Screening for Cardiac Relaxation Abnormalities Using Surface ECG Wavelets for Identifying High-Risk Cardiac Phenotypic Abnormalities

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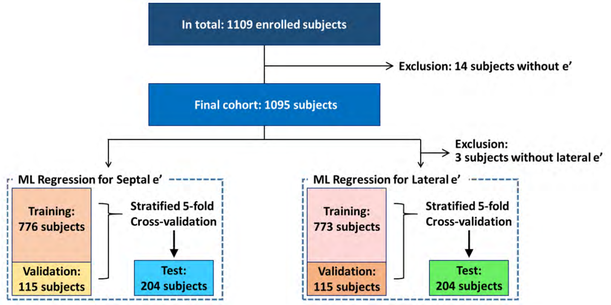
Introduction

- Left ventricular diastolic dysfunction (LVDD) is recognized to play a major role in the pathophysiology of heart failure.
- As echocardiography can be expensive as a screening tool, clinical tools for selection of the right patients for echocardiography remain to be established.
- We developed machine learning algorithms that directly estimate myocardial relaxation using body-surface signal processed electrocardiogram (spECG) as a first step of LVDD screening.

Methods

Study Flow Chart

- From 3 centers in the North America, total 1109 patients (including 81 healthy subjects) with various degrees of heart failure were prospectively enrolled to the study.
- Technicians performed spECG simultaneously with normal 12-lead ECG without taking extra time or effort.
- Echocardiography was performed on the same day as the spECG.

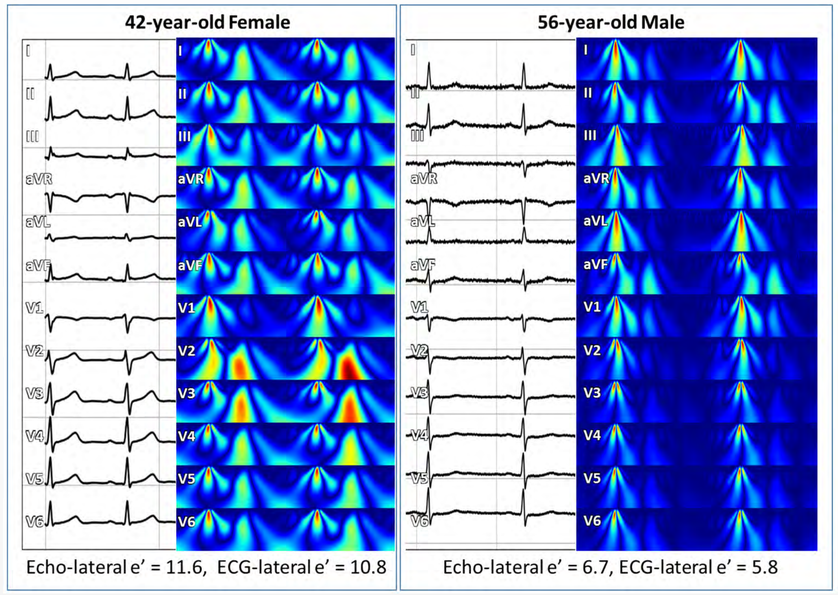


Machine learning algorithms

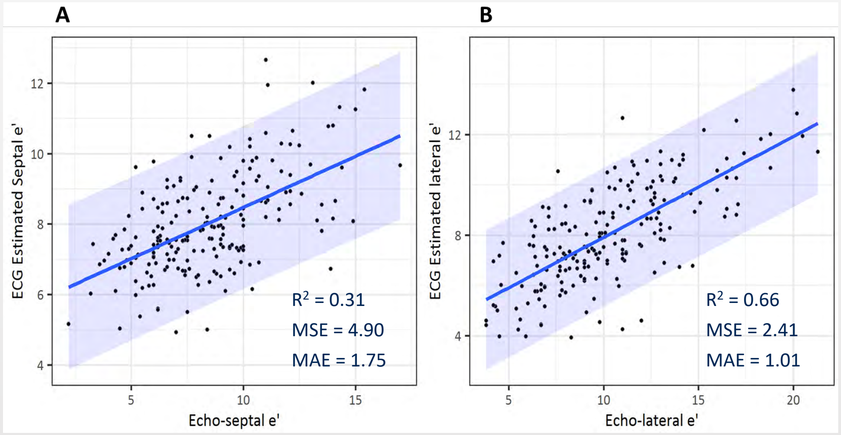
- Among over 500 features obtained from continuous wavelets transform of spECG, meaningful features were selected using topological data analysis (Ayasdi Workbench v7.4).
- Patients were divided into training, validation, and test set.
- Using cloud-based (PSC Bridge) H2O AutoML packages, machine learning regression with stacking algorithms were developed in the training and validation set. After stratified-5-fold cross validation, the performance of the developed models were evaluated in the test set.

