Single Beat Approach to Left Ventricular Diastolic Chamber Stiffness Independent of Relaxation Time Constant Tau

Chun Schiros[1], Thomas Denney[2], Jose Tallaj[3], Gilbert Perry[3], Steven Lloyd[3], Louis Dell'Italia[3], and Himanshu Gupta[3]

[1]University of Alabama at Birmingham, Birmingham, Alabama, United States, [2]Auburn University, Alabama, United States, [3]University of Alabama at Birmingham, Alabama, United States

PURPOSE

Left ventricular (LV) diastolic chamber stiffness (β) provides key information about LV diastolic properties. Single beat method, based on single LV pressure measurement and corresponding LV volumes, has been proposed to derive LV diastolic chamber stiffness. Due to incomplete left ventricular (LV) relaxation, relaxation time constant τ is used to correct for min pressure in computing LV diastolic chamber stiffness[1]. It is extremely important to identify the minimum volume and corresponding LV pressure which are crucial for defining the true/corrected β. However τ is affected by heart rate and indirectly by LV end-diastolic pressure (LVEDP). Further there are multiple methodologies for calculating τ, including mono-exponential method[2] and hybrid logistic method[3], resulting in various τ values. Therefore, the corrected minimum pressure and volume corresponding to 3.5τ[4], where LV is considered completely relaxed, may not be always reliable. There is even debate about true τ value where the LV is considered relaxed[5]. Therefore single beat approach that is independent of τ and incorporates true volumetric data to calculate corrected β will be attractive to define diastolic physiology especially in patients with suspected diastolic heart failure. Here we propose a novel single beat approach to corrected LV diastolic chamber stiffness independent of τ that utilizes cMRI LV volumetric measurements.

METHODS

Twenty-six patients with normal LVEF and no acute myocardial infarction are studied using high-fidelity pressure measurement and cMRI. CMRI was performed on a 1.5-T MRI scanner (Signa, GE Healthcare, Milwaukee, Wisconsin) optimized for cardiac imaging. The electrocardiographically gated breath-hold steady-state free precision technique was used to obtain standard (2-, 3-, and 4-chamber long axis or 360^0 long axis and serial parallel short-axis) views using the following typical parameters: slice thickness of the imaging planes 8 mm, field of view 40cm, scan matrix 256×128, flip angle $45°$, repetition/echo times 3.8/1.6 ms.

The measured chamber stiffness is computed as the stiffness constant β_m from LV diastolic pressure-volume (P-V) relationship $P = \alpha e^{\beta V}$, fitted by 3 pairs of P-V coordinates: P-V at the time of minimum pressure (P_{min}), pre-atrial kick P-V, and LV end-diastolic P-V[1]. To avoid using inaccurate P_{min} and volume due to abnormally slow relaxation, corrected diastolic chamber stiffness β_c is computed by replacing the first pair of P-V coordinates at the time of P_{min} to $P_0 - V_0$ at $P \sim 0$mmHg[6]. $V_0 = LVEDV(0.6 - 0.006LVEDP)$ and $P_0 = \alpha V_0^{\beta}$, where α and β were previously defined [6]. Volume at $P=15$mmHg, denoted as V_{15} is computed using the fitted model.
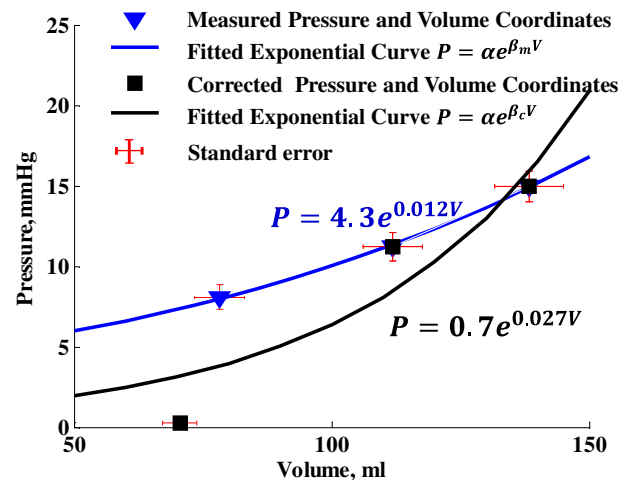
RESULTS

Although β_c is correlated with β_m (r=0.45, P=0.022), it is significantly greater than β_m (0.027±0.01 vs 0.012±0.006, P<.0001). β_c also significantly correlates negatively with V_{15} (r=-0.53, P=0.016) and correlates positively with log(LVEDP)/LVEDV (r=0.39, P=0.04), which is consistent with the theoretical model. The mean β_c and β_m curves are depicted in the figure.

Figure: LV diastolic pressure (P)-volume (V) relationship using measured LV diastolic minimum pressure and its corresponding volume (blue) vs. volume and pressure at pressure ~0mmHg (black) as the first pair of coordinates for the exponential curve fitting (blue: $P = \alpha e^{\beta_m V}$; black: $P = \alpha e^{\beta_c V}$, β_m=measured stiffness and β_m= corrected stiffness). It demonstrates a stiffer chamber without the contribution to pressure of incomplete relaxation using the measured LV minimum pressure.

DISCUSSIONS AND CONCLUSIONS

The corrected LV diastolic chamber stiffness β_c, incorporating $P_0 - V_0$ at the time of $P \sim 0$mmHg, is obtained independent of τ. It provides evaluation of LV passive filling property that is not affected by incomplete relaxation and is relatively simple to measure that utilizes routinely obtained LV pressure and volume measurement from cMRI.

REFERENCES

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