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HRX 2023 AbstracX

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On behalf of the HRX Production Team and the Cardiovascular Digital Health Journal, we would like to express our sincere thanks to our reviewers for their contribution in helping us select the accepted AbstracX. Your dedication and efforts contributed to the success of the HRX AbstracX.

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UMass Chan Medical School

ABSTRACT SESSION 1

Thursday, September 21, from 3:15-4:15 PM

FEASIBILITY OF REMOTE MONITORING FOR FATAL CORONARY HEART DISEASE FROM SINGLE LEAD ECG

Liam Butler; Turgay Celik; Ibrahim Karabayir; Lokesh Chinthala; Mohammad Samie Tootooni; David D. McManus; David Herrington and Oguz Akbilgic

Background: Fatal Coronary Heart Disease (FCHD) is a proxy for sudden cardiac death (SCD), affecting >17 million people/ year globally, with high prevalence even in younger adults. Electrocardiographic Artificial Intelligence (ECG-AI) models assessing cardiovascular disease risk have been developed but few exist for FCHD. ECG-AI based FCHD risk prediction tools, which are currently lacking, based on single lead ECG data from wearable devices would enable scalable screening and/or monitoring of younger populations.
Objectives: To develop a single lead ECG-based deep learning model for FCHD risk prediction and assess prediction concordance between paired clinical and Apple Watch ECGs.
Methods: A FCHD lead I ECG-based 1D convolutional neural network model was developed using 420,834 ECGs (68,094 patients), obtained from UTHSC, TN. The final model was tested on paired lead I clinical and Apple Watch ECGs collected at the same visit from 55 volunteers (unknown FCHD status). The concordance of FCHD risk between the two ECG modalities was assessed using paired correlation analysis.
Results: The UTHSC lead I ECG-AI model was developed on 80% data (5-fold cross-validation) and resulted in AUC=0.74 on the 20% holdout data. When implemented on 55 paired ECGs, there was strong positive correlation (Fig. 1) between predictions obtained from the two ECG modalities (correlation coefficient=0.82, p<0.001).
Conclusion: FCHD risk may be predicted from 1 lead ECGs using Apple Watches with moderate accuracy and be concordant with clinical ECGs. ECG-AI models implemented on Apple Watch ECGs can help screen large populations for FCHD with ease and at low cost. Adding clinical variables in deep survival models might improve accuracy (further work). Some limitations of this pilot work include: lead I ECG-AI FCHD model is preliminary and not optimized, and the resolution (signal depth) of Apple Watch ECGs needs to be adjusted to match clinical ECGs (A/D conversion), yet such documentation is lacking.

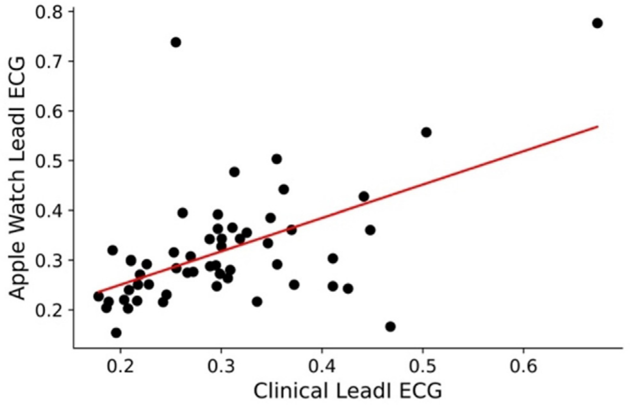
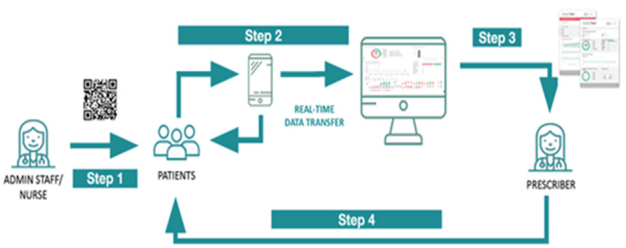


Figure 1 Linear relationship between predictions from Lead I of a clinical ECG vs Apple Watch ECG

TRANSFORMING OUR POST-ATRIAL FIBRILLATION ABLATION FOLLOW UP PATIENT PATHWAY USING FIBRICHECK: A SMARTPHONE DIGITAL APP USED FOR REMOTE MONITORING

Sharon Toora; Ajay Sharma; Neil T. Srinivasan and Paula McAuley

Background: Post-atrial fibrillation (AF) ablation clinics are typically in person, whereby 12-lead electrograms (ECG) and/or Holter monitors can detect recurrence. During the COVID-19 pandemic, at our site, nurse-led clinics were telephonic, and timely access to these investigations became difficult.
Objective: To determine if the validated smartphone application FibriCheck, which uses photoplethysmography to detect AF, can remove the need for in-person monitors, thereby reducing costs.
Methods: Adult patients post-AF ablation from September 2021 to January 2023 from Essex Cardiothoracic Centre, UK were consented and given two different seven-day subscriptions to FibriCheck leading up to their three and 12-month appointments respectively. They were asked to measure their heart rate and rhythm up to three times a day during that period. A detailed summary was sent from FibriCheck to the arrhythmia nurse, prior to patient's appointment.
Results: 147 patients participated in this study. 78% were male. The average age was 62 years. An average of 27 measurements were taken by each patient during the subscription period. Compliance was uniform across all ages. 39 patients (26.5%) detected AF recurrence during their subscription period within 12 months. Of these, 28 patients were symptomatic, with the most reported symptom being dyspnea. We estimate that due to the use of FibriCheck, 147 ECGs and 55 seven-day Holters were avoided, equaling net savings of £19,040 and 73.5 outpatient clinic hours.
Conclusion: Using FibriCheck, 12-lead ECGs and Holters were avoided, reducing the burden on primary care, and releasing Holter monitors to patients with higher acuity. This also equated to significant cost and time savings, allowing for increased



efficiency of the service, and making a positive impact on the carbon footprint. This is an easily replicated and cost-efficient service. Further expansion of FibriCheck is in progress, for follow up of patients post-synchronised cardioversion for AF.

