of the jet(s) on 2D or 3D colour Doppler images in the short-axis view. ¶ Measured as the sum of the circumferential lengths of each regurgitant jet vena contracta (not including the non-regurgitant space between the separate jets) divided by the circumference of the outer edge of the valve. Circumferential extent of PVR best not to be used alone, but in combination with vena contracta width and/or area. ∂ Dependent on aortic compliance; considerably limits its utility in the elderly population, also influenced by heart rate. ø When total stroke volume is calculated from LV volumes, use of 3D echocardiography and preferably contrast echocardiography is recommended to avoid underestimation of LV volumes, RVol, and RF. RVol cut-offs may be lower in low-flow states. # May be functionally important at lower values depending on the acuteness of PVR, size and function of the LV. Modified with permission from Zoghbi et al[9] and Lancellotti et al[8].

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