Please note: Dr. Doltra is supported by a research grant from the European Society of Cardiology (ESC). Dr. Huppertz is a full-time employee of Siemens AG. Dr. Kelle received a Young Investigator Travel Award from the Council on Cardiovascular Radiology and Intervention of the American Heart Association to present some of the results of this study at the AHA Scientific Sessions 2013 in Dallas, Texas. All other authors have reported that they have no relationships relevant to the content of this work to disclose. Drs. Hamdan and Doltra contributed equally to this work.

REFERENCES

1. Hamdan A, Asbach P, Wellnhofer E, et al. A prospective study for comparison of MR and CT imaging for detection of coronary artery stenosis. J Am Coll Cardiol Img 2011;4:50–61.

2. Yoon YE, Kitagawa K, Kato S, et al. Prognostic value of coronary magnetic resonance angiography for prediction of cardiac events in patients with suspected coronary artery disease. J Am Coll Cardiol 2012;60:2316–22.

3. Hulten EA, Carbonaro S, Petrillo SP, Mitchell JD, Villines TC. Prognostic value of cardiac computed tomography angiography: a systematic review and meta-analysis. J Am Coll Cardiol 2011;57:1237–47.

4. Lipinski MJ, McVey CM, Berger JS, Kramer CM, Salerno M. Prognostic value of stress cardiac magnetic resonance imaging in patients with known or suspected coronary artery disease: a systematic review and meta-analysis. J Am Coll Cardiol 2013;62:826–38.

5. Kelle S, Nagel E, Voss A, et al. A bi-center cardiovascular magnetic resonance prognosis study focusing on dobutamine wall motion and late gadolinium enhancement in 3,138 consecutive patients. J Am Coll Cardiol 2013;61:2310–2.

Annulus Instead of LVOT Diameter Improves Agreement Between Echocardiography Effective Orifice Area and Invasive Aortic Valve Area

Calculating effective orifice area (EOA) in aortic stenosis (AS) relies on geometric assumptions regarding the left ventricular outflow tract (LVOT). There is no consensus on the optimal site for LVOT measurement on transthoracic echocardiography (TTE), with guidelines permitting flexibility (1). Given varied LVOT morphology and increased ellipticity below the annulus (2), we hypothesized that EOA calculated from the annulus diameter—as compared with subannular diameters—would improve agreement with aortic valve area (AVA) by invasive hemodynamics.

We examined 114 consecutive adult patients with symptomatic AS referred for transcatheter aortic valve implantation (TAVI) with complete TTE and invasive hemodynamics within 60 days, after exclusion of patients with greater than mild tricuspid regurgitation or inadequate studies. Two blinded, independent readers interpreted TTEs, and EOA was compared using diameters at the annulus and 0.5 and 1.0 cm subannular. LVOT was stratified as hourglass-shaped (LVOT diameter 0.5 cm below annulus greater than annulus diameter) or funnel-shaped (remaining cases). Invasive AVA was calculated using the Gorlin equation (mean of 3 thermodilution cardiac output measurements) and was corrected for the catheter size.

Mean age was 78.9 ± 8.9 years, and 61.4% (70 of 114) were male. Severe AS by invasive hemodynamics (AVA <1.0 cm^2) was present in 87.7% (100 of 114) of patients, whereas the remainder had moderate AS. There was no overall difference between mean AVA (0.75 ± 0.24 cm^2) and EOA using the diameter at the annulus (0.76 ± 0.23 cm^2, $p = 0.59$; mean difference -0.01 ± 0.21 cm^2, $r = 0.61$), 0.5 cm subannular (0.73 ± 0.25 cm^2, $p = 0.34$; mean difference 0.02 ± 0.23 cm^2, $r = 0.58$), or 1.0 cm subannular (0.78 ± 0.29 cm^2, $p = 0.23$; mean difference -0.03 ± 0.27 cm^2, $r = 0.51$) (**Figure 1**). Agreement within 0.20 cm^2 between AVA and EOA was observed in 71.9% (82 of 114) of cases using the annulus diameter, with reduced agreement using 0.5 cm (62.3%, 71 of 114, $p = 0.12$) or 1.0 cm (56.1%, 64 of 114, $p = 0.01$) subannular.