POINT OF CARE AI DRIVEN ER2EP REFERRALS FOR NON-VALVULAR ATRIAL FIBRILLATION PATIENTS IN THE EMERGENCY DEPARTMENT

Kim Schwab

Background: Emergency Room to Electrophysiology (ER2EP) Atrial Fibrillation (AF) referrals may result in shorter times to ablation and optimal medical therapy. An effective way to facilitate ER2EP referrals can be the use of point of care digital health solutions like an Artificial Intelligence/Machine Learning (AI/ML) clinical decision support tool.
Objective: To determine if a cloud based Artificial Intelligence/Machine Learning (AI/ML) clinical decision support tool can aid in guideline-driven care and procedures.
Methods: This RCT enrolled patients $>$ 18 years old who presented to the ER with a diagnosis of Atrial Fibrillation. Subjects were excluded if they were receiving anticoagulation (AC) for an indication other than AF, hemodynamically unstable, or lacked capacity to provide informed consent. Patients were randomized 1:1 to receive either standard of care or cloud based AI/ML ER2EP clinical support tool (Lucia AF mobile app) to detect and treat AF. Follow up phone calls up to 30 days evaluated for ER2EP referral compliance, adverse events, and readmission.
Results: Overall, 40 patients were enrolled, 43% female, 57% male, 70% Hispanic, 30% Non-Hispanic. Twenty-two patients cared for by physicians receiving ER2EP output (55%) were compared to controls. ER2EP patients had more primary AF patients (22.3% vs 54.6%, P=0.025), although both cohorts received similar rates of anticoagulation (66.7% vs 72.7%, p=.68). Anticoagulation, scoring of CHA2DS2-VASc, EP referrals, LAAC device placement, and RF ablation rates were higher in the ER2EP cohort (95% CI = -55.1, -11.6, P = 0.003). One hundred percent of ER2EP recommendations were followed.
Conclusion: ER2EP have a greater rate of AF diagnosis, with higher rates of AC, scoring of the CHA2DS2-VASc, EP referrals, LAAC device placement, and RF ablation within 30 days.

ECG-DERIVED METRICS FOR CONTINUOUS STRESS MONITORING IN VULNERABLE GROUPS: A PROSPECTIVE STUDY ON INFORMAL COMMUNITY-BASED CAREGIVERS

Stacey McKenna; Andrew Miller; Naomi McCord; Holly Easlea and Austin Gibbs

Background: Informal caregivers face persistent stressors that can negatively impact their physical and mental health, leading to an increased risk of chronic stress-related health issues, including CVD and stroke. Implementing preventive strategies to identify and effectively manage chronic stress is essential.
Objective: To monitor the cardiovascular health and stress of unpaid community-based caregivers in Northern Ireland using HeartKey® ECG software.
Methods: Caregivers wore a Bittium® Faros ambulatory ECG device over continuous user-defined periods. HeartKey software processed the ECG data, which was then assessed for abnormalities by an Associate Specialist in Cardiology. Weekly wellness reports provided caregivers insight into their well-being using various ECG-derived metrics. The Physiological Stress metric, which uses HR and HRV inputs (among others) to generate a continuous stress score (0-100), was used to quantify caregiver stress. The validity of this metric has been verified against clinically recognized stress assessment methods.
Results: Seventeen caregivers were monitored for an average of 4.6 days per week for up to 12 weeks (mean wear time: 23 days). Potential cardiac abnormalities were found in four caregivers, leading to GP referrals for further investigation. Elevated stress was common, with an average time spent in medium and high-stress states of 19.2% and 5.4%, respectively. Among the seven caregivers monitored for $\geq$4 weeks, three experienced a $>$11% reduction in the average weekly time spent in medium and high-stress states, which was attributed to the introduction of proactive lifestyle changes to combat the identified stress issues.
Conclusion: Continuous ECG monitoring with HeartKey is an effective means of tracking stress and assessing the efficacy of stress reduction measures. The early identification of ECG abnormalities in 24% of caregivers highlights the importance of cardiovascular health interventions in high-stress populations.

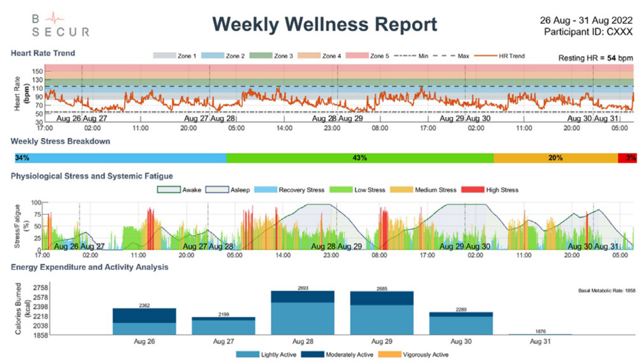


Figure 1 An example of the weekly wellness reports provided to caregivers featuring analysis of heart rate trends, physiological stress, systemic fatigue, and energy expenditure.

DETECTION OF MYOCARDIAL SCAR AMONG CARDIAC SARCOIDOSIS PATIENTS ON CMR IMAGING USING DEEP LEARNING ON ECG SIGNALS

Ishan Vatsaraj; Shane Loeffler; Eugene G. Kholmovski; Jonathan Chrispin and Natalia A. Trayanova

Background: Sarcoidosis is a rare multisystem genetic disease. About 20% of Sarcoidosis patients have cardiac involvement. Previous studies have shown that cardiac sarcoidosis (CS) patients are at high risk for lethal ventricular arrhythmia (VA) risk when there is a fibrotic remodeling in the heart. However, fibrosis is detected by Late Gadolinium Enhancement (LGE) MRI - a cardiac imaging modality of high cost and limited availability. Thus, developing an algorithm that can predict the presence of fibrosis using a common screening tool, such as the ECG, would be invaluable in identifying which CS patients should undergo LGE-MRI to establish the need for primary prevention of VA.
Objectives: To predict fibrosis detectable by LGE-MRI in CS patients using a deep learning (DL) model on the 12 lead ECG and EHR data.
Methods: Deep Learning models were built using ECG and EHR data for 242 CS patients. The LGE-MRI images of these patients were reviewed and annotated by experts to mark the presence/absence of enhancement. Outliers and patients with missing data

were removed. The 12 lead ECG waveforms were segmented into individual heartbeats to increase the dataset size. The DL model architecture consisted of a CNN-BiLSTM model to extract features from the ECG signals. These extracted features were combined with the EHR data and were passed to a standard feed-forward network for the downstream classification task. The model was optimized using the Adam optimizer; a standard Binary Cross Entropy loss function was used.
Results: A final cohort of 196 CS patients' data were used to train and test the deep learning model. On the hold-out test set, the model achieved 73% accuracy and 60% sensitivity, respectively.
Conclusion: A CNN-BiLSTM model can be used to predict the presence of fibrosis detectable by LGE-MRI from ECG signals accurately and with high sensitivity. This model can be deployed in real-world settings and used as a screening tool for predicting fibrosis in CS patients.

