

TVnet: automated global analysis of tricuspid valve plane motion in CMR long-axis cines with residual neural networks for assessment of right ventricular function

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Background

Right ventricular (RV) function evaluation is an integral part of comprehensive cardiac assessment, including for pulmonary hypertension, congenital heart disease and arrhythmogenic RV cardiomyopathy (ARVC)¹. It is commonly assessed by measuring tricuspid annular plane systolic excursion (TAPSE) and peak systolic velocity (RV s') on echocardiography². However, it is highly sensitive to imaging window and small changes in the beam angle, limiting reliability³. Cardiovascular magnetic resonance (CMR) is the imaging gold-standard for assessing RV structure and function, and is highly reproducible. CMR can assess tricuspid valve (TV) motion using four-chamber (4Ch) and RV two-chamber (2Ch) cines, with higher diagnostic performance than single-plane analysis, validated against invasive right heart catheterisation⁴. However, manual placement of the TV insertion points is highly time-consuming for routine clinical workflows. TVnet, a deep-learning framework for automatically tracking the TV in 4Ch cines⁵ has been recently validated, but without the orthogonal plane (RV 2Ch) which is helpful to more reliably characterise TV motion.

Purpose

We further extend TVnet to automatically track RV 2Ch cines and derive analysis of global TV motion parameters (global TAPSE and RV s') on par with expert level performance.

Methods

74 patients undergoing CMR (1.5T Siemens MR scanner) with 4Ch and RV 2Ch views were retrospectively included in this ethically-approved study. The patients had the following cardiovascular conditions: myocardial infarction (n=43), ARVC (n=28) and Takotsubo cardiomyopathy (n=3). The dual-stage deep-learning pipeline with a residual neural network backbone^{5,6} (Figure 1A) was trained using 69 patient datasets and 15 patients were randomly chosen for testing. The TVnet trained on 4Ch cines⁵ was used to automatically annotate the 4Ch cines of the testing set for global analysis comparison. For manual reference, the software Segment⁷ was used to manually annotate the TV insertion points in all imaging data (1,865 RV 2Ch images, 375 4Ch images). The global TAPSE and RV s' were derived as the mean perpendicular motion from the end-diastolic plane from both chamber views (Figure 1B).

Results

TVnet achieved a fast processing accuracy (<1 second per cine) and successfully tracked the TV insertion points from the RV 2Ch cine with a plane tracking error of 0.08 ± 0.83 mm. The integrated pipeline yielded an excellent clinical-metric agreement with the manual reference (Figure 2) for both global TAPSE (error= 0.42 ± 0.68 mm, ICC=0.95) and RV s' (error= -0.10 ± 0.71 cm/s, ICC=0.85).

Conclusion

TVnet demonstrated excellent performance in both tracking the TV insertion points in RV 2Ch cines and deriving global TAPSE and RV s' compared to manual reference. TVnet can eventually provide a complete automatic inline analysis of TV plane motion for a fast, reliable and reproducible assessment of RV function in routine clinical workflows.