In patients with funnel-shaped LVOTs ($n = 47$), AVA and EOA using the annulus diameter were similar (0.74 ± 0.24 cm^2 vs. 0.77 ± 0.28 cm^2, $p = 0.30$; mean difference -0.03 ± 0.21 cm^2), whereas EOA was overestimated using the diameter 0.5 cm (0.83 ± 0.30 cm^2, $p = 0.006$; mean difference -0.09 ± 0.22 cm^2) and 1.0 cm (0.94 ± 0.34 cm^2, $p < 0.001$; mean difference -0.20 ± 0.26 cm^2) subannular. Among individuals with hourglass-shaped LVOTs ($n = 67$), AVA and EOA using the annulus diameter were similar (0.76 ± 0.25 cm^2 vs. 0.76 ± 0.20 cm^2, $p = 0.86$; mean difference 0.00 ± 0.21 cm^2), whereas EOA was underestimated using the diameter 0.5 cm (0.66 ± 0.18 cm^2, $p < 0.001$; mean difference 0.10 ± 0.20 cm^2) and 1.0 cm (0.67 ± 0.20 cm^2, $p = 0.001$; mean difference 0.09 ± 0.21 cm^2) subannular.

This study demonstrates that the EOA calculated from the annular diameter—rather than the LVOT diameter 0.5 or 1.0 cm below the annulus—results in the best agreement with the AVA determined by invasive hemodynamics in AS patients referred for TAVI. Although the overall mean differences between AVA and EOA using alternate diameters were not statistically significant, comparisons by LVOT morphology demonstrate meaningful differences. Specifically, mean EOA using the annular diameter was similar to AVA regardless of LVOT morphology, whereas use of an LVOT diameter below the annulus resulted in significant and meaningful overestimation of EOA in patients with funnel-shaped LVOTs and underestimation of EOA in those with hourglass-shaped LVOTs.

Study limitations include the use of AVA as the reference standard; although this has recognized limitations (3), it has historically been considered a reference standard (2,3). The study was limited to patients referred for TAVI, as invasive valve hemodynamics are often not routinely performed in other cohorts; therefore, a majority of subjects had severe