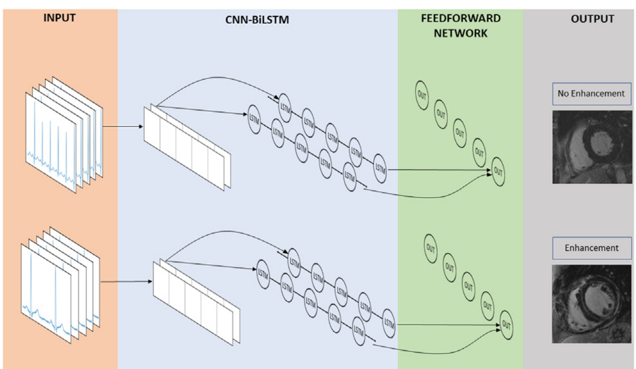


Figure 1 Deep Learning Model Pipeline

ABSTRACT SESSION 2

Friday, September 22, from 9:45-10:45 AM

ARTIFICIAL INTELLIGENCE-BASED WALL THICKNESS ANALYSIS TO PREDICT ARRHYTHMOGENIC MYOCARDIAL SUBSTRATE

Christian D. Marton; Christopher Villongco; David Krummen and Gordon Ho

Background: Accurate identification of arrhythmogenic tissue underlying ventricular tachycardia (VT) is essential for guiding catheter ablation. While myocardial wall thickness analysis of cardiac CT is a promising approach, existing semi-automatic segmentation methods are labor-intensive and time-consuming. We developed an AI-based, end-to-end automated process to create wall thickness maps from raw CT DICOMs.
Objectives: In this study, we aimed to develop and test an end-to-end automated pipeline to segment the left ventricle (LV), calculate wall thickness, and display it as a color gradient on a 3D mesh.
Methods: We trained a 3D U-Net segmentation model to segment 8 cardiac structures on 18 cardiac CTs (~250 slices each) from a previously validated MM-WHS dataset. The U-Net-derived segmentation masks were used to derive and display wall thickness onto a patient-specific 3D mesh.
Results: The U-Net segmentation model was tested on 2 held-out patients from the MM-WHS dataset with a mean Dice-score of 0.89 $\pm$ 0.08. The end-to-end pipeline was then tested on a CT from a patient undergoing catheter ablation of VT at UCSD and compared to manual segmentation masks. The U-Net-derived wall thickness analysis (Fig1B) agreed with manual segmentation (Fig1A) in predicting a large region of wall thinning in the anterior and anteroseptal LV. Invasive high-density bipolar voltage mapping revealed a large region of low voltage scar corresponding to the predicted region (Fig1C). Invasive activation mapping localized the VT channel within wall thinning at the basal anteroseptal LV (Fig1D). Ablation at this site and substrate homogenization eliminated VT at the 3-month follow-up.
Conclusion: Our AI-based end-to-end segmentation method accurately localizes wall thinning regions compared to invasive substrate mapping. The automated method could more efficiently and accurately guide VT ablation. Further studies are underway to validate the effectiveness of our method in larger populations.

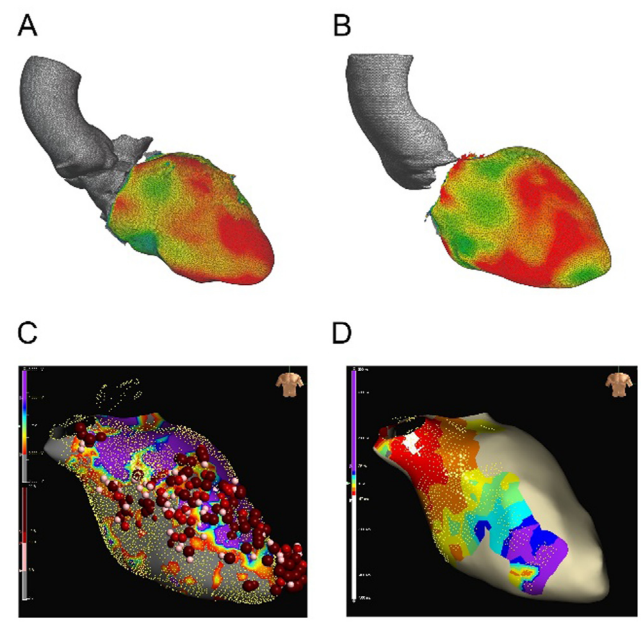


Figure 1 Wall thickness calculations in the manual, electrophysiologist-generated (A) and U-Net-generated (B) endocardial LV anatomies show agreement in the anterior and anteroseptal region of wall thinning (red). Wall thickness maps correlate to invasive high-density voltage (C) and activation maps (D) obtained during the ablation procedure.

USING REMOTE MONITORING OF CPAP USE AND COMPLIANCE TO MANAGE PATIENTS WITH OBSTRUCTIVE SLEEP APNEA AND ATRIAL FIBRILLATION

Leah Sarang Park; Nicolle Sara Milstein; Kerry Limberg; Alexandra Musat; Owen Les; Advay G. Bhatt; Mohammadali Habibi; Mark W. Preminger; Tina C. Sichrovsky; Dan L. Musat and Suneet Mittal

Background: Patients with atrial fibrillation (AF) are screened for obstructive sleep apnea (OSA); if present, continuous positive airway pressure (CPAP) therapy may reduce AF. However, a mechanism to objectively assess use and compliance with CPAP is needed.

Objectives: The aim of this study was to assess the utility of a remote monitoring program to determine CPAP use and compliance in AF patients with OSA managed by an electrophysiology (EP) practice.
Methods: We enrolled consecutive AF patients who underwent evaluation for OSA [mild ($5 \leq$ AHI < 15), moderate ($15 \leq$ AHI < 30), severe (AHI ≥ 30)] and were prescribed CPAP. Most devices wirelessly transmitted monthly CPAP data to a secure, cloud-based center. Compliance was defined as CPAP use ≥ 4 hours/night for $\geq 70\%$ of the month. We called patients to understand why they stopped CPAP or were non-compliant.
Results: The study cohort included 495 patients (65±10 years; 150 (30%) female) with predominantly paroxysmal (263, 53%) or persistent (224, 45%) AF. OSA was diagnosed in 424 (86%) patients: mild (172, 41%), moderate (116, 27%), severe (136, 32%). Although recommended for all, only 230 (54%) patients started CPAP therapy (wireless data transmission possible in 213 (93%) patients). During 31±24 months of follow-up, the wireless communication failed in 42 (20%) patients. Only 62 (36%) patients remained compliant (Figure 1). CPAP discontinuation was common over time (Figure 2), most commonly due to discomfort to the CPAP apparatus.
Conclusion: CPAP is recommended in AF patients with OSA. We found (1) only half of prescribed patients started CPAP, (2) 20% of CPAP machines failed to transmit compliance data, and (3) 2/3 of the remaining patients either stopped or were non-compliant with CPAP. These data suggest that remote monitoring of CPAP compliance is important for objective clinical management of AF patients with OSA and highlight the need for major advances to the CPAP apparatus for therapy delivery and monitoring.

