saline transthoracic echocardiography study showed a significantly larger shunt than pre-PFO closure. 3D TEE demonstrated residual shunting from the superior aspect of the left atrial disc (white arrow). The right atrial (RA) 3D TEE view revealed a prominent ridge of solid tissue, the ER (black dotted line), preventing the RA disc (white dotted line) from resting flush on the FO because the FO was partially obscured at its anterosuperior border by the high insertion of the ER. Flow was seen from the inferior edge of the RA disc through the PFO, which was "held open" by the "rigid" device.

A further example of this anatomy is shown in **Figure 1B**. To achieve complete PFO closure, we found either a softer more compliant device (Gore Helex septal occluder, W. L. Gore & Associates, Inc., Flagstaff, Arizona) (**Figure 1C**) or a smaller device where the left and right atrial discs can be placed independently (Premere device from St. Jude Medical, St. Paul, Minnesota) (**Figure 1D**) to be better suited. The identification of a prominent ER is essential to guide optimal device selection.

Anna C. Kydd, MD
Duncan McNab, MD
Patrick A. Calvert, MD, PhD
Stephen P. Hoole, DM
Sushma Rekhraj, MD
Horst Sievert, MD
Leonard M. Shapiro, MD
Bushra S. Rana, MD*
*Papworth Hospital
Papworth Everard
Cambridge CB23 2RE
United Kingdom
E-mail: bushra.rana@papworth.nhs.co.uk

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Comparison of Coronary Magnetic Resonance and Computed Tomography Angiography for Prediction of Cardiovascular Events

We compared coronary magnetic resonance angiography (CMRA) and coronary multislice computed tomography angiography (CTA) for prediction of cardiac events in patients with suspected or known coronary artery disease (CAD) scheduled for elective coronary angiography (ICA).

We included 110 consecutive patients with suspected or known CAD scheduled for ICA, reported in a previous study (1). Thirty-three (30%) had prior CAD. Each patient was examined in a clinical 3.0-T cardiac magnetic resonance (CMR) scanner (Achieva 3 Tesla, Philips, Best, the Netherlands) and a 64-slice computed tomography scanner (SOMATOM Sensation 64, Siemens Healthcare, Erlangen, Germany). Coronary assessment was performed as described previously (1). Follow-up data were collected by reviewing clinical records or by phone interviews. Cardiac events were defined as cardiovascular death, nonfatal myocardial infarction, need for revascularization, invasive angiography, or hospitalization attributable to cardiac causes. Events that occurred in the first 3 months were excluded.

Sixty-two patients (56.4%) had at least 1 significant lesion (50% luminal diameter stenosis in segments ≥1.5 mm with quantitative ICA as reference). Thirty-four (30.9%) had 1-vessel disease, 17 (15.5%) had 2-vessel disease, and 11 (10%) had 3-vessel or left main (LM) disease (1). The follow-up was 40 ± 16 months. Thirty-seven cardiac events were recorded, including 1 cardiac death (0.9%), 4 myocardial infarctions (3.6%), surgical revascularization (9 [8.2%]), or percutaneous revascularization (14 [12.7%]), and ICA or hospitalization (9 [8.2%]). Seven events that occurred in the first 3 months were excluded; 30 events were analyzed.

No significant differences in event-free survival were observed between coronary CTA and CMRA (log-rank test $p = 0.97$). No differences were observed when the analysis was performed based on the number of vessels affected (3-vessel or LM disease, $p = 0.97$; 2-vessel disease, $p = 0.60$; and 1-vessel disease, $p = 0.340$) or per-vessel (right coronary, $p = 0.79$; LM, $p = 0.99$; left anterior descendent, $p = 0.97$; and circumflex, $p = 0.99$). The hazard ratio was 4.69 (95% confidence interval: 1.80 to 12.24, $p = 0.002$) for positive versus negative coronary CTA and 3.17 (95% confidence interval: 1.36 to 7.36, $p = 0.007$) for CMRA (**Figure 1**).

Our findings were as follows: 1) the absence of coronary stenosis in CMRA or coronary CTA identifies patients at low risk for cardiac events; and 2) in patients with suspected or known CAD already scheduled for ICA, CMRA and coronary CTA provide similar prognostic information on an intraindividual basis.

