Assessment of Transvalvular Flow Jet Eccentricity in Aortic Stenosis

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Introduction: Aortic valve eccentricity measurement may be related to valve hemodynamic in patients with aortic stenosis (AS). However, it is difficult to characterize with transthoracic Doppler echocardiography (TTE) velocity measurements. A recent study suggests that eccentricity can be estimated from CMR phase-contrast flow velocity measurements using jet displacement and flow velocity angle [1]. The aim of this study is to characterize aortic valve eccentricity on aortic stenosis patients.

Table 1. Patients' Characteristics

	Mean ± SD
Age (years)	63 ± 16
Male gender n(%)	32(64)
Heart rate (bpm)	64 ± 11
Weight (Kg)	76 ± 13
Height (cm)	169 ± 9
Body surface area (m^2)	1.82 ± 0.19
Body mass index (Kg/m^2)	26 ± 3
Systolic arterial pressure (mmHg)	128 ± 22
Diastolic arterial pressure (mmHg)	71 ± 11
Valve morphology	
Tricuspid n (%)	33 (73)
Bicuspid n (%)	16 (33)

Methods: Eight (8) healthy subjects and 49 patients with mild to severe AS ($0.60\ cm^2 \leq EOA \leq 1.79\ cm^2$) were included in this study. Aortic valve replacement (AVR) event was considered on a three years follow-up. TTE measurements were performed according to the ASE guidelines [2]. CMR study was performed within 4 weeks after TTE study with the use of a 1.5 Tesla scanner. Phase-Contrast retrospective examination was performed in standard short-axis planes in the left ventricular outflow tract (LVOT) at -12 mm upstream from the aortic valve annulus and in the ascending aorta at +10 mm downstream of the annulus. CMR imaging parameters consisted of: ET (2.76-3.05ms), flip angle (15°), phase (24), pixel spacing (1.32-2.07 mm), RT (4.6-4.92ms), thickness (10mm), matrix (256x208). Valve effective orifice area was computed using continuity equation ($EOA=SV/VTI_{Ao}$) [2] and valvulo arterial impedance was computed by: ZVA=(SAP+MPG)/SVi. Where SV is the stroke volume, VTI_{Ao} is the velocity-time integral in the aorta, SAP is the systolic arterial pressure, MPG is the aortic mean pressure gradient and SVi is the SV index to body surface area. We characterized transvalvular flow jet eccentricity using peak velocity displacement and on plane angle from aortic lumen center measured at 10 mm downstream the aortic valve (Figure 1).

Results: Forty-nine patients with mild to severe AS (64% men, age 63±16 years) and eight healthy subjects (75% men, age 34±8 years) were studied CMR, Table 1. Flow peak velocity jet displacement was 3.16±1.15 mm, 6.69±1.12 mm and 11.3±2.46 mm for normal, mild eccentric and eccentric groups, respectively (Figure 2.A). Flow peak velocity jet eccentric angle was 41±14 °, 16±4 ° and 6±3 ° for normal, mild eccentric and eccentric groups, respectively (Figure 2.B). On a correlate analysis (Table 2), we found: 1) stroke volume (SV), LV diastolic diameter (LVd) and relative wall thickness ratio (RWTr) correlated well with flow velocity peak displacement; 2) LVd and RWTr correlated well with flow velocity peak; 3) Eccentricity grade correlated well with SV, EOA, LVd, RWTr and ZVA. AVR correlated well with flow velocity peak angle ($r=0.26$, $p<0.05$) and showed a tendency with flow velocity peak angle ($r=-0.23$, $p=0.11$) and eccentricity grade ($r=-0.23$, $p=0.1$). On a survival cox analysis for RVA and flow velocity peak angle we obtained: $p=0.07$, HR(CI 95%)=1.03(0.99 to 1.06).

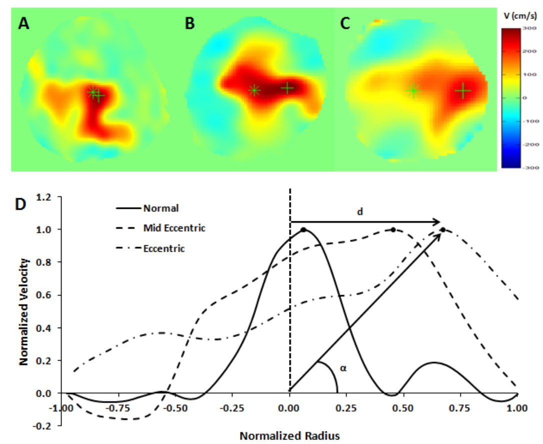

Figure 1. Measurement of transvalvular flow jet eccentricity. Panel a shows a normal central flow velocity jet. Panel B shows a mid eccentric flow velocity jet. Panel C shows an eccentric flow velocity jet. Panel D shows flow velocity profiles from A, B and C. Peak velocity displacement (d) and angle (α) were measured from lumen center.

Discussion and Conclusion: Flow velocity peak displacement and angle measured from velocity map at vena contracta level were able to characterize flow velocity eccentricity downstream aortic stenotic valves. A recent study suggested that valve eccentricity velocity jet could be important on the development of ascending aortic dilation, mainly in patients with bicuspid valves [3]. In this study, valve morphology did not have affect on eccentricity parameters. However, it is important to notice that eccentricity analysis was performed at vena contracta level and not at ascending aorta level. Eccentricity parameters showed to be related to AS severity and LV function. Interestedly, flow velocity peak angle may be closely related to RVA event on one year follow-up. Aortic flow velocity eccentricity parameters showed to be able to characterize transvalvular flow hemodynamic on AS patients and may provide further information about patient outcome.

Table 2. Correlates	Displacement		Angle		Eccentricity Grade	
	r	P	r	p	r	P
Stroke volume	0.25	<0.05	-0.19	NS	0.25	<0.05
Effective orifice area	0.21	NS	-0.17	NS	0.25	<0.05
LV diastolic diameter	0.45	<0.001	-0.42	<0.001	0.37	<0.001
Relative wall thickness ratio	-0.37	<0.001	0.39	<0.001	-0.31	<0.05
Valvulo arterial impedance	-0.18	NS	0.12	NS	-0.25	<0.05

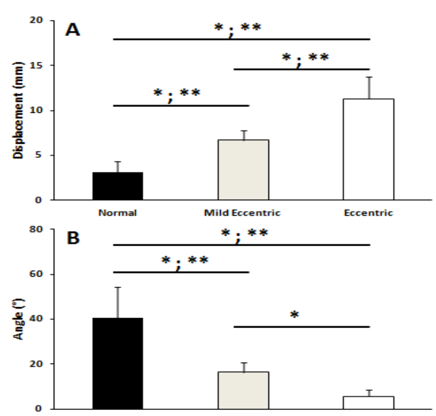

Figure 2. Comparison of flow velocity jet displacement (A) and angle (B) between the normal (n=18), mild eccentric (n=26) and eccentric groups (n=13) (* p<0.01; ** p<0.001).

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References: 1. Sigovan M et al. J Magn Resn Imaging 2011; 34: 1226-1230. 2. Quinones et al. JASE 2002; 167-184. 3. Hope MD et al. JACC Img 2011; 4(7):781-7.