TVnet: a deep-learning approach for enhanced right ventricular function analysis through tricuspid valve motion tracking

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Purpose: The evaluation of right ventricular (RV) function is crucial in the assessment of various cardiovascular conditions [1]. Traditional methods like tricuspid annular plane systolic excursion (TAPSE) and peak systolic and diastolic velocity (RV s' and RV e') measurement on echocardiography have limitations due to their sensitivity to changes in imaging window and beam angle. Despite cardiovascular magnetic resonance (CMR) being a more reliable method for assessing RV structure and function, manual placement of tricuspid valve (TV) insertion points on long-axis cines, which would enable measurement of these parameters, is time-intensive for routine clinical workflows. To address this, we aim to expand TVnet [2], a recently validated deep-learning framework for four-chamber (4Ch) cines, to include RV two-chamber (2Ch) cines for a more comprehensive characterisation of TV motion [3].

Materials and Methods: In this study, 204 subjects were evaluated, comprising 187 patients from the University of Oxford and 17 healthy volunteers from Yale University, all imaged using a 1.5T Siemens MR scanner. The patients were diagnosed with conditions such as arrhythmogenic RV cardiomyopathy (n=141), myocardial infarction (n=43), and Takotsubo cardiomyopathy (n=3). Training for the dual-stage deep-learning pipeline, built on a residual neural network backbone [2], was carried out using 162 datasets (149 patients and 13 healthy volunteers). The remaining 38 patients and 4 volunteers were used for testing. Automatic annotation of the 4Ch cines in the testing set was achieved using the TVnet previously trained on 4Ch cines [2]. Manual annotation of the TV insertion points was performed on all 5,200 RV 2Ch images and 3,320 4Ch images, with global TAPSE, RV s' and RV e' derived from the mean perpendicular motion from the end-diastolic plane in both chamber views (Figure 1).

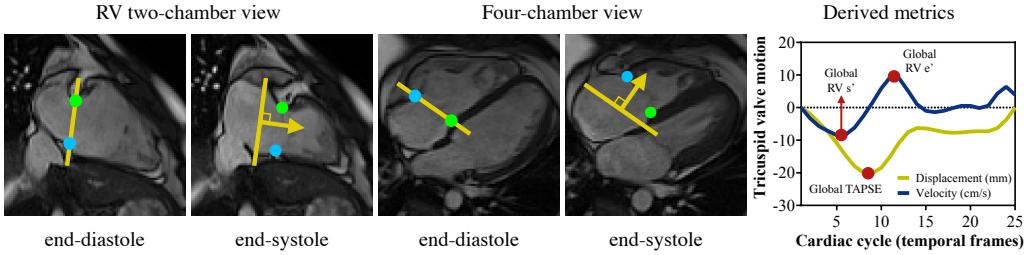

Figure 1. Illustration of TV point annotation in 2Ch and 4Ch cines, along with derived clinical metrics from time-resolved annotations.

Results: TVnet successfully tracked the TV insertion points from the RV 2Ch cine with a plane tracking error of -0.13±1.19 mm against expert annotation. The integrated pipeline also showed excellent agreement with the manual reference for global TAPSE (error=0.03±0.74 mm, ICC=0.96), RV s' (error=0.07±0.44 cm/s, ICC=0.97) and RV e' (error=0.01±0.63 cm/s, ICC=0.97) in the test set.

Conclusions: TVnet exhibited excellent performance in tracking TV insertion points in RV 2Ch cines and deriving global TAPSE, RV s' and RV e' metrics. Future work involves dataset expansion. It promises to offer a fully automated, swift, and reproducible method for assessing RV function in regular clinical procedures.

Medical/clinical significance: The implementation of TVnet offers a more precise and efficient methodology for tracking tricuspid valve insertion points on long-axis cine in RV function assessment, including TAPSE, RV s' and RV e'. By automating this process, TVnet reduces manual effort and potential inconsistencies, aiding in a more reproducible and reliable evaluation of RV function, even in heterogeneous diseases.

Prospect of application: TVnet can be easily adapted to clinical practice. Its capacity for automated, swift, and accurate tracking on standard 4Ch cines and easily obtained RV 2Ch cines could enhance the reliability and efficiency of right ventricular function assessment, thereby potentially contributing to improved patient management and outcomes.

References

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