The prognostic value of CMRA is not well known. One study (2) demonstrated more cardiac events in

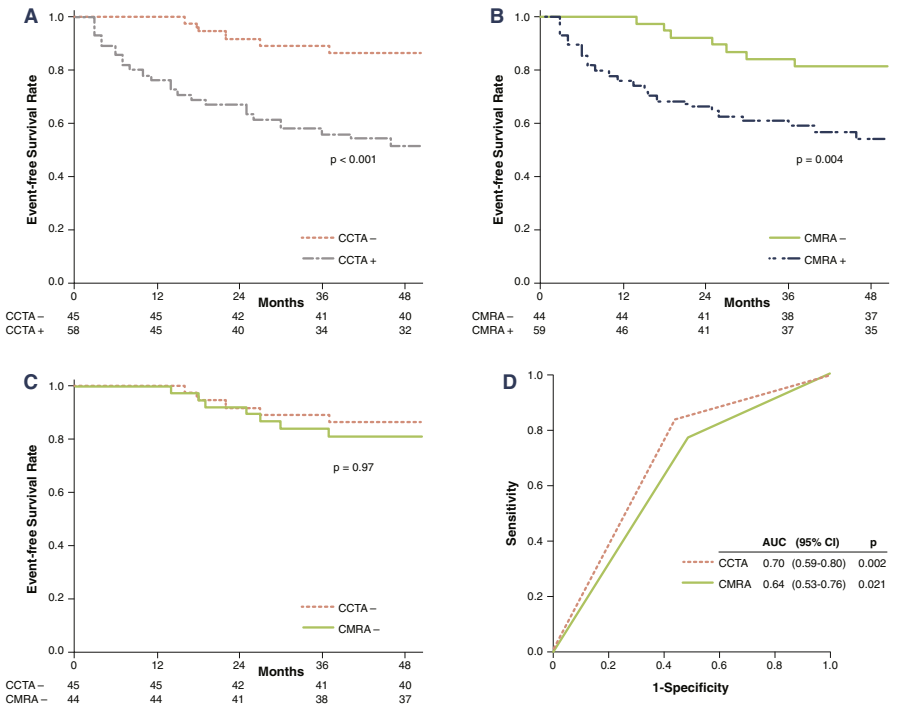

FIGURE 1 Kaplan-Meier Curves and Receiver Operating Characteristic Analysis

(A and B) Kaplan-Meier event-free survival curves for patients with (+) and without (−) significant stenosis on coronary computed tomography angiography (CTA) and coronary magnetic resonance angiography (CMRA). **(C)** Curves for patients without significant lesions on coronary CTA and CMRA. Coronary CTA displayed a trend toward a higher performance. **(D)** Receiver operating characteristic curves for event prediction. AUC = area under the curve, CI = confidence interval.

patients with stenosis on CMRA. Coronary CTA has been demonstrated to predict cardiovascular events (3). We showed no significant differences between CMRA and coronary CTA in prognostic assessment, although we did not evaluate the incremental utility of each technique to the other.

Cardiac MR provides prognostic information with regard to ischemia and viability assessment (4,5). Coronary angiography could be integrated into MR protocols to increase its prognostic value, although this has not been assessed. Our study included patients with an ICA indication; however, CMRA is intended for patients with low-intermediate CAD suspicion who do not necessarily require ICA. Although 30% of our patients had known CAD, our results did not change after its exclusion. The small sample size and number of hard events should be accounted for when the conclusions are analyzed; however, in our study, a minimum of 100 patients was sufficient to demonstrate that coronary CTA and MR angiography had equal predictive value (power >90%, McNemar test for noninferiority analysis). Finally, we did not perform a multivariate analysis. This should be further assessed.

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Ashraf Hamdan, MD
Adelina Doltra, MD
Alexander Huppertz, MD, PhD
Ernst Wellnhofer, MD, PhD
Eckart Fleck, MD, PhD
Sebastian Kelle, MD, PhD*

*German Heart Institute Berlin
Department of Internal Medicine/Cardiology
Augustenburger Platz 1
13353 Berlin
Germany
E-mail: kelle@dhzb.de

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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