JACC: CARDIOVASCULAR INTERVENTIONS VOL. 11, NO. 3, 2018

PUBLISHED BY ELSEVIER

EDITORIAL COMMENT

Quantifying Paravalvular Aortic Regurgitation in Transcatheter Aortic Valve Replacement

The Pursuit of Perfection*

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Over the past decade, transcatheter aortic valve replacement (TAVR) has witnessed significant improvements in operator experience, reduction in complications, and development in device technology to improve the safety and efficacy of aortic valve replacement. Nevertheless, improvement is always possible, especially as we move TAVR into lower-risk groups and younger patients. In this regard, optimizing the TAVR result by reducing paravalvular aortic regurgitation (AR) is an important goal (1). Although valve design, valve sizing, and valve positioning are important targets, accurate diagnosis of paravalvular AR at the time of valve placement is imperative in order to use procedural interventions such as valve post-dilation and/or paravalvular regurgitation (PVR) closure. Though not fully understood, it is likely that limitations in accurate quantification of PVR (i.e., underestimation) provides the explanation for why many investigators have demonstrated an association between even "mild" PVR and worse outcomes (2).

SEE PAGE 287

In this issue of *JACC: Cardiovascular Interventions*, Abdel-Wahab et al. (3) aim to improve this diagnostic step. They used a novel software to measure the change in contrast density in the left ventricular (LV) outflow tract after aortic root contrast injection. They sought to correlate the novel in-lab quantitative videodensitometric aortic regurgitation (VD-AR) assessment with the well-established assessment by cardiac magnetic resonance. By retrospectively analyzing images from 135 patients, the investigators demonstrated a significant correlation ($r = 0.78$; $p < 0.001$) between the 2 modalities. They established that a VD-AR >10% demonstrated excellent sensitivity and good specificity for mild AR; and a VD-AR >25% demonstrated excellent sensitivity and specificity for moderate-severe AR.

In contemporary practice, assessing AR generally takes into account some or all of 3 specific modalities: echocardiography, hemodynamics, and aortography (**Figure 1**). Although transthoracic and transesophageal echocardiography have long been a mainstay for diagnosis of type and degree of AR, they may be sometimes limited in accuracy and reproducibility (4,5). Nevertheless, echocardiography is an important tool in the procedure suite for AR assessment, in addition to other potential complications, and is almost indispensable for distinguishing paravversus valvular AR. We also place a substantial emphasis on hemodynamic assessment in our TAVR procedures, carefully comparing both aortic diastolic and LV end-diastolic pressure before and after TAVR, the quality of the dichrotic notch after TAVR, slope of the LV diastolic pressure increase, and response of the LV end-diastolic pressure and aortic diastolic pressure to the long R-R interval following a premature ventricular contraction.

Aortography is also an extremely important part of our post-TAVR implantation routine. It allows assessment of coronary flow, confirmation of depth of implantation, insight into annular trauma, and most importantly, analysis of AR. Contrast aortography has

*Editorials published in *JACC: Cardiovascular Interventions* reflect the views of the authors and do not necessarily represent the views of *JACC: Cardiovascular Interventions* or the American College of Cardiology.

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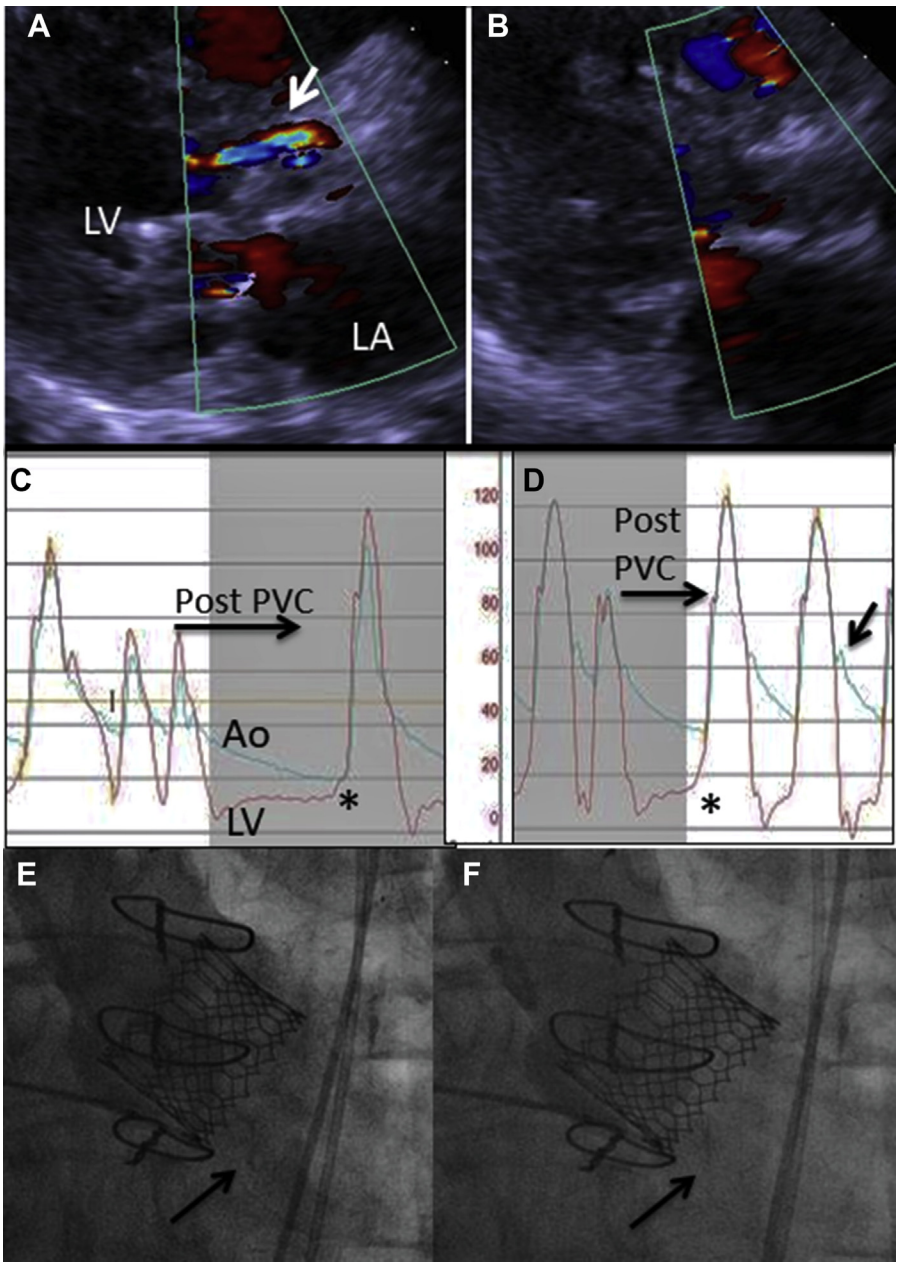
ISSN 1936-8798/$36.00 https://doi.org/10.1016/j.jcin.2017.10.005

