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EDITORIAL COMMENT

Hybrid Imaging to Assess Prosthesis–Patient Mismatch After TAVR

In Search of Validation*

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Almost 40 years ago, Rahimtoola (1) introduced the concept of prosthesis-patient mismatch (PPM) "when the effective prosthetic valve area, after insertion into the patient, is less than that of a normal human valve." Current guidelines define presence of PPM when the prosthetic effective orifice area indexed to body surface (EOAi) is <0.85 cm^2/m^2 (2,3), with abundant evidence suggesting a deleterious effect of PPM on both all-cause and cardiac mortality (4).

Echocardiography is the main imaging modality used for assessment of prosthetic valve function, with valve area being derived from the continuity equation:

$$LVOT\ area \times LVOT\ TVI = EOA \times Aortic\ TVI,$$

where LVOT is the left ventricular outflow tract, TVI the time velocity integral, and EOA effective orifice area. The LVOT is assumed to have a circular shape, with the area being calculated as:

$$LVOT\ Area = \frac{\pi \times LVOT\ diameter^2}{4}.$$

However, because the LVOT is elliptical in shape, a hybrid approach combining computed tomography (CT)-derived LVOT measurements with echo Doppler-derived flow in the continuity equation has been proposed to correct for the elliptical LVOT shape (5,6).

In this issue of *JACC: Cardiovascular Interventions,* Mooney et al. (7) compare this hybrid method with traditional echocardiography in the assessment of PPM in 765 patients from a registry of the PARTNER (Placement of Aortic Transcatheter Valves) II trial. The major findings of this paper are that following transcatheter aortic valve replacement (TAVR): 1) the median EOAi calculated by the hybrid method was 15% larger than by traditional echocardiography; 2) by using the same cutoff values to define PPM, the hybrid CT method halves the incidence of PPM (from 45% by standard echo to 24%); and 3) neither CT- nor echo-based calculated EOAi was associated with all-cause mortality or rehospitalization. However, each of these findings requires further discussion before embracing the hybrid CT-echo method.

First, the true LVOT area below the valve plane (which is also the site where Doppler measurements are taken) is elliptical, and as such, underestimated by using the LVOT minor diameter in traditional echo calculations. It comes, therefore, as no surprise that by substituting a direct, more anatomically correct LVOT area measurement from CT into the continuity equation, the calculated aortic (prosthetic) valve area increases. Indeed, the magnitude of changes in EOAi noted in this study is similar to previous reports comparing CT and echo (5,6). Although using a very precise measure of LVOT area is conceptually very appealing, we must remember this approach has not yet been validated in clinical practice. Indeed, for the traditional echo approach, concordance of Doppler-derived aortic valve gradient with invasively measured pressure gradient (8) and of calculated aortic valve area by continuity equation with valve area by the Gorlin formula (9) have been verified by simultaneous echo-catheterization studies. To the best of our knowledge, such

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validation studies have not been reported for the hybrid method. Furthermore, EOAi and aortic valve area calculated by conventional approach have been time and again linked to patient outcomes (2–4). Adopting a different methodology without direct validation, and without additional data or clear implications to patient outcomes, may be premature at this time.

Second, PPM exists for the individual patient independent of how we estimate EOAi. Indeed, a patient with symptomatic PPM and an EOAi of <0.85 cm^2/m^2 by echo will not be less dyspneic because the calculated EOAi by CT is now >0.85 cm^2/m^2. In this sense, the observed lower incidence of PPM with the CT method is artificial, as nothing changed for the individual patient. Furthermore, neither method is perfect: echo erroneously assumes a circular LVOT, whereas CT assumes pre-TAVR LVOT measurements are the same as post-TAVR LVOT measurements; both assume flow through the LVOT is laminar, with identical flow velocities throughout the entire cross section. By far the more important question is which method best identifies patients with true PPM? Given the robust evidence on echo-derived PPM influencing outcomes after surgical aortic valve replacement (4), as well as the ability to predict lack of left ventricular mass regression in the current study, echocardiography-derived EOAi remains the gold standard at this time.

