VALIDATION OF A DEEP LEARNING-BASED ALGORITHM IN QUANTIFYING TRICUSPID VALVE REGURGITATION

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BACKGROUND

Tricuspid regurgitation (TR) severity assessment on transthoracic echocardiography (TTE) remains challenging. An automated tool for diagnosing and quantifying TR offers significant advantages in clinical practice.

This study developed and validated an automated AI-based workflow integrating multiple echocardiographic parameters to quantify TR severity, aiming to improve diagnostic consistency and patient outcomes.

METHOD

The AI algorithm was developed using three large TTE databases comprising approximately 1,600 patients and validated on an independent cohort of 642 patients from Prince of Wales Hospital, Hong Kong (159 without TR, 186 with mild TR, 137 with moderate TR, and 160 with severe TR). TR severity, determined by expert echocardiographers, was used as the ground truth. The AI workflow incorporated six deep learning models: five focused on measuring key parameters—vena contracta width (VCW), TR jet area, PISA radius, EROA, and continuous-wave TR velocity (CWTR)—using standard apical four-chamber color Doppler (A4C CD) and right ventricular inflow color Doppler (RV inflow CD) images. The sixth model employed a convolutional neural network (CNN) to predict TR severity from full TTE video sequences. The outputs from these models were integrated into a multi-parameter TR grading system, where each parameter was assigned a severity score and weight, with the weighted sum normalized to a scale of 0 to 1. Root mean square error (RMSE), correlation, and intraclass correlation coefficient (ICC) were used to evaluate the performance of the AI workflow. The results were calculated as the mean of the AI's comparisons with each cardiologist individually, who provided the ground truth, and also from pairwise comparisons among the cardiologists.

RESULTS

The AI workflow successfully analyzed TR severity in 97.7% of cases, with an average processing time of 80 seconds per case. The model achieved an overall accuracy of 0.72 for grading all TR severity levels. For distinguishing between significant TR (moderate or severe) and non-significant TR (none or mild), the model demonstrated high performance, with an accuracy of 0.91 (95% CI: 0.88–0.94), sensitivity of 0.93 (95% CI: 0.90–0.96), and specificity of 0.90 (95% CI: 0.85–0.92). The AI showed lower RMSE than cardiologists' pairwise agreement for most parameters. Correlation (0.70–0.89) and ICC values were comparable to or better than those of the cardiologists, demonstrating the AI's reliability.

CONCLUSIONS

An AI-based multiparametric workflow enables fast, accurate, and reliable TR severity assessments. The AI models demonstrates acceptable performance, comparable to or better than those of the three expert cardiologists. By standardizing TTE evaluations, it can improve diagnoses, risk stratification, and treatment planning, ultimately enhancing patient care.