Results

spECG: Illustrative Cases



Estimation of Echocardiographic e' using ECG



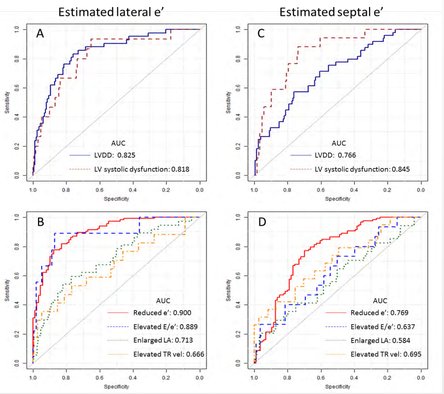
Patient Characteristics: Overall

Factor	Overall
n	1095
Age, years	58 [45 - 68]
Female, n (%)	537 (49.0)
Body mass index, m2/kg	29.2 [25.1 - 34.2]
Heart rate, /min	69 [60 - 78]
HF stages C or D, n (%)	357 (32.6)
Echocardiography	
IVSd, mm	10 [8 - 11]
LV end-diastolic dimension, mm	46 [43 - 51]
LV end-systolic dimension, mm	30 [27 - 34]
LV ejection fraction, %	63 [58 - 67]
LA volume, ml	45 [35 - 59]
E/A ratio	1.00 [0.80 - 1.30]
Lateral e'	9.8 [7.8 - 12.1]
Septal e'	7.7 [6.0 - 9.9]
TR maximum velocity, m/s	2.30 [2.00 - 2.50]
Guidelines-based LVDD, n (%)	324 (29.6)
Reduced e' *	625 (57.1)
Elevated E/e' **	100 (9.2)
Enlarged LA ***	206 (19.1)
Elevated TR velocity ****	87 (10.3)

Patients with Low and High ECG-estimated Lateral e'

Factor	Low estimated e'	High estimated e'	p value
n	102	102	
Age, years	62 [54 - 71]	50 [34 - 62]	<0.001
Female, n (%)	24 (23.5)	70 (68.6)	<0.001
Body mass index, m2/kg	30.8 [26.2 - 35.5]	28.0 [24.5 - 34.1]	0.096
Heart rate, /min	71 [63 - 79]	68 [59 - 75]	0.181
HF stages ≥C, n (%)	43 (42.2)	21 (20.6)	0.001
Echocardiography			
IVSd, mm	10 [9 - 11]	10 [8 - 11]	0.003
LV end-diastolic dimension, mm	48 [44 - 52]	47 [44 - 50]	0.177
LV end-systolic dimension, mm	31 [27 - 35]	30 [27 - 32]	0.136
LV ejection fraction, %	62 [56 - 67]	65 [61 - 68]	0.003
LA volume, ml	48 [35 - 58]	42 [33 - 53]	0.037
E/A ratio	0.85 [0.70 - 1.07]	1.20 [1.00 - 1.44]	<0.001
Lateral e'	8.1 [6.7 - 9.6]	12.3 [9.9 - 14.2]	<0.001
Septal e'	6.0 [4.8 - 7.1]	10.2 [8.5 - 11.4]	<0.001
TR maximum velocity, m/s	2.20 [1.80 - 2.60]	2.10 [1.33 - 2.30]	0.105
Guidelines-based LVDD, n (%)	37 (36.3)	5 (4.9)	<0.001
Reduced e' *	90 (88.2)	26 (25.5)	<0.001
Elevated E/e' **	8 (7.8)	1 (1.0)	0.035
Enlarged LA ***	65 (63.7)	97 (95.1)	<0.001
Elevated TR velocity ****	12 (14.1)	5 (6.1)	0.124
SpECG-predicted lateral e', cm/s	6.7 [5.8 - 7.3]	9.4 [8.7 - 10.5]	by def

Prediction of LV Diastolic and Systolic Function Using Estimated e' Values



- ECG estimated e' lateral values showed significant association with the guidelines-based LVDD, LV systolic dysfunction, and every component of LVDD.
- Estimated septal e' also showed some correlations but they were weaker than those of lateral e'.

Incremental Value of spECG upon Traditional Findings

	AUC	95% CI	Specificity	Sensitivity	p val
Clinical findings (age, obesity, and hypertension)	0.723	0.645 - 0.802	92.9%	45.1%	
+ traditional ECG	0.757	0.677 - 0.837	76.2%	64.1%	0.12
+ spECG-derived e'	0.856	0.797 - 0.915	90.5%	66.0%	0.01

- Adding estimated lateral e' to logistic regression models showed significant improvement of prediction of LVDD.

Conclusions

- A quantitative estimation of myocardial relaxation can be performed using features that are relatively easily obtained using body surface spECG.
- This cost-effective strategy may be a valuable first clinical step for assessing the presence of LV systolic and diastolic dysfunction and potentially aid early diagnosis and management of heart failure patients.

Disclosures: Dr. Sengupta - Consultant/Advisor for Heart Sciences and Ultromics. Other authors have nothing to disclose.