Third, and probably the most important finding of this study, is the lack of association between PPM (by both the echo and CT method; EOAi analyzed as both continuous and categorical variable) and mortality and rehospitalization within 1 year post-TAVR. These findings are in contrast with what occurred in high-risk patients from the PARTNER I trial, where PPM after TAVR was associated with poor outcomes (albeit after excluding periprosthetic regurgitation) (10). Similar to the present study, Thyregod et al. (11) reported no significant differences in major adverse cardiac events, cardiac-related hospitalizations, or New York Heart Association functional class within the first 2 years post-TAVR for patients with versus those without severe PPM. Taken together, these findings suggest PPM may be clinically less important after TAVR than after surgical aortic valve replacement, especially considering the lower incidence of PPM post-TAVR.

Lastly, why should one use a hybrid CT-echo approach instead of traditional echocardiographic assessment? Current echo-based definitions for PPM are borne out of outcomes research, and echo measurements were validated against invasive hemodynamic studies. Also, why should we assume the CT and echocardiographic definitions for PPM are the same, that is, <0.85 cm^2/m^2? As the authors already pointed out, using CT LVOT area in the continuity increases the estimated valve area by 15% to 20%, and the cited published reports suggest a higher cutoff should be used for the CT-based definition of severe aortic stenosis. Given existing information, one would assume that the CT-based definition of PPM will follow a similar path: with cutoff values being 15% to 20% larger. As it stands, unless CT-based calculations provide additional clinical information, using 2 methods will only provide 2 estimated EOAi for each patient, and will only confuse an already complicated problem. Sometimes less is more.

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REFERENCES

1. Rahimtoola SH. The problem of valve prosthesis-patient mismatch. Circulation 1978;58:20–4.

2. Nishimura RA, Otto CM, Bonow RO, et al., American College of Cardiology/American Heart Association Task Force on Practice Guidelines. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2014;63:e57–185.

3. Zoghbi WA, Chambers JB, Dumesnil JG, et al. Recommendations for evaluation of prosthetic valves with echocardiography and Doppler ultrasound: a report from the American Society of Echocardiography's Guidelines and Standards Committee and the Task Force on Prosthetic Valves. J Am Soc Echocardiogr 2009;22:975–1014.

4. Head SJ, Mokhles MM, Osnabrugge RL, et al. The impact of prosthesis-patient mismatch on long-term survival after aortic valve replacement: a systematic review and meta-analysis of 34 observational studies comprising 27 186 patients with 133 141 patient-years. Eur Heart J 2012;33:1518–29.

5. Clavel MA, Malouf J, Messika-Zeitoun D, Araoz PA, Michelena HI, Enriquez-Sarano M. Aortic valve area calculation in aortic stenosis by CT and Doppler echocardiography. J Am Coll Cardiol Img 2015;8:248–57.

6. Kamperidis V, van Rosendael PJ, Katsanos S, et al. Low gradient severe aortic stenosis with preserved ejection fraction: reclassification of severity by fusion of Doppler and computed tomographic data. Eur Heart J 2015;36:2087–96.

7. Mooney J, Sellers SL, Blanke P, et al. CT defined prosthesis-patient mismatch downgrades frequency and severity, and demonstrates no association with adverse outcomes following TAVR. J Am Coll Cardiol Intv 2017;XX:xxx–xx.

8. Currie PJ, Seward JB, Reeder GS, et al. Continuous-wave Doppler echocardiographic assessment of severity of calcific aortic stenosis: a simultaneous Doppler-catheter correlative study in 100 adult patients. Circulation 1985;71:1162–9.

9. Oh JK, Taliercio CP, Holmes DR Jr., et al. Prediction of the severity of aortic stenosis by Doppler aortic valve area determination: prospective Doppler-catheterization correlation in 100 patients. J Am Coll Cardiol 1988;11:1227–34.

10. Pibarot P, Weissman NJ, Stewart WJ, et al. Incidence and sequelae of prosthesis-patient mismatch in transcatheter versus surgical valve replacement in high-risk patients with severe aortic stenosis: a PARTNER trial cohort-A analysis. J Am Coll Cardiol 2014;64:1323–34.

11. Thyregod HG, Steinbrüchel DA, Ihlemann N, et al. No clinical effect of prosthesis-patient mismatch after transcatheter versus surgical aortic valve replacement in intermediate- and low-risk patients with severe aortic valve stenosis at mid-term follow-up: an analysis from the NOTION trial. Eur J Cardiothorac Surg 2016;50:721–8.

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