Prediction of Cardiac Mechanical Relaxation Abnormalities from Surface ECG Wavelets: Replication in Two Cohorts

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BACKGROUND

The impairment of myocardial relaxation is a common finding in left ventricular diastolic dysfunction(LVDD)and is a strong predictor of cardiovascular and all-cause mortality. The electrical and mechanical domains of cardiac function are closely coupled. Consequently, subtle changes in the myocardial electrical milieu may lead to myocardial relaxation abnormalities. These small changes in the surface ECG frequency spectrum can be magnified using signal-processing techniques.

OBJECTIVE

We investigated a novel signal-processed electrocardiography (spECG) technique to extract electrophysiological patterns associated with abnormal myocardial relaxation.

METHODS

StudyPopulation

Prospective, cross-sectional study in two independent institutional cohorts:

- Icahn School of Medicine at Mount Sinai (New York, NY), n=188
- WVU Heart and Vascular Institute (Morgantown, WV), n=102

Signal processed-surface electrocardiography

- 12-lead surface ECG at the time of echocardiogram (Figure 1A)
- Signal-processing using continuous wavelet transform to create time-frequency-energy displays (Figure 1B)

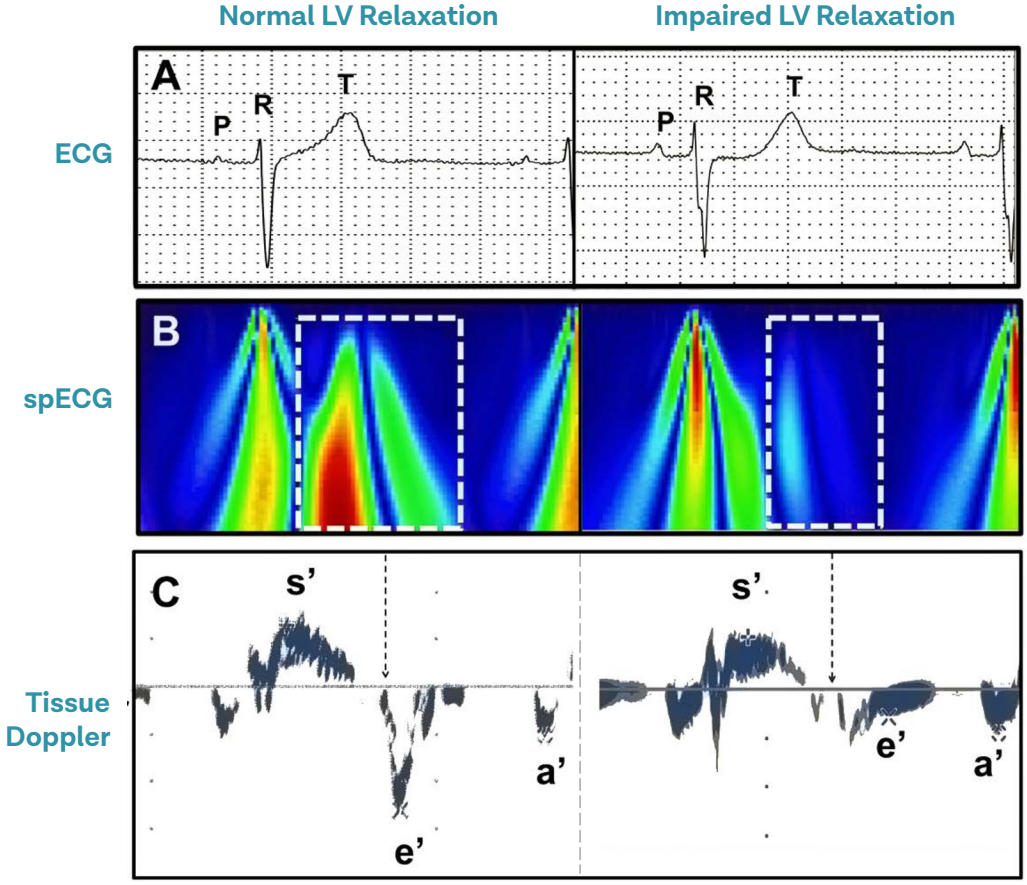
Echocardiography

- Complete 2D, Doppler, and tissue Doppler echocardiography (Figure 1C)
- Abnormal relaxation was defined using cohort-specific tissue Doppler z-scores values

Machine learning-based classification

- Random Forest ensemble classifier with Monte Carlo cross-validation

FIGURE 1



The conventional ECG (A), spECG (B) area ligned with tissue Doppler echocardiography derived longitudinal mitral annular velocity waveforms from left ventricular septum (C) during ejection (s'),early (e') and late diastolic relaxation (a'). Energy dynamics in spECG: blue - low energy, red - high energy.