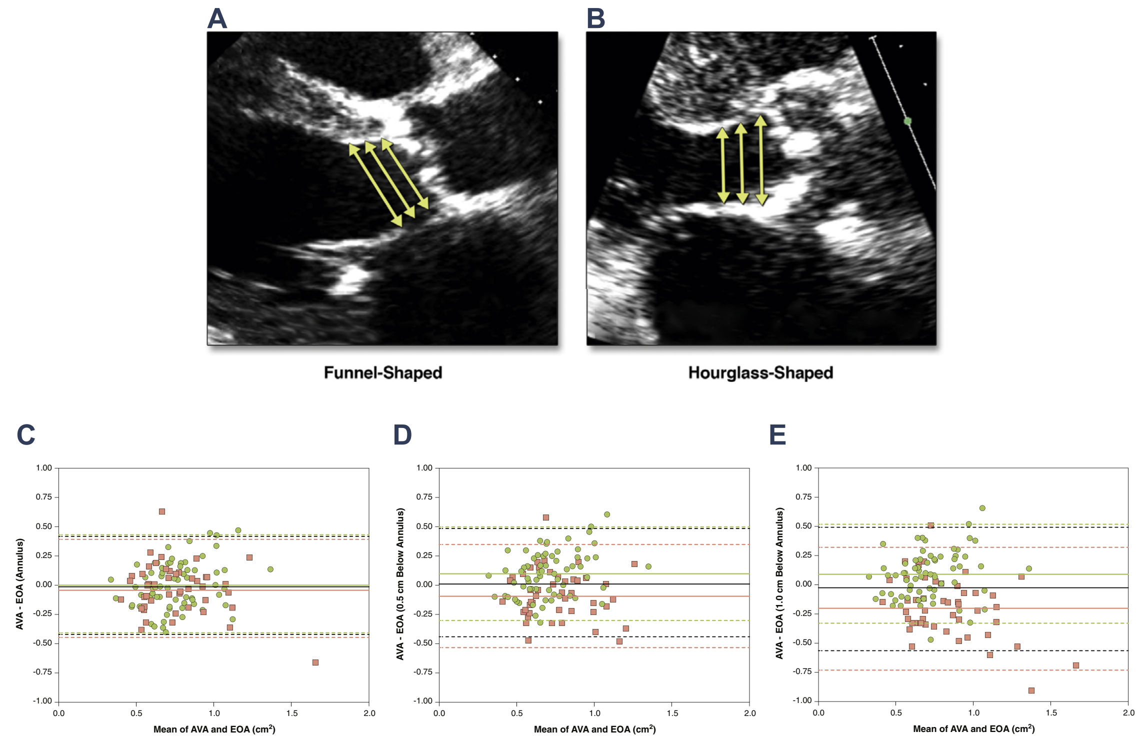

FIGURE 1 **Effect of Alternative LVOT Diameters on EOA**

These images demonstrate **(A)** funnel- and **(B)** hourglass-shaped left ventricular outflow tract (LVOT) morphologies. **Yellow arrows** depict locations of compared diameter measurements. Bland-Altman plots compare aortic valve area (AVA) by invasive hemodynamics to effective orifice area (EOA) by transthoracic echocardiography using **(C)** annulus diameter and at **(D)** 0.5 cm and **(E)** 1.0 cm below the annulus. **Black lines** demonstrate overall mean values **(solid lines)** and limits of agreement (**dashed lines**, ±2 SD). **Green circles and lines** depict individuals with hourglass-shaped LVOT, whereas **pink boxes and lines** depict those with funnel-shaped LVOT. Values are provided in the text.

AS. Although 3-dimensional TTE might improve LVOT measurement, it was not available and could not be assessed. Finally, although the annulus may not match the region of pulse-wave Doppler sampling, precise localization may be challenging, and the increasing ellipticity below the valve (2) may introduce a larger error.

These findings demonstrate that EOA using the annulus diameter results in the best agreement with invasive hemodynamics. In contrast, the use of subannular diameters results in significant overestimation or underestimation of EOA, depending on LVOT morphology.

Troy M. LaBounty, MD*
Rhonda Miyasaka, MD
Stanley Chetcuti, MD
Paul M. Grossman, MD
George Michael Deeb, MD
Himanshu J. Patel, MD
Anna Booher, MD
Smita Patel, MD
David S. Bach, MD

*Departments of Medicine and Radiology
University of Michigan Medical Center
1500 East Medical Center Drive
SPC 5853, Room 2365
Ann Arbor, Michigan
E-mail: labt@med.umich.edu

http://dx.doi.org/10.1016/j.jcmg.2014.03.021

Please notes: Dr. Chetcuti has served as a consultant to Medtronic. Dr. Grossman has received a research grant from Harvard University. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

REFERENCES

1. Baumgartner H, Hung J, Bermejo J, et al. Echocardiographic assessment of valve stenosis: EAE/ASE recommendations for clinical practice. Eur J Echocardiogr 2009;10:1–25.

2. Baumgartner H, Kratzer H, Helmreich G, Kuehn P. Determination of aortic valve area by Doppler echocardiography using the continuity equation: a critical evaluation. Cardiology 1990;77:101–11.

3. Grossman W. Grossman's Cardiac Catheterization, Angiography, and Intervention. 6th edition. Philadelphia: Lippincott Williams & Wilkins, 2000:197–207.