RESULTS

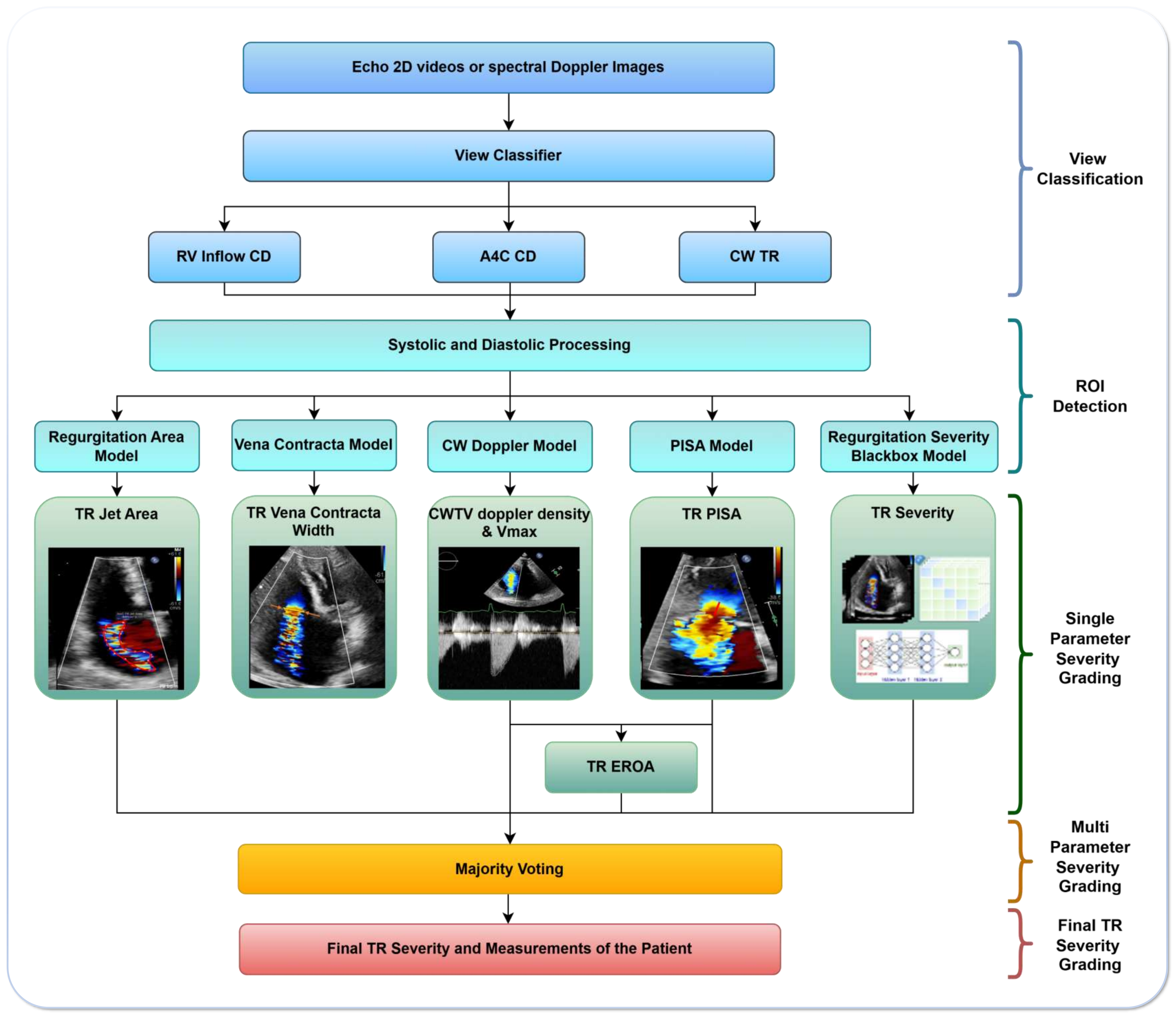

Figure 1 Workflow of the AI-measured Tricuspid Regurgitation

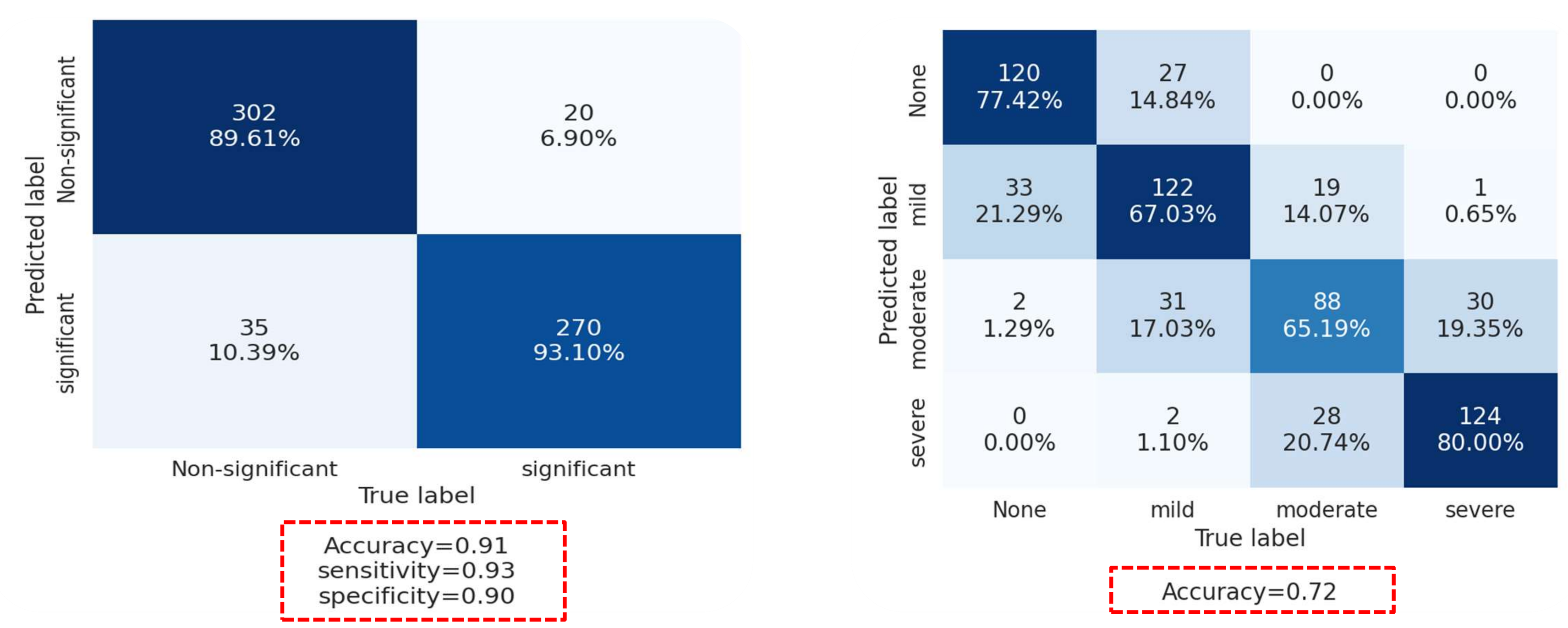

Figure 2 Confusion Matrix of Classification Results

TR related parameters	RMSE	Mean RMSE (among 3 readers)	Correlation	Mean Correlation (among 3 readers)	ICC	Mean ICC (among 3 readers)
TR Jet Area	3.28	3.89	0.84	0.85	0.83	0.8
TR VC	0.16	0.35	0.73	0.62	0.72	0.28
TR PISA Radius	0.13	0.2	0.82	0.68	0.77	0.66
TR VFR	44.15	74	0.81	0.64	0.79	0.6
TR ERO	0.29	0.4	0.7	0.74	0.65	0.64
CWTR Vmax	0.4	0.46	0.88	0.84	0.87	0.82
CWTR VTI	14.6	13.83	0.89	0.88	0.87	0.87
TR Rvol	10.51	22.5	0.84	0.57	0.84	0.53