TABLE

	Cohort 1 (n=188)	Cohort 2 (n=102)
Age, years	57 ±12	50 ±14
Female, n (%)	110 (59)	59 (58)
NYHA class I, n (%)	121 (64)	71 (70)
NYHA class II, n (%)	55 (29)	21 (21)
NYHA class III, n (%)	9 (5)	9 (9)
NYHA class IV, n (%)	3 (2)	1 (1)
Ejection fraction, %	62.7 ±5.8	60.8 ±8.2
LV mass index, g/m^2	80.4 ±25.5	69.8 ±18.9
Left atrium volume index, mL/m^2	34.9 ±13.6	24.3 ±9.3
E/A ratio	1.1 ±0.4	1.2 ±0.4
Septal e′, cm/s	7.1±2.1	8.6±2.7
Lateral e′, cm/s	9.1±2.8	10.4±3.5
Low average e′ (below cohort-specific mean), n (%)	100 (53)	72 (73)
Average E/e′	10.0±4.2	9.7±5.1
Tricuspid regurgitation velocity, m/s	2.2 ±0.5	2.0 ±0.5

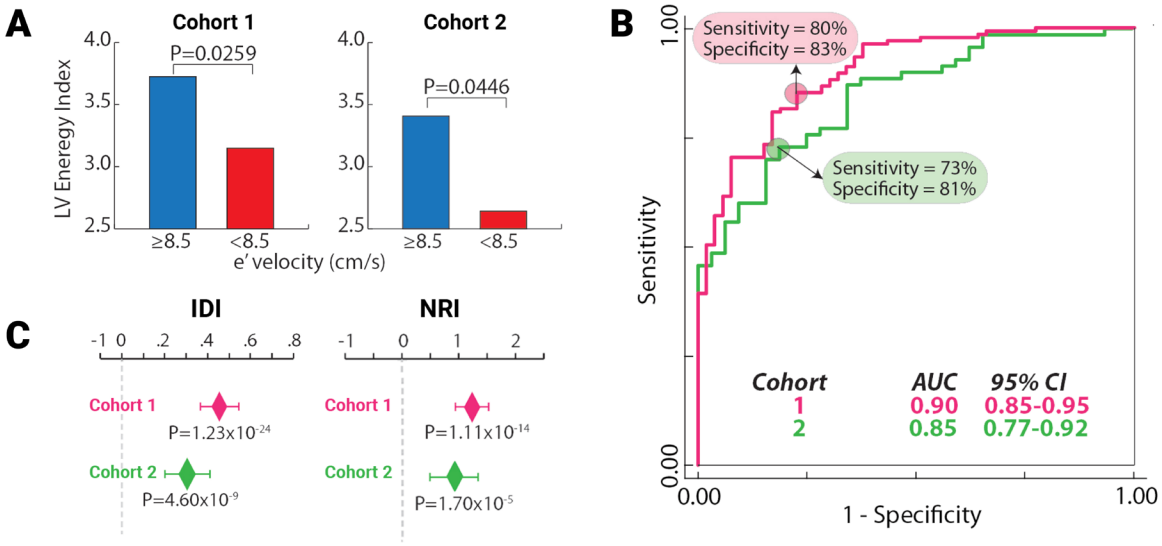
RESULTS

- Repolarization energy was significantly lower in patients with abnormal relaxation (Figure 2A).
- The area under receiver-operating characteristic curve (AUC) for prediction of myocardial relaxation impairment was 0.90 (95% Confidence interval,CI:0.85-0.95) in the first cohort. While the second cohort included younger patients, the diagnostic accuracy of spECG was still comparable with an AUC of 0.85 (95% CI0.77-0.92, Figure 2B).
- For both cohorts, spECG showed significant net reclassification improvement and integrated discrimination improvement over traditional surface ECG for predicting abnormal relaxation (Figure 2C).

Cohort 1

Cohort 2

FIGURE 2



Left ventricular (LV) repolarization energy inpatients with normal and abnormal relaxation (A), are a under receiver-operating characteristic curve (AUC) for prediction of myocardial relaxation impairment in the two cohorts (B), incremental value of Random Forrest models over and beyond the conventional ECG demonstrated by incremental discrimination improvement (IDI) and Net Reclassification Index (NRI) (C).

CONCLUSION

The spECG provided a robust prediction of abnormal myocardial relaxation and may be a valuable screening strategy for intervening during early stages of LVDD.

DISCOLSURE

- Marton Tokodi, MD: Nothing to disclose
- Partho P. Sengupta, MD: Advisor to HeartSciences; Consultant to Hitachi Aloka; has research grant from Hitachi Aloka and EchoSenseLtd.