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Naraen, A, Wong, H S, Zeinali, M, Zolgharni, Massoud ORCID logoORCID: https://orcid.org/0000-0003-0904-2904, Samways, J, Saleh, K, Wu, F, Liang, Y, Shun-Shin, M, Howard, J, Wu, S, Huang, W, Keene, D, Whinnett, Z and Arnold, A (2026) Machine learning can detect left bundle branch area capture from individual-beat lead-restricted ECGs. In: ESC Congress 2026, 28–31 August 2026, Munich, Germany.

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Machine learning can detect left bundle branch area capture from individual-beat lead-restricted ECGs

A. Naraen[1], H.S. Wong[1], M. Zeinali[2], M. Zolgharni[2], J. Samways[1], K. Saleh[1], F. Wu[1], Y. Liang[1], M. Shun-Shin[1], J. Howard[1], S. Wu[3], W. Huang[3], D. Keene[1], Z. Whinnett[1], A. Arnold[1]

[1]Imperial College Healthcare NHS Trust, London, United Kingdom of Great Britain & Northern Ireland
[2]University of West London, London, United Kingdom of Great Britain & Northern Ireland
[3]The First Affiliated Hospital of Wenzhou Medical University, Wenzhou, China
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Background: Left bundle branch area pacing (LBBAP) has emerged as a more physiological pacing modality than conventional ventricular pacing. However, the challenge of ECG interpretation to determine successful LBBAP remains a barrier to widespread adoption. This is much more challenging when precordial leads are unavailable as can occur when using pacing system analysers.

Automated LBBAP detection from 12-lead ECGs and lead-restricted ECGs could reduce complexity of implants, accelerate procedural learning curves and facilitate follow-up.

Aim: We used artificial intelligence to automate discrimination of LBBAP capture from non-LBBAP capture from digital 12-lead ECGs and limb-lead restricted ECGs acquired during pacemaker implant procedures using artificial intelligence.

Method: 12-lead ECGs of individual paced-beat QRS complexes were isolated and extracted from continuous digital ECG recordings using a custom semi-automatic beat segmentation pipeline. The high volume paced ECG data from each case was clustered using HDBSCAN to form compact groups with similar QRS morphology for expert labelling as LBBAP or non-LBBAP (as defined by the EHRA 2023 CSP consensus criteria). A beat-level convolutional classifier was trained to predict these labels, with cluster-level optimisation to align learning with expert labels. One model used all 12 ECG leads another was restricted to the 6 limb leads (I-III, aVR,L,F). The models were trained on ECGs acquired at a tertiary centre in the UK and externally validated on ECGs from a tertiary centre in China. Measures analysed included accuracy (ACC), F1-score (F1), area under the receiver operating characteristic curve (AUROC), area under the precision-recall curve (AUPRC) and expressed as value (95% confidence interval).

Results: The UK training set comprised 244,787 beats forming 2,593 clusters from 225 patients. The 12-lead ECG model demonstrated strong cluster-level performance in identifying LBBAP across 10-fold cross-validation; ACC of 0.93 (0.92–0.94), F1 0.89 (0.87–0.91), AUROC 0.95 (0.94–0.96) and AUPRC 0.92 (0.91–0.94). The external validation (67 patients, 643 clusters; class ratio 1:0.9) showed similar strong generalisation: ensemble model ACC 0.92, F1 0.92, AUROC 0.97, AUPRC of 0.96.

The 6-lead ECG model produced reasonably strong performance; ACC 0.84 (0.81-0.87), F1 0.77 (0.73–0.81), AUROC 0.87 (0.84–0.90) and AUPRC 0.78 (0.72–0.83). The external validation group showed similar results; ACC 0.84, F1 0.75, AUROC 0.84, AUPRC 0.83 (Figure 1).

Conclusion: AI successfully automates LBBAP ECG recognition even when only limb leads are available.

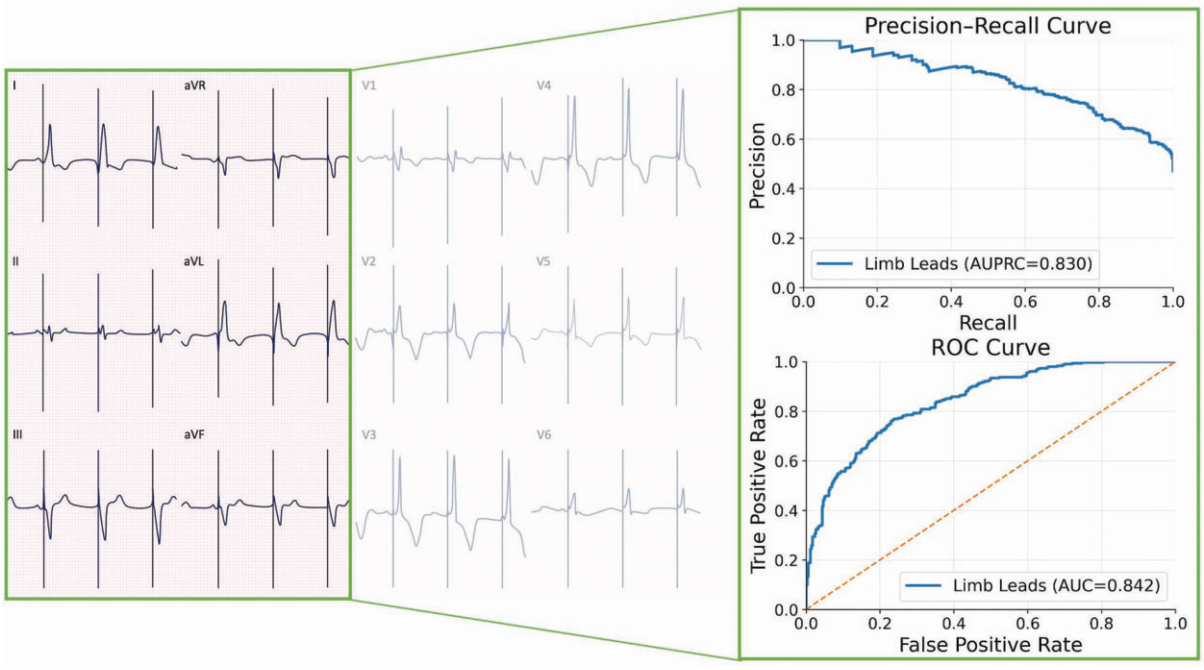


Figure 1: 6-lead model analysis curves

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