Figure 1

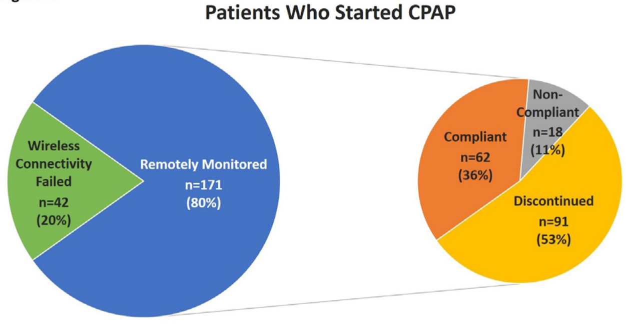


Figure 1

Figure 2

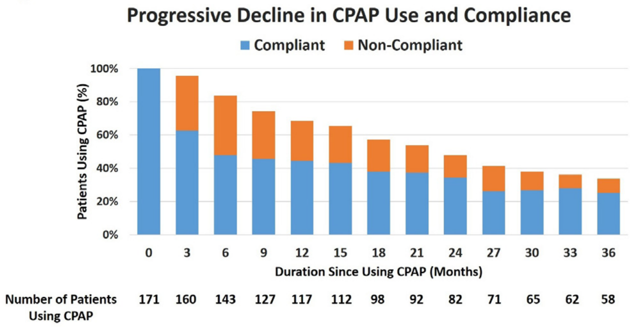


Figure 2

CONTEXTUALLY TAILORED TEXT MESSAGES TO AUGMENT CARDIAC REHABILITATION: THE VIRTUAL APPLICATION-SUPPORTED ENVIRONMENT TO INCREASE EXERCISE (VALENTINE) STUDY

Kashvi Gupta; Jieru Shi; Walter Dempsey; Bhramar Mukherjee; Sachin Kheterpal; Predrag Klasnja; Brahmajee K. Nallamothu and Jessica Golbus

Background: We previously found text messages (TM) delivered as part of a comprehensive mobile health intervention may augment physical activity levels in patients enrolled in cardiac rehabilitation (CR) during its initiation phase, although optimal TM tailoring is unknown.
Objectives: Determine optimal time and environment to deliver TMs to CR enrollees after initiating CR.
Methods: We conducted a micro-randomized trial that delivered TMs to low and moderate-risk patients, ages 18-75 enrolled in CR. Participants received a compatible smartwatch (Apple

Table 1 Moderator analysis of contextually tailored text messages to promote physical activity amongst *Apple Watch* users in VALENTINE study.

	Overall		Initiation Phase	
Moderator	RRR	CI, p-value	RRR	CI, p-value
Time of day				
Morning vs Lunch	0.93	0.84-1.02, 0.1	0.88	0.63-1.21, 0.4
Morning vs Afternoon	0.95	0.85-1.06, 0.4	0.97	0.73-1.29, 0.8
Morning vs Evening	0.93	0.84-1.03, 0.2	0.86	0.63-1.19, 0.4
Lunch vs Afternoon	1.02	0.93-1.12, 0.6	1.01	0.86-1.42, 0.4
Lunch vs Evening	1.00	0.91-1.10, 0.9	0.99	0.78-1.24, 0.9
Afternoon vs Evening	0.98	0.90-1.06, 0.6	0.89	0.70-1.11, 0.4
Time of week				
Weekend vs Weekday	0.97	0.90-1.05, 0.5	0.96	0.78-1.18, 0.7
Message type				
Anti-sedentary vs Walking	0.92	0.85-0.99, 0.04	0.95	0.76-1.19, 0.7
Personalization				
Name vs no name	0.99	0.95-1.04, 0.8	0.91	0.79-1.06, 0.2
Age category				
Young (<65) vs Old (≥65)	1.04	0.98-1.11, 0.2	1.27	1.07-1.51, 0.006
Activity status				
Less active vs Active	0.98	0.92-1.04, 0.6	0.91	0.75-1.1, 0.33
Heart Failure				
Heart failure vs None	1.03	0.97-1.10, 0.3	1.02	0.81-1.13, 0.9
Indication for CR				
PCI vs CABG	1.04	0.95-1.14, 0.4	0.84	0.56-1.26, 0.4
Valve repair vs CABG	1.03	0.93-1.15, 0.6	0.72	0.47-1.09, 0.1
Valve repair vs PCI	0.99	0.91-1.08, 0.9	0.85	0.70-1.05, 0.1

Abbreviations: RRR, relative risk ratio; CI, confidence interval; CR, cardiac rehabilitation; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft. Highlighted cells indicate significant values.

Table 2 Moderator analysis of contextually tailored text messages to promote physical activity amongst *Fitbit Versa 2* users in VALENTINE study.

Moderator	Overall		Initiation Phase	
	RRR	CI, p-value	RRR	CI, p-value
Time of day				
Morning vs Lunch	0.94	0.82-1.07, 0.3	1.02	0.72-1.44, 0.9
Morning vs Afternoon	1.04	0.91-1.19, 0.6	1.38	0.97-1.97, 0.08
Morning vs Evening	1.04	0.89-1.22, 0.6	1.18	0.82-1.69, 0.4
Lunch vs Afternoon	1.11	0.99-1.24, 0.07	1.35	1-1.82, 0.05
Lunch vs Evening	1.12	0.97-1.28, 0.1	1.15	0.82-1.63, 0.4
Afternoon vs Evening	1.01	0.89-1.14, 0.9	0.85	0.585-1.24, 0.4
Time of week				
Weekend vs Weekday	0.95	0.87-1.03, 0.2	0.936	0.70-1.26, 0.7
Message type				
Anti-sedentary vs Walking	1.00	0.93-1.09, 0.9	1.07	0.83-1.38, 0.6
Personalization				
Name vs no name	0.99	0.95-1.04, 0.8	0.83	0.66-1.04, 0.1
Age category				
Young (<65) vs Old (≥65)	0.99	0.91-1.07, 0.7	0.94	0.78-1.13, 0.5
Activity status				
Less active vs Active	0.95	0.88-1.02, 0.1	0.89	0.76-1.04, 0.14
Heart Failure				
Heart failure vs None	0.99	0.89-1.1, 0.9	0.914	0.77-1.09, 0.3
Indication for CR				
PCI vs CABG	0.99	0.93-1.06, 0.8	0.885	0.74-1.06, 0.2
Valve Repair vs CABG	1.01	0.92-1.11, 0.9	1.31	1.03-1.67, 0.03
Valve Repair vs PCI	1.02	0.92-1.13, 0.8	1.48	1.17-1.87, 0.001

Abbreviations: RRR, relative risk ratio; CI, confidence interval; CR, cardiac rehabilitation; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft. Highlighted cells indicate significant values.

