Usefulness of Cardiovascular Magnetic Resonance to Assess Valvulo Arterial Impedance in Aortic Stenosis Patients

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Introduction: Valvulo arterial impedance (ZVA) is an independent and powerful predictor of poor outcome for patients with aortic stenosis (AS) severity [1]. ZVA provides an estimate of the cost in mmHg for each systemic mL of blood indexed for body size pumped by the left ventricle. Transthoracic echocardiography (TTE) is widely used to evaluate AS severity. However, there are often discrepancies among the TTE measurements used to compute ZVA (stroke volume and mean pressure gradient). Cardiovascular magnetic resonance (CMR) may be used to corroborate stenosis severity by computing effective orifice area (EOA), mean pressure gradient (MPG) and ZVA. The aim of this study is to examine the agreement of TTE and CMR for the estimation of EOA, MPG and ZVA in patients with AS.

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)

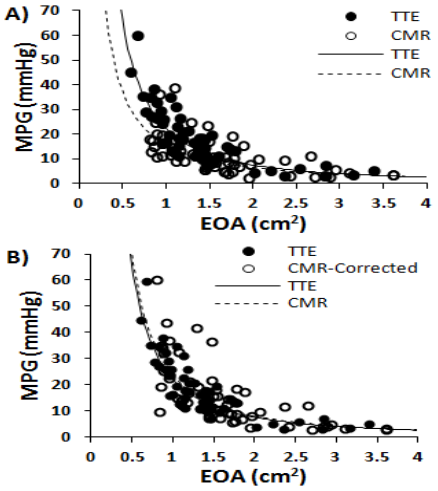

Figure 1. Mean transvalvular pressure gradient as a function of EOA. Panel A shows measured MPG. Panel B shows the predicted correction of MPG. Filled circles are TTE measurements and the solid line represents the corresponding curve fit. Non-filled squares are CMR measurements at 10mm from the aortic valve and the dashed line represents the corresponding curve fit.

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. 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). Aortic MPG and valve EOA were computed using Bernoulli's equation and continuity equation [1]. We calculated the corrected aortic mean pressure gradient (MPG) by including CMR measurements in the following formula (combination of Bernoulli formula and continuity equation): $MPG=(CO/(44.3\times HR\times SEP\times EOA))^2$[3,4]. Valvulo arterial impedance was computed by: $ZVA=(SAP+MPG)/SV_i$. A threshold of $ZVA>3.5 mmHg.mL^{-1}.m^{-2}$ was considered for classifying patients at risk. Patient outcome was followed during three years.

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 using TTE and CMR, Table 1. SV measured by TTE was similar to SV measured by CMR (79±13 mL vs. 77±18 mL respectively, p=NS, bias = -2.18 mL and agreement limits: -28.96 to +24.67 mL). On a dichotomy analysis for low and high SV (SV<63 mL, median value) we found a significant difference between TTE and CMR for low SV (p<0.001) and a no significant difference for high SV (p=NS). Overall there was a good correlation and concordance between TTE-derived and CMR-derived EOA (1.18±0.28 vs. 1.42±0.42, r=0.88, bias=0.26, limits of agreement:-0.34 to 0.87). Figure 1.A shows the fitted curves for MPG TTE and MPG CMR (r=0.69). Figure 1.B shows the fitted curves for MPG TTE and predicted MPG CMR (r=0.73) and had a good concordance bias=-2.3mmHg, limits of agreement:-17.79 to 13.18. A low correlation between ZVA TTE and ZVA CMR, using non corrected MPG, was found (r=0.31). When MPG CMR was corrected, ZVA TTE and ZVA CMR had a good correlation (r=0.62) and a good concordance bias=0.12 $mmHg.mL^{-1}.m^{-2}$, limits of agreement:-1.13 to 1.36, Figure 2. ZVA TTE classified 27 (55%) patients at risk, ZVA CMR 23 (47%) and ZVA CMR corrected 25 (51%). After three years outcome follow 10 patients underwent valve replacement surgery, ZVA TTE identified 9, ZVA CMR 6 and ZVA CMR corrected 7. Cox survival analysis led to p<0.05, HR(CI 95%)=9.04(1.14 to 71.72), p=0.26, HR(CI 95%)=2.07(0.58 to 7.36) and p=0.16, HR(CI 95%)=2.06(0.66 to 10.15) for ZVA TTE, ZVA CMR and ZVA CMR corrected, respectively.

Discussion and Conclusion: EOA, MPG and ZVA are the three main parameters used to assess AS severity and patient outcome. There was a good concordance between EOA measured by CMR and that measured by TTE. However, CMR underestimates the MPG compared to TTE affecting ZVA CMR estimation. EOA measured by CMR can be used to confirm AS severity grading by TTE in case of inconsistencies. However, CMR underestimates MPG and a significant difference with TTE was found for low SV. The proposed model could be an issue to manage this difference and improve ZVA CMR estimation by correcting MPG and confirming low SV. ZVA CMR using corrected MPG had a good concordance with ZVA TTE which showed to be a good predictor of patient outcome in spite the reduced number of events.

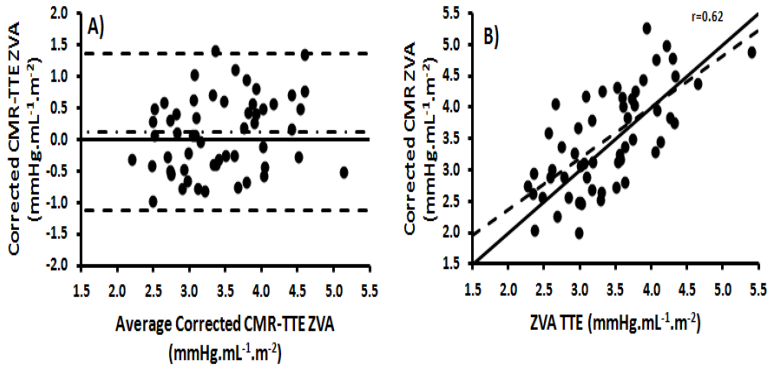

Figure 2. ZVA concordance and correlation. Panel A shows Bland-Altman plot for corrected ZVA. Panel B shows the plot of ZVA.

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