Accurate prediction of left ventricular diastolic dysfunction in 2D echocardiography using ensemble of deep convolutional neural networks

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Introduction: Deep convolutional neural networks (CNNs) have been shown to be reliable in evaluating geometrically assessed systolic heart function, however, studies evaluating diastolic heart function, which reflects hemodynamic status, are scarce. This study presents a novel CNNs approach for recognition and evaluation of different diastolic left ventricular (LV) function measurements.

Purpose: To create a new CNNs approach in the assessment of LV diastolic function and compare the results with clinicians' measurements.

Methods: A total of 4586 2D echocardiographic images were extracted from the studies of 330 patients referred with varying indications. The ensemble of four CNNs was trained (80/20% training/validation patient split) for the assessment of transmitral inflow (E and A wave peak velocities), mitral septal and lateral annular velocities (e'), tricuspid regurgitation systolic velocity (Vmax) and detection the left atrial endocardium in apical four-chamber views. Additionally, E/A ratio, average E/e' ratio and left atrial volume index (LAVi) values were calculated for the evaluation of diastolic dysfunction according to the 2016 ASE/EACVI recommendations. CNNs performance in detecting diastolic dysfunction was compared to expert cardiologists on a set of 20 separate cases.

Results: Study results on the validation data showed that CNNs accurately predicted peak E/A ratio, average E/e' ratio (R^2=0.88 and R^2=0.89, respectively) and tricuspid regurgitation Vmax (R^2=0.82). Figure 1 illustrates different functional LV measurements among the obtained echocardiographic images. Regarding the geometrical assessment of diastolic function, the segmentation model traced the left atrial endocardial border (intersection over union = 0.94) and subsequently was used in predicting the LAVi (R^2=0.92). The ensemble of four CNNs had the area under the ROC curve of 0.93 for the detection of diastolic dysfunction when compared to expert cardiologists.

Conclusion: Deep CNNs demonstrate the capacity to detect peak velocities across different Doppler imaging modes and delineate left atrial endocardium border while using a relatively small dataset. Combining multiple CNNs has the potential of performing an accurate assessment of the diastolic LV function.

Figure 1. Functional LV measurements among the obtained echocardiographic images: A. Mitral lateral annular velocity; B. Tricuspid regurgitation systolic velocity; C. Transmitral inflow.