*RMSE, correlation, and ICC were calculated as the mean of the AI's comparisons with each cardiologist individually.
Mean RMSE, mean correlation, and mean ICC were calculated from pairwise comparisons among the cardiologists (reader 1 vs. 2, reader 2 vs. 3, reader 1 vs. 3).

Table 1 Metrics of AI vs. Cardiologists for TR-Related Parameters

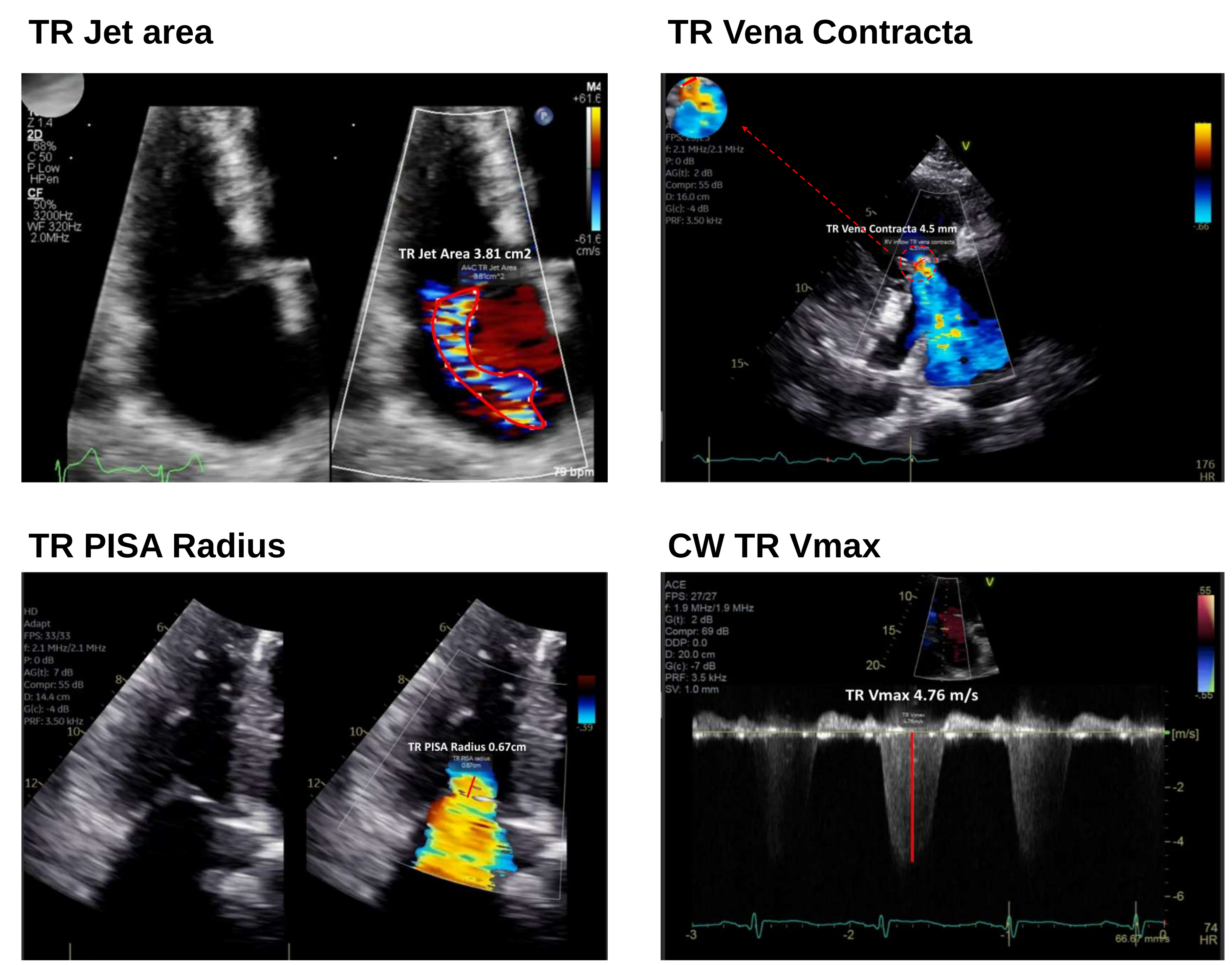

Figure 3 TR-related Parameters Measured by AI