Watch or FitBit Versa 2) and were randomized to receive a TM or no TM at 4 user-selected time points over 6-months. TMs were meant to be actionable in real-time and were tailored on time of day, day of week, weather, and phase of CR. TMs were walking or anti-sedentary (e.g., stretching) and half were personalized with participants' names. Our primary outcome was step count 60-minutes following a TM. To account for measurement differences between devices, we assessed results separately by device and focused on the initiation phase of the study (i.e., 0-4 weeks after enrollment).
Results: 108 participants were included with mean age 59.5 (10.7) years, 36 (32.4%) female, and 68 (63%) an Apple Watch. During the initiation phase of the study, use of TMs increased step counts by 17% in the 60-minutes after a TM for Fitbit users and by a non-significant 10% for Apple Watch users. For Apple Watch users, walking TMs significantly increased step count vs anti-sedentary TMs, and the impact of TMs was greatest for younger participants as compared to older participants (Table 1). For FitBit users, TMs were more effective at lunch vs afternoon and for CR participants who underwent valve repair (as compared to PCI or CABG) (Table 2). Personalization did not impact TM efficacy.
Conclusion: TMs can augment the benefits of CR early after initiation with the potential for differential effects across varying contexts and scope for optimization.

ARTIFICIAL INTELLIGENCE-ENABLED ELECTROCARDIOGRAM ALGORITHM FOR SIMULTANEOUS ASSESSMENT OF LEFT VENTRICULAR SYSTOLIC AND DIASTOLIC DYSFUNCTION

Eunjung Lee; Rahul Dhawan; Zachi Itzhak Attia; Francisco Lopez-Jimenez; Paul A. Friedman; Horng H. Chen and Jae K. Oh

Background: Assessment of left ventricular (LV) systolic and diastolic dysfunction (LVSD and LVDD, respectively) is essential for the evaluation and management of cardiac disease. A rapid, easily performed test to assess both LVSD and LVDD is lacking.
Objectives: We aimed to develop an artificial intelligence-enabled electrocardiogram (AI-ECG) algorithm to simultaneously identify LVSD, defined as LV ejection fraction (EF) <50%, and LVDD, defined as increased left ventricular filling pressure. We also aimed to assess the prognostic performance of 4 groups (normal LV function, LVSD only, LVDD only, and both LVSD and LVDD) determined by a single AI-ECG model classifying both LVSD and LVDD.
Methods: We trained a multi-output convolutional neural network using 12-lead ECGs performed within 14 days of transthoracic echocardiography from 120,699 patients (98,736 for training and 21,963 for validation) to predict LVSD and LVDD. The trained model was evaluated using the area under the curve (AUC) of the receiver operating curve, accuracy, sensitivity, and specificity. We also assessed whether the model discriminates the risk of all-cause mortality using Kaplan-Meier estimate and Cox proportional hazards regression was used to estimate the hazard.
Results: For LVSD, AI-ECG model had the AUC of 0.91, accuracy 93.5%, sensitivity 54.8%, and specificity 97.4%. For LVDD, the model had the AUC 0.91, accuracy 87.3%, sensitivity 59.8%, and specificity 95.1% (Table). When the test patients were separated into 4 groups, the mortality of 4 groups determined from echocardiography (HR 1.8, 95% CI 1.8-1.8) and AI-ECG (HR 1.7, 95% CI 1.7-1.8) was comparable (Figure) with the worst outcome in the group having both LVSD and LVDD. The group with solitary LVDD had worse outcome than solitary LVSD.
Conclusion: The AI-ECG simultaneously and rapidly detects LVSD and LVDD with an excellent mortality prognostic information that is equivalent to that found using echocardiography.

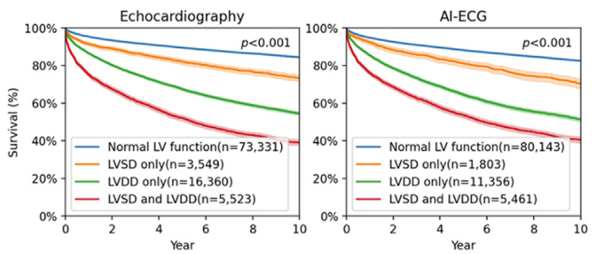


Figure. Prognosis for LVSD and LVDD patients separated into 4 groups (normal LV function, LVSD only, LVDD only and both LVSD and LVDD) by echocardiography and AI-ECG.

Figure 1 Prognosis for LVSD and LVDD patients separated into 4 groups (normal LV function, LVSD only, LVDD only, and both LVSD and LVDD) by echocardiography and AI-ECG.

Table Performance of AI-ECG for echocardiographically determined LVSD and LVDD.

	AUC	Accuracy	Sensitivity	Specificity
LVSD	0.91	93.5%	54.8%	97.4%
LVDD	0.91	87.3%	59.8%	95.1%

AI-ASSISTED SHORT-TERM FORECASTING OF IMPENDING ATRIAL FIBRILLATION EPISODES USING A WEARABLE ECG PATCH

Soonil Kwon; Jangwon Suh; Jungmin Ko; Hyo-Jeong Ahn; So-Ryoung Lee; Wonjong Rhee; Eue-Keun Choi and Seil Oh

Background: While predicting the presence of atrial fibrillation (AF) using sinus rhythm ECGs has proven to be feasible, less is known about forecasting the timing of AF episodes.
Objectives: This study aims to investigate AI-assisted short-term forecasting for impending atrial fibrillation episodes, utilizing single-lead ECG monitoring with a wearable ECG patch.
Methods: In this single-center prospective cohort study, 98 patients requiring ambulatory ECG monitoring for paroxysmal AF participated in 3- or 7-day single-lead monitoring using a wearable ECG patch. Deep learning, employing ResNet architecture, classified ECG strips based on the occurrence of AF within 5 minutes. AF and non-AF datasets were constructed from 30-second ECG strips (Figure 1), with training, validation, and test datasets organized in a 7:1:2 ratio. The ratio between AF and non-AF datasets was maintained at 1:2. The results were averaged over five runs with different random seeds. Diagnostic parameters and model calibration were evaluated to measure performance.
Results: A total of 55,870 non-AF and 27,935 AF ECG strips were generated. The deep learning performance in predicting an AF episode improved as the time approached the onset of AF, achieving an AUROC of 0.90±0.01, AUPRC of 0.77±0.03, and F1-score of 0.75±0.02 (Figure 2A). The model was well calibrated, regardless of the timing of ECG strips (Figure 2B). The AF datasets exhibited significantly higher heart rates, RMSSD of RR intervals, and premature atrial complex burdens, while showing significantly lower premature ventricular complex burdens compared to non-AF datasets (Figure 2C). Visualization of ECG feature attribution using Grad-CAM revealed that deep learning focused on frequent premature atrial complex or atrial tachycardia to forecast impending AF episodes (Figure 2D).
Conclusion: Short-term forecasting of impending AF episodes was feasible using AI analysis of single-lead ECG monitoring.

