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Validation by cardiac catheterization of noninvasive evaluation of left ventricular chamber and myocardial stiffness as a diastolic function using speckle tracking echocardiography

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Background: Left ventricular (LV) diastolic function is mainly composed of LV relaxation and LV stiffness. We reported that pulmonary capillary wedge pressure (ePCWP) and LV relaxation assessed by Tau (eTau) are noninvasively evaluated by speckle tracking echocardiography (STE). The minimum LV diastolic pressure (mLVP) was reported to have a strong correlation with Tau. Therefore, LV chamber stiffness (c-stiffness) may be assessed with the use of two LV diastolic pressure-volume coordinates: the mLVP and volume and the end-diastolic pressure (EDP) and volume.

Purpose: We sought to noninvasively assess LV stiffness using STE and validate the value by cardiac catheterization.

Methods: Echocardiography and catheterization were performed in 124 patients (age 72±8) (70 angina pectoris, 20 prior myocardial infarction, 19 hypertensive heart disease, 11 congestive heart failure and 4 paroxysmal atrial fibrillation). The ePCWP (mmHg) is noninvasively obtained as 10.8 – 12.4 $\times$ Log (left atrial active emptying function/minimum volume) and the eTau (ms) is obtained as isovolumic relaxation time/(ln 0.9 $\times$ systolic blood pressure – ln ePCWP) as previously reported. The mLVP (e-mLVP) was estimate using Tau. The estimated EDP (e-EDP) was calculated as 12.3 – 10.1 $\times$ Log (left atrial active emptying function / minimum volume). LV c-stiffness (mmHg/ml) was calculated as LV pressure change (from mLVP to EDP) obtained by catheterization divided by LV volume change during diastole which equals to stroke volume by echocardiography. Estimated c-stiffness (e-c-stiffness) was noninvasively obtained using e-mLVP and e-EDP. Furthermore, LV myocardial stiffness (m-stiffness) was calculated by LVED stress / LV longitudinal strain by STE, where LV stress (kdynes/cm^2) was calculated as 0.334 $\times$ pressure $\times$ dimension / [thickness (1 + thickness/dimension)]. The estimated m-stiffness (e-m-stiffness) was calculated using e-EDP.

Results: The eTau and e-EDP estimated by STE had a good correlation with Tau and EDP invasively obtained by catheterization (r=0.75 and 0.63, respectively, both $p<0.001$). There was a good correlation between Tau and mLVP (Tau = 2.06 mLVP + 33.7, r=0.70). The estimated LVED stress had good correlation with ED stress obtained by catheterization (r=0.77, $p<0.001$). The e-c-stiffness and e-m-stiffness had a good correlation with those obtained by catheterization (e-c-stiffness; 0.116±0.07 and c-stiffness; 0.115±0.06, r=0.603, e-m-stiffness; 0.81±0.41 and m-stiffness; 0.85±0.45, r=0.89, respectively). Bland-Altman analysis revealed a good agreement between e-c-stiffness and c-stiffness, and between e-m-stiffness and m-stiffness without fixed and proportional bias.

Conclusion: This study demonstrated that LV stiffness may be noninvasively assessed by STE with reasonable accuracy and may have utility and value in the routine clinical practice for the diagnosis and treatment in patients with diastolic dysfunction.