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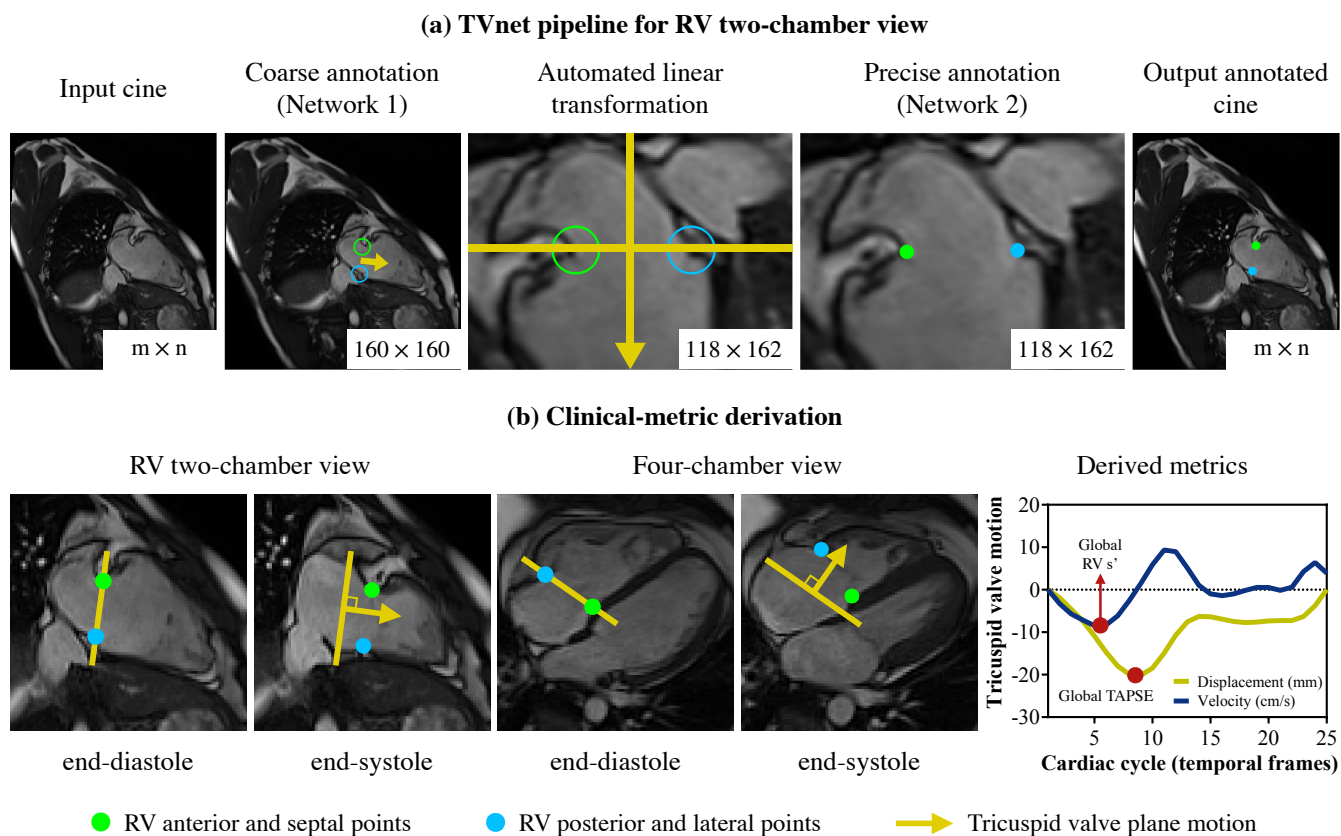


Figure 1. (A) Deep learning pipeline and (B) clinical-metric derivation.

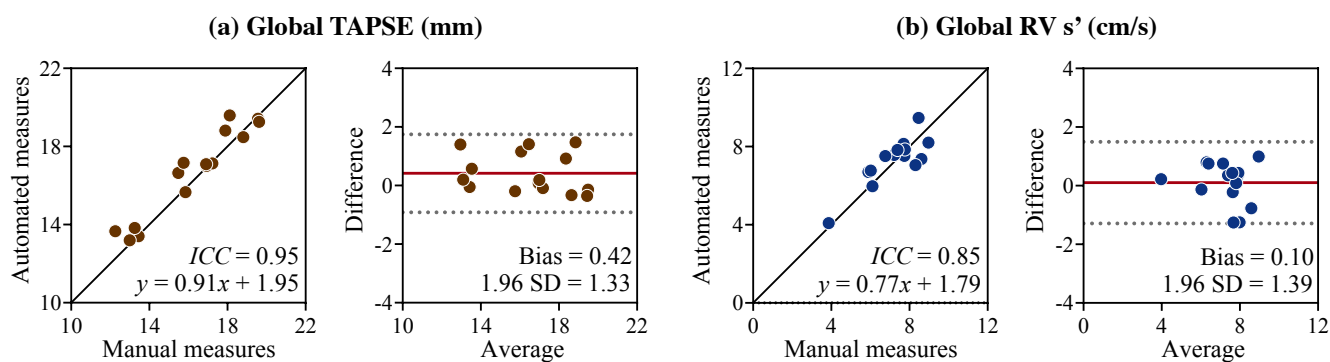


Figure 2. Regression and Bland-Altman plots.