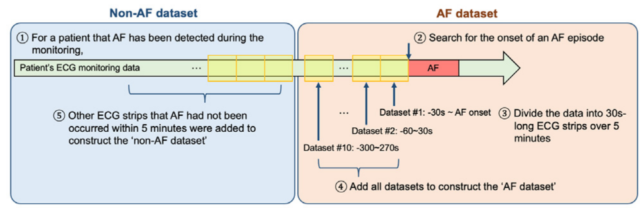


Figure 1. The illustration of dataset construction for the AI-assisted short-term forecasting of impending AF episodes under ECG monitoring. Abbreviations: AF, atrial fibrillation; ECG, electrocardiogram

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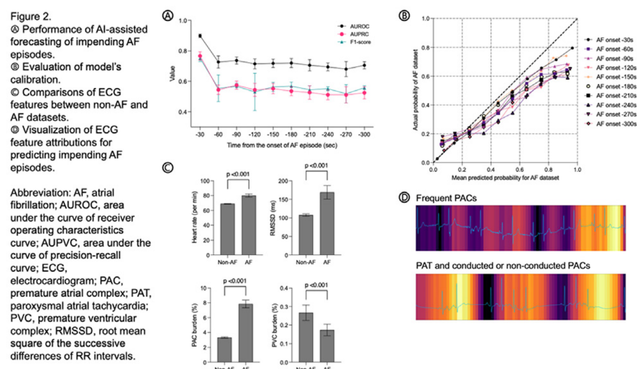


Figure 2 (A) Performance of AI-assisted forecasting of impending AF episodes. (B) Evaluation of model's calibration. (C) Comparisons of ECG features between non-AF and AF datasets. (D) Visualization of ECG feature attributions for predicting impending AF episodes. Abbreviation: AF, atrial fibrillation; AUROC, area under the curve of receiver operating characteristics curve; AUPVC, area under the curve of precision-recall curve; ECG, electrocardiogram; PAC, premature atrial complex; PAT, paroxysmal atrial tachycardia; PVC, premature ventricular complex; RMSSD, root mean square of the successive differences of RR intervals.

ABSTRACT SESSION 3

Saturday, September 23, from 11:00-12:00 PM

INTEGRATED ACTIVITY AND RHYTHM DATA FOR PERSONALIZED ATRIAL FIBRILLATION MANAGEMENT FOLLOWING CATHETER ABLATION: A WEARABLE DEVICE APPROACH

Nikhil Ahluwalia; Hakam Abbass and Richard J. Schilling

Background: Wearable devices with cardiac electrical activity sensors and activity tracking capabilities may facilitate personalized Atrial Fibrillation (AF) management post-catheter ablation (CA), allowing for a better understanding of the relationship between AF episodes and patient activity levels.
Objectives: To assess the clinical utility of paired activity and rhythm data surrounding AF catheter ablation (CA) and evaluate longitudinal activity as an outcome measure.
Methods: A script analyzed paired ECG and activity data from Apple Watch devices in patients undergoing first-time CA for AF. Inclusion required activity data from 90 days pre-CA. The post-ablation period comprised two 90-day blocks: blanking period and follow-up. Activity was defined as daily step count

hierarchically measured by wearable device or smartphone. AF events were days with AF confirmed on a wearable derived ECG.
Results: 23 patients were enrolled, undergoing 37 CA procedures. 12 (48%) were EHRA III/IV at baseline. Median ECG recordings were 1 (0, 14) pre-CA, 53 (11, 100) during blanking, and 73 (25, 184) between day 91-365. Median daily activity change was +1111 (+16%) steps/day ($p<0.001$). 12 (48%) individuals had a significant increase. (figure 1) 13 (56%) patients experienced recurrence at 1-year, with a median time-to-recurrence of 112 (95, 191) days post-blanking. 7 (54%) had a significant activity reduction during AF events. (figure 2)
Conclusion: Paired rhythm and activity data enable personalized assessment of AF burden, impact on activity, and recurrence detection and can offer quantitative insights into patient outcomes over time. Activity data serves as a patient-reported measure of symptom burden and treatment efficacy, underscoring the importance of incorporating such data in the evaluation of AF management strategies. A prospective study to evaluate the impact of patient-led, wearable post-ablation surveillance on clinical care and patient experience is warranted.

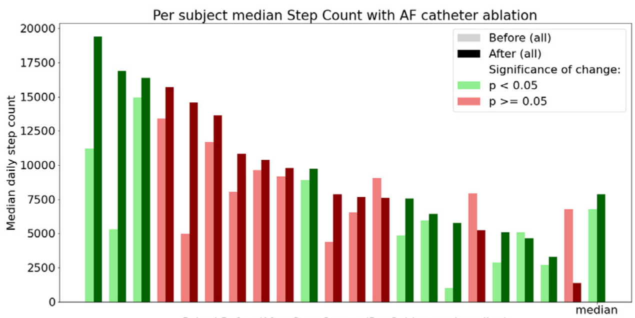


Figure 1 Per-subject breakdown of median daily activity prior to and after catheter ablation of atrial fibrillation. The statistical significance of the change is denoted as green colour.