FIGURE 1 **Integrated Approach to Assess Aortic Regurgitation After TAVR**



Transthoracic echocardiography demonstrates anterior PVR **(arrow)** before **(A)** and after **(B)** post-dilation. Hemodynamic evaluation demonstrates lack of aortic dichrotic notch, aortic diastolic/LVEDP equalization with long R-R interval after a PVC **(asterisk)** before post-dilation **(C)**, and prominent dichrotic notch **(arrow)** and good aortic diastolic/LVEDP separation **(asterisk)** after post-dilation **(D)**. Aortography demonstrates LVOT opacification during diastole **(arrow)** after TAVR **(E)** and corrected by post-dilation **(F)**. Ao = Aorta; LA = left atrium; LV = left ventricle; LVEDP = left ventricular end-diastolic pressure; LVOT = left ventricular outflow tract; PVC = premature ventricular contraction; PVR = paravalvular regurgitation; TAVR = transcatheter aortic valve replacement.

been used for grading the severity of AR for over half a century. In the original paper by Sellers et al. (6), 30 to 40 ml of dye was injected over 1 to 1.5 s in the aortic root in the anteroposterior and lateral projections to estimate AR. The Sellers et al. (6) method was to compare the relative opacification of the aortic root and LV in a subjective manner. Unfortunately, this method has only moderate correlation to

the degree of AR determined by more quantitative measurements as demonstrated by the authors (3).

The current paper (3) is, therefore, an important step forward to better establish objective parameters for AR classification by aortography. Importantly, the authors very clearly address the limitations of the current study, which also allows them to provide the steps for a successfully protocolized workflow. For instance, 57% of patients (208 of 364) could not be analyzed due to overlap of the LV with the descending aorta or diaphragm. The authors, therefore, explain their method to reduce overlap with other radiopaque structures for accurate VD-AR measurement.

Sellers used 30 to 40 ml of dye in his original paper, and the patients in this study had 25 to 30 ml of dye injected into the root (3). The authors go on to provide a protocol using 20 ml of dye that can be further reduced to 8 ml of dye with an electrocardiogram-gated injection system. However, an important point that is not addressed is the pressure at which the contrast is delivered via the currently used pressure-triggered injectors. Although the intent may be to inject 20 ml of dye in 1 s, injectors may inject substantially less dye per second if the pressure limit is not set appropriately (typically 1,000 psi for 5-F catheter). Therefore, the actual injection rate (not intended) should be reported in future studies to further validate contrast aortography.

Because many patients with chronic kidney disease come for TAVR, we have gotten used to using 50:50 diluted contrast medium for both implantation aortography and post-TAVR aortography, thereby reducing the contrast used for both of these steps to a total of 15 to 20 ml of dye. Whether diluted contrast can be effectively used in the VD-AR system provided here is not clear but would be of interest. In a similar vein, it appears that the VD-AR process requires overlay of a computed tomography (CT)-based region of interest on the fluoroscopy image; whether non-contrast CT is adequate for creating this region of interest remains unclear. We have demonstrated previously the use of noncontrast CT–fluoroscopic overlay, though it is unclear from this report whether that is feasible for the VD-AR process in chronic kidney disease patients (7).

The authors also address that many of their patients (40%) were in atrial fibrillation, and that despite a relatively similar heart rate, this resulted in a wider agreement limit than patients in normal sinus rhythm (3). Due to the variability in diastolic phase duration in atrial fibrillation patients, whether controlling the heart rate to an even greater degree or acquiring more beats would make the process more accurate would be important for future studies. Another area of importance is the feasibility and efficiency of using this method in procedure suites that are not routinely using it, and the ease of bedside manipulation (vs. off-line analysis as performed in the current paper [3]). The authors suggest that the VD-AR process may require only 3 min, though a larger study is currently underway. In the current era, where procedural time needs to be efficient, an automated analysis is essential for the success of this diagnostic modality.

In routine practice, no one method of AR assessment is adequate. In reality, the integration of echocardiography, aortography, and hemodynamics provides the most accurate answer with respect to cause and severity of PVR. As Abdel-Wahab et al. (3) demonstrate here, making angiographic quantification more objective is an important step forward. Taking these diagnostic developments into account, along with future device improvements, should allow us to move further to our goal of providing a perfect TAVR result to all of our patients.

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KEY WORDS aortic regurgitation, paravalvular regurgitation, TAVR