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Multivariable ECG machine Learning is Superior to QRS Duration and Traditional Criteria for Left Ventricular Hypertrophy in Patients with Left Bundle Branch Block

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Background

- The utility of ECG to diagnose left ventricular hypertrophy (LVH) in patients with left bundle branch is limited.[1]
- Traditional ECG criteria for LVH are heavily reliant on voltages, which are not valid in the setting of left bundle branch block.
- We previously showed QRS duration is a modest classifier for LVH in presence of LBBB.[2]
- Machine learning methods have the potential to improve classification of LVH by ECG.

Research Questions

- We sought to compare the diagnostic yield of ECG using (i) QRS duration, (ii) published LVH criteria, and (iii) machine learning (ML) models to detect increased left ventricular mass indexed (LVMi) in the setting of LBBB.

Methods and Materials

- 12-lead ECGs were processed to reconstruct orthogonal X, Y, Z leads using Kors's matrix and obtain root-mean-squared (3D) ECG.
- R wave, S wave and overall amplitudes, voltage-time-integrals (VTIs), and other ECG features were extracted from all ECG leads.
- ML algorithms [logistic regression (LR), support vector classifier (SVC), decision trees (DT), random forest (RF), gradient boosted machine (GBM) and boosted trees (BT)] were trained to predict increased LVMi (women >95 g/m^2, men >115 g/m^2) from ECG features on a training set of 2668 ECGs with typical LBBB and echocardiogram within 45 days before or after ECG.
- LVM was measured using ASE biplane method of discs.
- We obtained ROC AUCs for prediction of increased LVMi by (i) QRS duration, (ii) published LVH criteria, and (iii) ML models in **a separate validation set** of adults with typical LBBB.

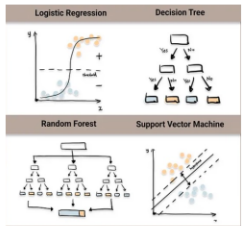

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Table 1. Validation set population characteristics

Variable	Women (N=219) Median (IQR)	Men (N=194) Median (IQR)
Age, years	74 (65-83)	72.5 (66-80)
BSA, m^2	1.9 (1.7-2.1)	2.1 (2.0-2.3)
LV Mass, g	164 (133-197)	227 (187-275)
LVEDV, ml	101 (76-138)	147 (113-199)
LVESV, ml	45 (31-71)	68 (48-105)
LVEF, %	54 (45-63)	53 (38-63)
QRS duration, ms	149 (140-158)	157 (150-168)
Amplitude$_{QRS-3D}$, mV	1.4 (1.2-1.7)	1.7 (1.3-1.9)
VTI$_{QRS-3D}$, μVs	102 (85-123)	124 (99-150)

Table 2. Area under receiver operating characteristic curve (AUC), sensitivity, and specificity for prediction of increased LVMi (women >95 g/m2, men >115 g/m2) in validation set (N=413).

ECG criteria	AUC	Sensitivity	Specificity
QRS duration			
Men ≥160 ms	0.703	0.631	0.659
Women ≥150 ms	0.657	0.632	0.591
Klein (S_{V2} + R_{V5})	0.559	0.072	0.946
Peguero-Lo Presti (max S + S_{V4})			
Men ≥2.8 mV	0.611	0.785	0.295
Women ≥2.3 mV	0.634	0.805	0.288
Cornell voltage (R_{aVL} + S_{V3})			
Men ≥2.8 mV	0.575	0.492	0.581
Women ≥2.0 mV	0.614	0.678	0.439
Cornell VDP ((R_{aVL}+S_{V3}) *QRS duration)	0.632	0.849	0.234
S_{V2} + S_{V3} (>6.0 mV)	0.591	0.165	0.897
R aVL (≥1.1 mV)	0.549	0.079	0.912
R aVL VDP (>103 mV * msec)	0.571	0.461	0.644
Sokolow-Lyon (S_{V1} + max R (V5 or V6)), ≥3.5 mV	0.523	0.066	0.966
Sokolow-Lyon VDP			
Men >367.4 mV* ms	0.535	0.492	0.55
Women >322.4 mV*ms	0.58	0.506	0.659
Gubner-Ungerleider (R_I + S_{III}), >2.5 mV	0.558	0.04	0.935
Max R + max S in V1-V6 (>4.5 mV)	0.584	0.125	0.927
RI + SII (≥2.6 mV)	0.574	0	1
Machine learning model	**AUC**	**Sensitivity**	**Specificity**
Logistic regression			
Men	0.7	0.277	0.938
Women	0.659	0.195	0.917
Support vector classifier			
Men	0.61	0.462	0.651
Women	0.682	0.598	0.682
Decision trees			
Men	0.713	0.631	0.713
Women	0.654	0.621	0.659
Random forest			
Men	0.738	0.415	0.853
Women	0.712	0.425	0.871
Gradient boosted machine			
Men	0.702	0.4	0.853
Women	0.737	0.368	0.879
Boosted trees			
Men	0.668	0.431	0.791
Women	0.741	0.494	0.848

Results

- Among the validation set of **413** adults (53% women, age 73±12 yr) with LBBB, QRS duration alone had a higher AUC (women 0.657, men 0.703) for diagnosing increased LVMi compared to standard LVH criteria (Table 2).
- **RF** (women 0.712, men 0.738), **GBM** (women 0.737, men 0.702), and **DT** (women 0.654, men 0.713) models had better AUCs than QRS duration alone.

Conclusion

- In patients with LBBB, QRS duration ≥150 ms in women and ≥160 ms in men is a superior predictor of LVH than traditional voltage-based ECG criteria.
- However, ML methods outperform all traditional ECG criteria and QRS duration.

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Conflicts of Interest - None

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