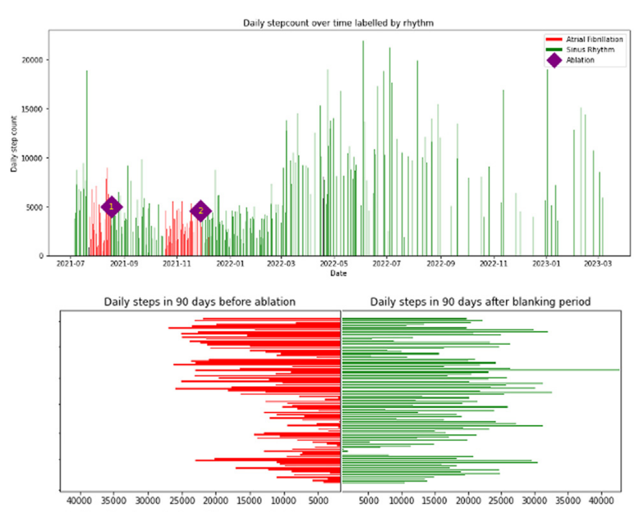
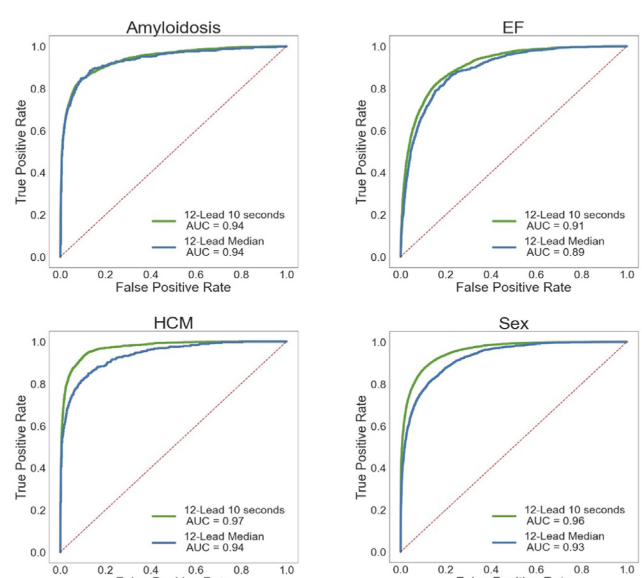


Figure 2 An example of the paired ECG and activity data taken from a single participant. Numeric representation with statistical significance of any difference is also reported (a) shows the daily activity over time around the period of catheter ablation. Rhythm on ECG for that day is denoted by bar colour; red for atrial fibrillation and green for sinus rhythm. (b) is a waterfall chart of stepcount during the 90 days prior (red) to ablation and 90 days after the blanking period (green).

12-LEAD MEDIAN BEAT IS ALL YOU NEED FOR STRUCTURAL HEART DISEASE SCREENING

Kathryn Mangold; Rickey Carter; Francisco Lopez-Jimenez; Paul A. Friedman and Zachi I. Attia

Background: We have published the use of convolutional neural networks (CNNs) to estimate the probability of structural heart diseases including hypertrophic cardiomyopathy (HCM), low ejection fraction (EF), and amyloidosis from the electrocardiogram (ECG). These studies used a 10 second 12-lead ECG as inputs to train the network.
Objectives: To compare the performance of a single heartbeat to a 10 second ECG when training neural networks for structural heart disease screening.
Methods: Unique research authorized patients were identified who had an ECG within 14 days of a transthoracic echocardiogram (TTE) to create a pool of ECG-TTE pairs. ECG-TTE pairs belonging to patients previously identified in our published studies with amyloidosis (2,095 pairs) and HCM (1,812 pairs) formed the basis of our cohort. Remaining pairs were labeled based on EF (low EF defined as $<=40\%$) for age and sex matching. Amyloid and HCM ECG-TTE pairs were then each age and sex matched in a desired ratio of 1:1:12 (disease: low EF: normal EF). The final cohort of 51,080 patients was 63% male with an average age of 59 $\pm$ 14 years with a low EF prevalence of 8%. This cohort was then split once randomly into training, validation, and testing tests in a ratio of 7:1:2. Splitting the cohort once ensured that the same ECGs were used for training, validation, and testing of all the ECG median models.
Results: The median beat 12-lead models estimated probabilities of amyloidosis, low EF, and HCM with an area under the curve (AUC) of 0.94 (95% Confidence Interval (CI) 0.92-0.95), 0.89 (95% CI 0.88-0.90), and 0.94 (95% CI 0.92-0.95), respectively. Patient sex was estimated with AUC of 0.93 (95% CI 0.92-0.93).
Conclusion: The 12-lead median models show comparable performance to the 10 second 12-lead models. This finding suggests that the salient features for ECG model predictions are encompassed just in a single heartbeat, which may guide future model explainability studies.



HOME HEART HOSPITAL (H3): A NEW HIGH-NEED AND COST CARE MODEL, FEASIBILITY & INITIAL 3-YEAR EXPERIENCE

Kareem Osman; Kaelin DeMuth; Yi Xing Liu; Ahmed F. Osman and Michael Shen

Background: HNHC patients account for 5% of the population but 50% of the US healthcare cost over the last two decades. There is no care platform to manage High Need High Cost (HNHC) patient populations using continuous monitoring/ telemetry and interventions in the outpatient setting. We created a Home Heart Hospital (H3) model with a new technology enabled platform of 24/7 monitoring and interventions at home in a value-based care setting.
Methods: On-site care consisted of nurse practitioner provision of physical examination, labs, imaging and intervention at the patient's home. Online care consisted of specialty (cardiology, infectious disease, nephrology, and pulmonology) intervention and follow-up via telemedicine and 24/7 mobile cardiac telemetry. A series of personalized processes and protocols evaluated and escalated care as needed, including an alert management system for monitoring and response to urgent care needs, including acute cardiac events.
Results: A total of 94 HNHC patients enrolled between 2/2019 and 10/2021 from a Medicare Advantage plan. Normalized admissions, length of stay (LOS), and Cost were analyzed with significant reductions compared to prior to H3. Three cases at home are presented: STEMI diagnosis and triage saving a life; Chemical AFib cardioversion, and the stabilization of a comorbid patient with 13 admissions during the prior 12 months with 1 admission due to COVID during H3. Three patients (3.2%) died in the hospital during H3: 2 sepsis and 1 pneumothorax from end-stage cancer. There was no mortality at home.
Conclusion: This is the 1st study demonstrating safety and feasibility of H3 with long-term clinical and financial outcomes. The implication of the study can be significant and potentially revolutionize HNHC Care which is currently without widely acceptable solutions. Further studies are warranted to test the scalability of H3 to treat cardiac disease, the #1 killer and #1 cost of HNHC care.

Table 1 Utilization Outcomes of H3 vs Conventional Care.

