



## The Year in Cardiology

# The Year in Cardiology 2012: echocardiography

Simon Ray\*

Department of Cardiology, University Hospitals of South Manchester, Manchester Academic Health Sciences Centre, Manchester, UK

Received 5 November 2012; accepted 8 November 2012

This paper was edited by Oliver Gaemperli, Cardiovascular Center, University Hospital Zurich, Zurich, Switzerland.

This brief review focuses on recent developments in the role of echocardiography for illuminating the pathophysiology of cardiac valve disease.

### Keywords

Echocardiography • Aortic stenosis • Mitral regurgitation • Paravalvular leak • Transcatheter aortic valve implantation

## Unravelling the complexities of aortic stenosis

Conventional criteria for severe aortic stenosis are an aortic valve area (AVA)  $<1 \text{ cm}^2$ , a mean gradient of  $>40 \text{ mmHg}$ , or a peak transvalvular velocity of  $>4 \text{ m/s}$ . A number of recent studies have demonstrated that these criteria may be individually inadequate and mutually inconsistent and that more sophisticated analysis may be required. The scenario of low-flow low-gradient aortic stenosis with impaired LV function is well recognized, but other haemodynamic variants are less well understood. In a landmark paper, Lancellotti *et al.*<sup>1</sup> used echocardiography to propose a new classification of aortic stenosis. They studied 150 patients with asymptomatic severe aortic stenosis, defined as an AVA  $<1 \text{ cm}^2$  and preserved LV function, defined as an LVEF  $>55\%$ . All had negative exercise tests. Subjects were divided into four groups on the basis of their peak gradient ( $>$  or  $<40 \text{ mmHg}$ ) and stroke volume index ( $>$  or  $<35 \text{ mL/m}^2$ ). Based on this, groups were defined as normal flow/high gradient, normal flow/low gradient, low flow/high gradient, and low flow/low gradient. The characteristics of the groups are summarized in *Table 1*. Patients with normal flow low gradient aortic stenosis (AS) have the best event-free survival, while those with low flow low gradient (LF/LG) have the worst outcome with low flow high gradient and normal flow high gradient intermediate. The LF groups were characterized by reduced longitudinal strain and higher BNP, suggesting that despite the apparently normal ejection fraction, low flow reflects myocardial contractile dysfunction and possibly fibrosis

and thus a more advanced phase of the disease. Consistent with this, Adda *et al.*<sup>2</sup> found that LF/LG AS was characterized by impaired longitudinal function on speckle tracking and by elevated valvuloarterial impedance as a measure of global afterload. In a study of patients with AVA  $<1 \text{ cm}^2$  and LVEF  $>40\%$  Dahl found that preoperative global longitudinal strain assessed by speckle tracking was an independent predictor of the outcome after aortic valve replacement, providing additional prognostic information over and above conventional measures including the ejection fraction.<sup>3</sup> The implication of these findings is that stroke volume should be assessed in conjunction with valve area, transvalvular gradient, and longitudinal strain for a complete assessment of AS, particularly where there are apparent discrepancies between AVA and mean gradient.

## Prediction and assessment of aortic regurgitation post-transcatheter aortic valve implantation

Paravalvular aortic regurgitation is a frequent occurrence after transcatheter aortic valve implantation (TAVI) procedures, is associated with an adverse outcome, and may be related to undersizing of the prosthesis on the basis of annular measurements made in a single plane. Its prediction and quantification remain problematic and a number of studies have emphasized the importance of a multiplanar or three-dimensional (3D) approach to annular

\* Corresponding author. Tel: +44 (0)161 291 2402, Fax: +44 161 291 2389, Email: [simon.ray@uhsm.nhs.uk](mailto:simon.ray@uhsm.nhs.uk)

Published on behalf of the European Society of Cardiology. All rights reserved. © The Author 2013. For permissions please email: [journals.permissions@oup.com](mailto:journals.permissions@oup.com)

**Table 1** Summary characteristics of the four categorizations of aortic stenosis (adapted from Lancellotti et al.<sup>1</sup>)

	NF/ LG	NF/ HG	LF/ HG	LF/ LG	P-value
n = 150	31%	52%	10%	7%	
AVAI (cm <sup>2</sup> )	0.47	0.45	0.39	0.45	0.04
Zva (mmHg/mL/m <sup>2</sup> )	3.7	3.9	5.9	6.0	<0.0001
LS (%)	16.7	16.0	14.8	13.6	0.002
SVI (mL/m <sup>2</sup> )	41	41	33	31	<0.0001
LVEF (%)	67	67	66	66	NS
Mean gradient (mmHg)	32	53	50	33	<0.0001
BNP (pg/mL)	34	67	110	95	<0.0001
Survival (%)	83	44	30	27	<0.0001

Survival is expressed as 2-year event-free survival.

AVAI, aortic valve area index; ZVa, ventriculo-arterial impedance; LS, longitudinal strain; SVI, stroke volume index; LVEF, left ventricular ejection fraction; BNP, brain natriuretic peptide; NF/LG, normal flow low gradient; NF/HG, normal flow high gradient; LF/LG, low flow low gradient; LF/HG, low flow high gradient.

measurements. Santos *et al.* estimated an annular area using both two-dimensional (2D) and 3D transoesophageal echo (TOE) and derived a 'mismatch index' defined as annulus area—prosthesis area, prosthesis area being derived from the nominal diameter of the valve.<sup>4</sup> Mismatch index from 3D TOE was the only independent predictor of AR. Gripari *et al.*<sup>5</sup> obtained similar findings using an area cover index obtained from 3D TOE and also identified calcification of the commissure between left and non-coronary cusps as a predictor of AR. The implication of these findings is that the 2D echo assessment of the aortic valve is inadequate for optimal sizing of TAVI prostheses, whereas 3D TOE assessment may have an important clinical role.

