Preserved Ejection Fraction in the Presence of Reduced LV Wall Strain in Hypertension: A Geometric Explanation Validated by MRI

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INTRODUCTION

Several research groups [1,2] have reported that, in hypertension patients with preserved or super-normal ejection fraction relative to normals, circumferential shortening strain measured by tagged MRI is depressed. The reasoning behind this apparent paradox is not well understood. This abstract presents a possible explanation of these clinical observations by expressing ejection fraction (*EF*) as a function of some commonly measured parameters in cardiac MRI such as 3-D wall thickening (*WT*), radius thickness (*RT*) ratio, longitudinal shortening (*LS*) and 3-D circumferential shortening (*Ecc*) and validating this expression with clinical cardiac MRI data.

METHODS

A total of 458 human subjects were scanned (normal volunteers (n=72) and patients with hypertension (n=151), mitral valve regurgitation (n=119), and myocardial infarction (n=116) were imaged per institutional guidelines after obtaining informed consent. Cine images were acquired on a 1.5T GE MRI system using ECG gated SSFP technique with the following parameters: slice thickness 8mm, Field-of-view 40×40 cm, scan matrix 256×128, flip angle 45 deg, TR/TE = 3.8/1.6ms, typical acquired temporal resolution < 50ms. Tagged images were acquired with a fast gradient-echo cine sequence with the slice prescription described above and with the following parameters: FOV =300mm, image matrix = 224x256, flip angle = 45 deg, TR/TE = 5.2/1.82ms, number of cardiac phases =20, slice thickness = 10mm. In each subject, ejection fraction, fractional shortening, 3D wall thickening, 3D *RT* ratio and 3-D circumferential shortening were measured using custom-written software.

A relationship between ejection fraction and *WT*, *RT*, *LS* and *Ecc* was derived assuming simple 2D deformation model where motion only occurred in the radial direction. This model accounted for radial thickening and circumferential shortening but not torsion. First midwall fractional shortening (FS_{mid}) was related to midwall *Ecc* (Ecc_{mid}) with the expression $FS_{mid} = 1 - \sqrt{1 + 2Ecc_{mid}}$. Since fractional shortening is usually computed at endocardium, fractional shortening at the endocardium, FS_{endo}, was related to midwall circumferential shortening (Ecc_{mid}) with the expression:

$$FS_{endo} = \left(1 + \frac{.5}{RT^{ED}_{endo}}\right) \cdot \left(1 - \sqrt{1 + 2Ecc_{mid}}\right) + \frac{.5}{RT^{ED}_{endo}} \cdot WT^{ED}, \quad (1)$$

where RT^{ED}_{endo} is the end-diastolic radius to thickness ratio and WT^{ED} is the end-diastolic wall thickness. *EF* is related to *FS* by the expression $EF=1-(1-FS)^2(1-LS)$. Substituting *FS* with equation (1) results in the following approximate expression for *EF* as a function of *Ecc*, *WT*, *LS*, and *RT*:

$$EF_{calc} = 1 - \left(1 - \left[\left(1 + \frac{.5}{RT^{ED}_{endo}}\right) \cdot \left(1 - \sqrt{1 + 2Ecc_{mid}}\right) + \frac{.5}{RT^{ED}_{endo}} \cdot WT^{ED}\right]\right)^2 (1 - LS), \quad (2)$$

Ejection fraction values were calculated in each subject using Equation (2) with measured Ecc_{mid}, WT^{ED}, *LS*, and RT^{ED} values and compared to measured ejection fraction values $EF_{measured}$.

RESULTS AND DISCUSSION

Equation (2) suggests that ejection fraction and circumferential shortening are related by wall thickness, longitudinal shortening and *RT* ratio. In hypertension, wall thickness increases, longitudinal shortening insignificantly varies and *RT* ratio decreases relative to normal due to concentric remodeling.

The Bland-Altman plot in Figure 1 and scatter plot in Figure 2 show good agreement between EF_{calc} and $EF_{measured}$ with a tendency of calculated *EF* to overestimate measured *EF* by ~9%. The correlation coefficient between calculated and measured *EF* was 0.78 (P<.001). These experimental results demonstrate that the midwall *Ecc*, through Equation (1) and (2) can predict ejection fraction over a wide range of volume and pressure loading conditions.

CONCLUSION

Equation (2) suggests that preserved ejection fraction in hypertension in the presence of reduced circumferential shortening is the result of geometric effects of concentric remodeling and not a reduction in myocardial contractility.

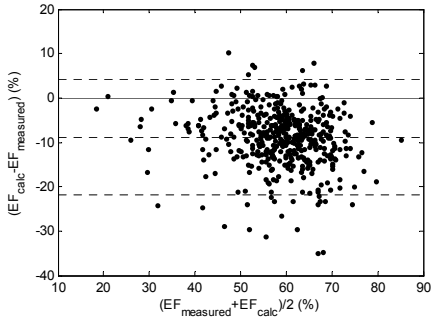

Figure 1 Bland-Altman plot of $EF_{measured}$ vs. EF_{calc}

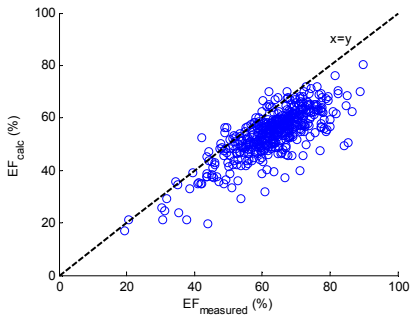

Figure 2 Scatter plot of $EF_{measured}$ vs. EF_{calc} (the black line indicates perfect correlation)

REFERENCES

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