	Conventional Care	H3
N	94	94
Total Patient Days	14,184	5,697
Normalized Admissions per patient (% difference)	4	1.88 (-56%)
ARR of Admission (NNT)	Reference	57% (1.74)
Normalized LOS per patient (% difference)	33	7.33 (-78%)
Total Cost per patient (95% CI)	$174,889 ($127,746, $222,031)	$107,516 ($82,723, $132,310)*

BIDIRECTIONAL COMMUNICATION BETWEEN AN ARTIFICIAL INTELLIGENCE DEVICE AND A 3-DIMENSIONAL NAVIGATION APPARATUS IMPROVES AUTOMATION OF MULTIPOLAR ELECTROGRAM MAPPING DURING PAROXYSMAL AND PERSISTENT ATRIAL FIBRILLATION

Sabine Lotteau; Julien Seitz; Clement Bars; Rebecca Sircoulomb; Alexandra Sans; Célia Terrol; Anthony Appetiti; Laurent Launay; Paola Milpied and Jerome Kalifa

Background: Real-time artificial intelligence (AI) software design to detect dispersed electrograms (EGMs) during atrial fibrillation (AF) procedures has previously been described but a communication with a 3D mapping environment was missing.
Objectives: Explore the feasibility of using a bidirectional communication between an AI mapping device and a 3D navigation apparatus to automate the adjudication, communication and tagging steps for mapping multipolar EGMs in AF patients.
Methods: A bidirectional connection between an AI software device (Volta Medical) and a 3-D mapping apparatus (Abbott) is established using a digital interface. Multipolar EGMs and x, y, z coordinates of the catheter electrode's location are pushed by the 3D mapping system to the AI software for real-time analysis. Adjudications are then reverted so that tags appear automatically on the 3D shell of the atria (Figure). In 29 AF patients, real-time adjudications and tagging were compared with simultaneous expert visual analysis of spatiotemporally dispersed EGMs. Patients were then ablated in AI-adjudicated regions exhibiting dispersion.
Results: When compared with visual adjudication, the implementation of EGM auto-tagging by the communicating 3D mapping system-AI software proved reliable: 97% sensitivity, 99% specificity. Post-ablation maps assessment showed that 82% of the ablated point leading to AF termination and/or a 20ms increase in AF cycle length corresponded to automated tags. Mean procedure time was 138 ± 33 min with a radiofrequency time to AF termination of 8 ± 7 min. Dispersion hotspots were mainly displayed at the left atrium anterior wall, roof, posterior wall, but also in the posterior right atrium.
Conclusion: Bidirectional communication AI mapping device-3D navigation apparatus allows for automation of the mapping workflow and represent a unique opportunity to collect large amounts of data and to strengthen the efficiency and reproducibility of personalized AF ablation.

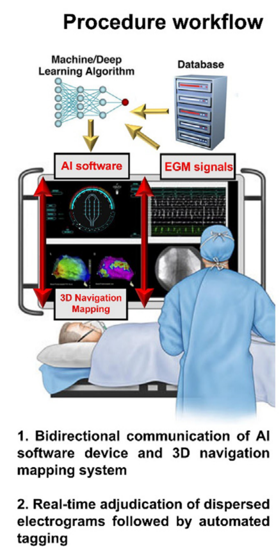


Figure: Real-time bidirectional communication between the 3D mapping system and the AI software device: automated adjudication/communication/tagging (ACT)

A MULTI-MODAL WORKFLOW FOR INTEGRATING AI-BASED CT SCAR IMAGING AND COMPUTATIONAL ECG MAPPING TARGETS FOR VENTRICULAR TACHYCARDIA ABLATION

Christopher Villongco; Christian D. Marton; Tony Moyeda; David E. Krummen and Gordon Ho

Background: Substrate and arrhythmia source localization is essential for effective catheter ablation. Cardiac CT can identify areas of arrhythmogenic substrate in ventricular tachycardia (VT) using wall thinning analyses. Separately, forward-solution computational ECG mapping (vMap®) of VT sources has been shown to correlate with exit sites at substrate borders.
Objectives: Combine AI-based CT wall thinning and ECG arrhythmia mapping (vMap®) analyses to fuse a patient-specific 3D anatomical model with predicted substrate and source targets. Load the model into an invasive electroanatomical mapping system to guide a VT procedure.

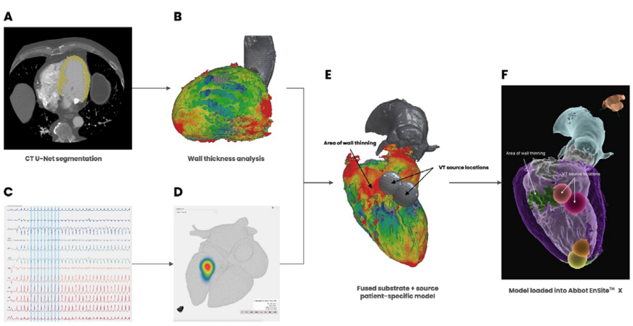


Figure 1 Workflow combining AI-based CT wall thinning (A, B) and vMap® ECG mapping (C, D) analyses to create a patient-specific anatomical model of substrate and source targets (E). The fused model was loaded into the Abbot EnSite™ X electroanatomic mapping system (F).

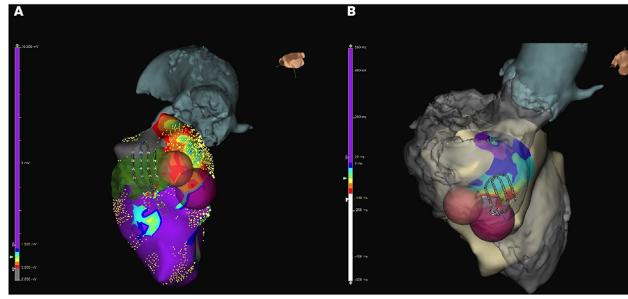


Figure 2 Overlay of fused model and EnSite™ X voltage (A) and VT activation (B) maps showing excellent correlation between measured and predicted source and substrate locations.

Methods: A 3D U-Net CNN model was combined with a physician-labelled segmentation mask to generate a patient-specific mesh of the left ventricular (LV) wall from CT (Fig 1A). Areas of wall thinning were identified from a wall thickness map computed on the endocardial surface (Fig 1B). VT sources were localized from the patient's ECG using the vMap™ system (Fig 1C-D). Source and substrate targets were co-registered on to the LV model (Fig 1E) and loaded into the Abbott EnSite™ X mapping system (Fig 1F) prior to an ablation procedure under an IRB-approved protocol.
Results: Wall thinning and VT sources were identified in the basal inferior LV (Fig 1E). A high-density mapping catheter (HDGrid) was placed at the predicted site, and focused activation mapping of VT revealed mid-diastolic signals confirming the VT critical isthmus located at the predicted site (Fig 2B). Ablation at this site terminated VT. Low voltage fractionated late potentials and deceleration zones also correlated with the predicted site of wall thinning (Fig 2A).
Conclusion: A combined AI-based CT wall thinning and vMap® ECG analysis accurately identified VT substrate, isthmus, and termination sites that agreed with invasive voltage and activation mapping. This multi-modal approach helped guide accurate and efficient VT ablation in this patient. Larger studies are underway.