Goncalves *et al.*<sup>6</sup> studied 72 TAVI patients 5 months after the procedure. The prevalence of paravalvular AR was 44% and this was moderate in 11%. Using real-time 3D TTE images they devised a systematic classification of the localization of paravalvular jets based on a clock face. Paravalvular jets were most common at 12–3 o'clock corresponding to the location of the commissure between the left and right coronary cusps. More importantly they cropped the 3D data sets to obtain the planimetered area of the vena contracta of the AR jet and were able to demonstrate a good relationship with a volumetric assessment of the AR severity. The three-dimensional-derived vena contracta area was far superior to 2D vena contracta width (AUC: 0.96 and 0.35, respectively). The technique is relatively complex and time consuming but provides an alternative method for the assessment of paravalvular AR after TAVI. Assessment by conventional 2D assessment of the vena contracta is not adequate for clinical use.

## Understanding functional mitral regurgitation

Saito *et al.*<sup>7</sup> used sophisticated 3D echo analysis to explore the relationship of tethering to leaflet geometry and functional mitral regurgitation (FMR) in 44 patients with symmetrical displacement of the papillary muscles. The total leaflet area was calculated at the point of the mitral leaflet closure and also closed area at mid-systole. The coaptation area was defined as total leaflet area – midsystolic area and coaptation index as (total leaflet area – midsystolic area)/total leaflet area × 100. They demonstrated that leaflet coaptation was reduced and the severity of mitral regurgitation increased with increasing degrees of papillary muscle displacement. The coaptation area was the strongest determinant of MR severity. Compared with controls the FMR group had mitral annular dilation but also an increased total leaflet area, suggesting that the enlargement of the leaflets had taken place as a result of the stresses imposed by chronic tethering. The total leaflet area was the same in patients with mild FMR and those with moderate or severe FMR but leaflet to annular area ratio, coaptation area, and coaptation index were all smaller in those with more severe regurgitation. This implies that annular dilation combined with inadequate leaflet remodelling in response to chronic tethering result in an increased severity of FMR. Lang and Adams<sup>8</sup> speculate that, while such sophisticated analysis of mitral complex geometry is currently too cumbersome for routine clinical use, it will in the future be used to guide surgical repair strategy.

**Conflict of interest:** none declared.

## References

- Lancellotti P, Magne J, Donal E, Davin L, O'Connor K, Rosca M, Szymanski C, Cosyns B, Pierard LA. Clinical outcome in asymptomatic severe aortic stenosis. *J Am Coll Cardiol* 2012;**59**:235–243.
- Adda J, Mielot C, Giorgi R, Cransac F, Zirphile X, Donal E, Sportouck-Dukhan C, Reant P, Laffitte S, Cade S, Le Dolley Y, Thuny F, Touboul N, Lavoute C, Averinos JF, Lancellotti P, Habib G. Low flow low gradient aortic stenosis is associated with severe left ventricular dysfunction as assessed by speckle tracking echocardiography. *Circ Cardiovasc Imaging* 2012;**5**:27–35.
- Dahl JS, Videbaek L, Poulsen M, Rudbaek T, Pellikka PA, Moller JE. Global strain in severe aortic valve stenosis: relation to clinical outcome after aortic valve replacement. *Circ Cardiovasc Imaging* 2012;**5**:613–620.
- Santos N, de Agustin JA, Almeida C, Goncalves A, Marcos-Alberca P, Fernandez-Goffin C, Garcia E, Hernandez-Antolin R, Perez de Isla L, Macaya C, Zamorano J. Prosthesis/annulus incongruence assessed by three dimensional transoesophageal echocardiography: a predictor of significant paravalvular aortic regurgitation after transcatheter aortic valve implantation. *European Heart Journal Cardiovasc Imaging* 2012;**13**:931–937.
- Gripari P, Ewe SH, Fusini L, Muratori M, Ng ACT, Cefalu C, Delgado V, Schlij MJ, Bax JJ, Marsan NA, Tamborini E, Pepi M. Intraoperative 2D and 3D transoesophageal echocardiographic predictors of aortic regurgitation after transcatheter aortic valve implantation. *Heart* 2012;**98**:1229–1236.
- Goncalves A, Almeida C, Marcos-Alberca P, Feltes G, Hernandez-Antolin R, Rodriguez E, Silva-Cardosa JC, Macaya C, Zamorano JL. Three dimensional echocardiography in paravalvular aortic regurgitation after transcatheter aortic valve implantation. *J Am Soc Echocardiography* 2012;**25**:47–55.
- Saito K, Okura H, Watanabe N, Obase K, Tamada T, Koyama T, Hayashida A, Neishi Y, Kawamoto T, Yoshida K. Influence of chronic tethering of the mitral valve on mitral leaflet size and coaptation in functional mitral regurgitation. *J Am Coll Cardiol* 2012;**5**:337–345.
- Lang RM, Adams DH. 3D echocardiographic quantification in functional mitral regurgitation. *J Am Coll Cardiol* 2012;**5**:346–347.