UC San Diego
Sulpizio Cardiovascular Center

Computer-Based Analysis of the 12-Lead Electrocardiogram to Localize Ventricular Arrhythmia Sources

VA San Diego Healthcare System

Gordon Ho MD, FHRS[1], Christopher T. Villongco PhD[2], Andrew Lin MD[1], Jonathan Chung MD[1], Jonathan C. Hsu MD, MAS, FHRS[1], Kurt S. Hoffmayer MD, PharmD, FHRS[1], Frederick Han MD[1], Gregory K. Feld MD, FHRS[1], Andrew McCulloch PhD[2], David E. Krummen MD, FHRS[1]

[1]Department of Medicine-Division of Cardiology [2]Department of Bioengineering, University of California San Diego and VA San Diego Medical Center, La Jolla, CA

INTRODUCTION

- The 12-lead electrocardiogram (ECG) can be used to estimate originating sources of arrhythmias.
- However, manual ECG interpretation is limited by inaccurate localization due to subtle QRS morphology changes and inability to depict the arrhythmia source on a 3D model of the heart.

OBJECTIVE

To demonstrate the feasibility and evaluate the accuracy of a novel quantitative computer algorithm to predict source locations of ventricular arrhythmias & pacing sites.

METHODS

- Under an IRB-approved protocol, patients presenting for clinically-indicated EPS and ablation of ventricular tachycardia (VT) or premature ventricular contractions (PVC) were enrolled.
- 12 lead ECG data were analyzed using a computer-based quantitative algorithm provided by Vektor Medical, Inc to localize ventricular activation sources during ventricular tachycardia (VT), premature ventricular complexes (PVCs), and pacing.
- Clinical source locations were determined using electroanatomic mapping (EAM) utilizing activation mapping and/or pacemapping.
- Accuracy was determined by consensus of 3 independent reviewers comparing the EAM results with the 3D model analysis output.
- Statistical analysis was performed using McNemar's test.

RESULTS

- In 6 patients, 30 spatially distinct ventricular activation patterns (22 pacing sites, 2 VTs, and 6 PVCs) were verified with standard invasive electroanatomic mapping.
- **The quantitative algorithm accurately mapped 28 out of 30 (93%, p < 0.001) known ventricular locations to the exact ventricular segment** (based on the 17 segment AHA heart model with additional segments including the RVOT, LVOT, epicardial LV summit, and papillary muscles).
- **The algorithm correctly mapped 30 out of 30 sites (100%, p<0.001) to the exact or an adjacent biventricular segment.**
- Computer-based analysis required 3±2 minutes per ECG.

Figure 1. The computer software non-invasively mapped arrhythmias using only a 12 lead ECG **(1A)** and displayed the output on a 3D model **(1B)**. In Patient #3, the mapped site in the posteroseptal RVOT correlated with invasive electroanatomic mapping **(1C)**, with LAT -24ms and 96% pacemap). Catheter ablation at this site eliminated the VT.

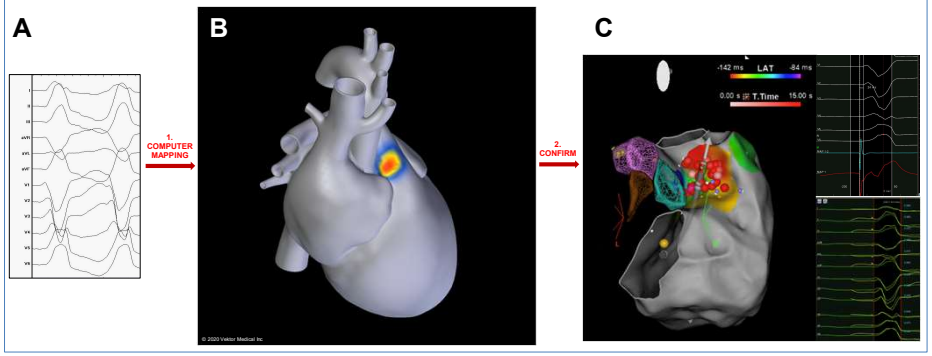


Table 1. Baseline Patient Characteristics

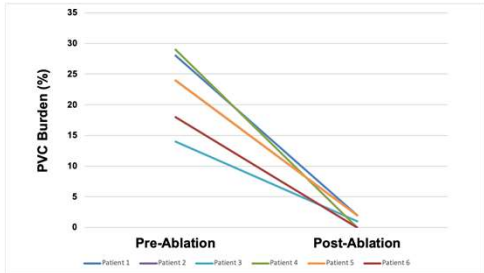
	Proportion of Pts / Mean
Age (yrs)	67 ± 14
Gender (% male)	80%
HTN	80%
DM	60%
AF	20%
H/O Cardiac Surgery	20%
CAD	20%
CHF	40%
Ischemic Cardiomyopathy	20%
Non-ischemic Cardiomyopathy	40%
LVEF (%)	47% ± 18%
LV Diameter (LVIDd, cm)	5.1 ± 0.6

Table 2. Arrhythmia and Substrate Characteristics

	Clinical Arrhythmia	Source Location	Invasive Mapping Data	# of Pacing Sites	Myocardial Scar	LVEF (%)
Patient 1	PVC	LVOT: Right Coronary SOV	Pacemap: 96%	5	None	70
Patient 2	1. VT 2. PVC	1. LV basal postero-septum 2. LV mid postero-lateral	1. LAT: -41ms, Pacemap: 97% 2. Pacemap: 95%	3	Yes	41
Patient 3	1. VT 2. PVC	1. RVOT: Posteroseptum 2. RV Inferolateral Wall	1. LAT: -24ms, Pacemap: 96% 2. Pacemap: 100%	5	None	44
Patient 4	PVC	LVOT: Aortic Valve Left-Right Commissure	LAT: -20ms, Pacemap: 97%	5	None	41
Patient 5	PVC	LVOT: Left Coronary SOV	LAT: -20ms, Pacemap: 98%	2	None	67
Patient 6	PVC	LV Aorto-Mitral Continuity	LAT: -34ms, Pacemap: 99%	2	Yes	65

RESULTS (con.)

Figure 2. PVC Burden Before and After Ablation



CONCLUSIONS

- Computational analysis can rapidly and accurately map biventricular arrhythmia locations onto a 3D model, based solely on a standard 12 lead ECG.
- Notably, the algorithm accurately mapped source sites in clinically relevant structures, such as the RVOT, LVOT, epicardial LV summit and papillary muscles.
- Larger and prospective studies are needed to confirm whether this technique may be used to guide clinical ablation.

Disclosures

Disclosures: Dr. Ho received research grants from the National Institutes of Health, American Heart Association and Abbott for work unrelated to this research and owns equity in Vektor Medical, Inc. Drs. Villongco and McCulloch own equity in Vektor Medical, Inc. Drs. Hsu received honoraria from Medtronic, Abbott, Boston Scientific, Biotronik, Janssen Pharmaceuticals, Bristol-Myers Squibb, Altathera Pharmaceuticals, Zoll Medical, and Biosense-Webster, equity in Acutus Medical and Vektor Medical, Inc, and research grants from Biotronik and Biosense-Webster. Dr. Feld, as CCEP Fellowship Training Program Director, receives fellowship training program stipends from Medtronic, Biotronik, Biosense Webster, St. Jude/Abbott, Boston Scientific, Inc, and has stock options or co-ownership in Acutus, Inc., toSense, Inc., and Perminova, Inc. Dr. Krummen owns equity in Vektor Medical, Inc.
Drs. Lin, Chung, Hoffmayer, and Han report no disclosures.