Manuscript (clean) Click here to view linked References

A Novel Computational Platform to Analyze Left Atrial Voltage Acquired from Electroanatomic Mapping

Julia H. Indik MD PhD[1], Alvaro Altamirano Ufion MD[1], Bradford Whitaker BA[2], Travis Geyer BS[2], Mahesh Balakrishnan MBBS[1], Khurram Butt MD[1], Jacob Klewer MD[1], Robert A. Indik PhD[3], Mathew D. Hutchinson MD[1]

[1]Department of Medicine, University of Arizona College of Medicine, Tucson, Arizona, USA

[2]Johnson & Johnson

[3]Department of Mathematics, University of Arizona, Tucson, Arizona, USA

Short title: Computational Platform for Left Atrial Voltage

Conflicts of Interest Statement: B. Whitaker and T. Geyer are employees of Johnson & Johnson. M. Hutchinson receives an honorarium from Biosense Webster, Inc for lectures. The remaining authors have no disclosures.

Funding sources: The authors have no funding sources to disclose.

Word count: 767

Key Words: atrial fibrillation, ablation, left atrium, voltage, fibrosis

Correspondence:

Julia H. Indik, MD PhD

University of Arizona College of Medicine

1501 N Campbell Ave, Tucson, AZ 85724-5037

jindik@arizona.edu

28 Atrial cardiomyopathy represents structural and electrophysiologic abnormalities
29 associated with atrial fibrillation (AF). Fibrosis, visualized with late gadolinium
30 enhancement on cardiac magnetic resonance imaging (MRI), is associated with low
31 voltage on electroanatomic mapping[1], and ablation outcomes [2]. Voltage data is readily
32 acquired in an ablation procedure but comparing voltage between subjects is
33 complicated by variation in atrial size and orientation. A computational analysis platform
34 is needed that can automatically align and scale atria of disparate sizes and orientation
35 to permit comparisons in pre-specified regions of interest to further understanding of left
36 atrial voltage distribution. The purpose of this study was to design a method to create
37 aligned and scaled individual or composite voltage maps for further data analysis of
38 patient cohorts.

39

40 Data were collected prospectively from patients undergoing AF ablation, and clinical
41 information stored in a REDCAP database. This study was approved by the University
42 of Arizona Institutional Review Board before data collection. The research reported in
43 this paper adhered to the Helsinki Declaration as revised in 2013. Three-dimensional
44 position and voltage data in sinus rhythm were collected using a PentaRay (2-6-2mm
45 interelectrode spacing) and ThermoCool SmartTouch SF (3.5mm tip) catheters in a
46 CARTO 3 system (Biosense Webster, Johnson & Johnson). Reference points were
47 selected from the posterior wall, identifying the ostia of the right superior pulmonary vein
48 (RSPV), right inferior pulmonary vein (RIPV), left superior pulmonary vein (LSPV) and
49 left inferior pulmonary vein (LIPV). Two additional locations on the anterior wall, septal-
50 anterior adjacent to the RSPV antrum and lateral-anterior adjacent to the left atrial

appendage, were tagged. Data were imported into customized MATLAB programs. Points were automatically assigned to pulmonary veins, roof (superior), posterior, anterior, anterior-lateral, and septal walls (Figure 1A). Next, a scaled coordinate transformation was performed to a standardized set of coordinates to account for differences in left atrial size and orientation between subjects. The reference points for the LSPV, RSPV and RIPV defined a plane on the posterior wall, with the RSPV set as origin and x axis as the direction from the RSPV to LSPV. The y axis was perpendicular to this plane, with the z axis as the cross product of the x and y axes. The coordinate system was scaled by setting the distance from the RSPV to LSPV to 50 dimensionless units.

Scaled, coordinate transformed voltage data can be analyzed and compared in any region of interest (ROI) between individual subjects or from a composite of multiple patients. To illustrate, we analyzed N=13 patients (11 male, age 65 ± 14 years, 6 undergoing redo ablation) with paroxysmal AF. Voltage maps of two subjects are shown in original coordinates (Figures 1B and 1C) and in transformed coordinates from an anterior view (Figures 1D and 1E), with black dots showing points that project to a selected ROI on the anterior wall, also highlighted in a composite voltage map of all 13 subjects (Figure 1F).

In conclusion, we present a novel methodology to quantify left atrial voltage to analyze a user-selected ROI. This platform is unique by aligning and scaling each individual map, which is necessary to compare ROIs across multiple subjects with different atrial sizes and orientations. Subsequent analyses can be performed over a database of subjects with appropriately chosen statistical tests. Patients with persistent AF can also be

analyzed once sinus rhythm is restored. Further investigations can examine other questions such as the impact of atrial anatomical variations, voltage change after ablation, and association with MRI findings. Additionally, variations of this platform can be developed for other cardiac chambers. While this manuscript is intended to present a methodology, it needs validation with a larger patient cohort.

Funding sources: The authors have no funding sources to disclose.

81 References

82 **1.** Kapa S, Desjardins B, Callans DJ, Marchlinski FE, Dixit S. Contact
83 electroanatomic mapping derived voltage criteria for characterizing left atrial scar
84 in patients undergoing ablation for atrial fibrillation. J Cardiovasc Electrophysiol
85 Oct 2014;25:1044-1052.
86 **2.** McGann C, Akoum N, Patel A, et al. Atrial fibrillation ablation outcome is
87 predicted by left atrial remodeling on MRI. Circ Arrhythm Electrophysiol Feb
88 2014;7:23-30.

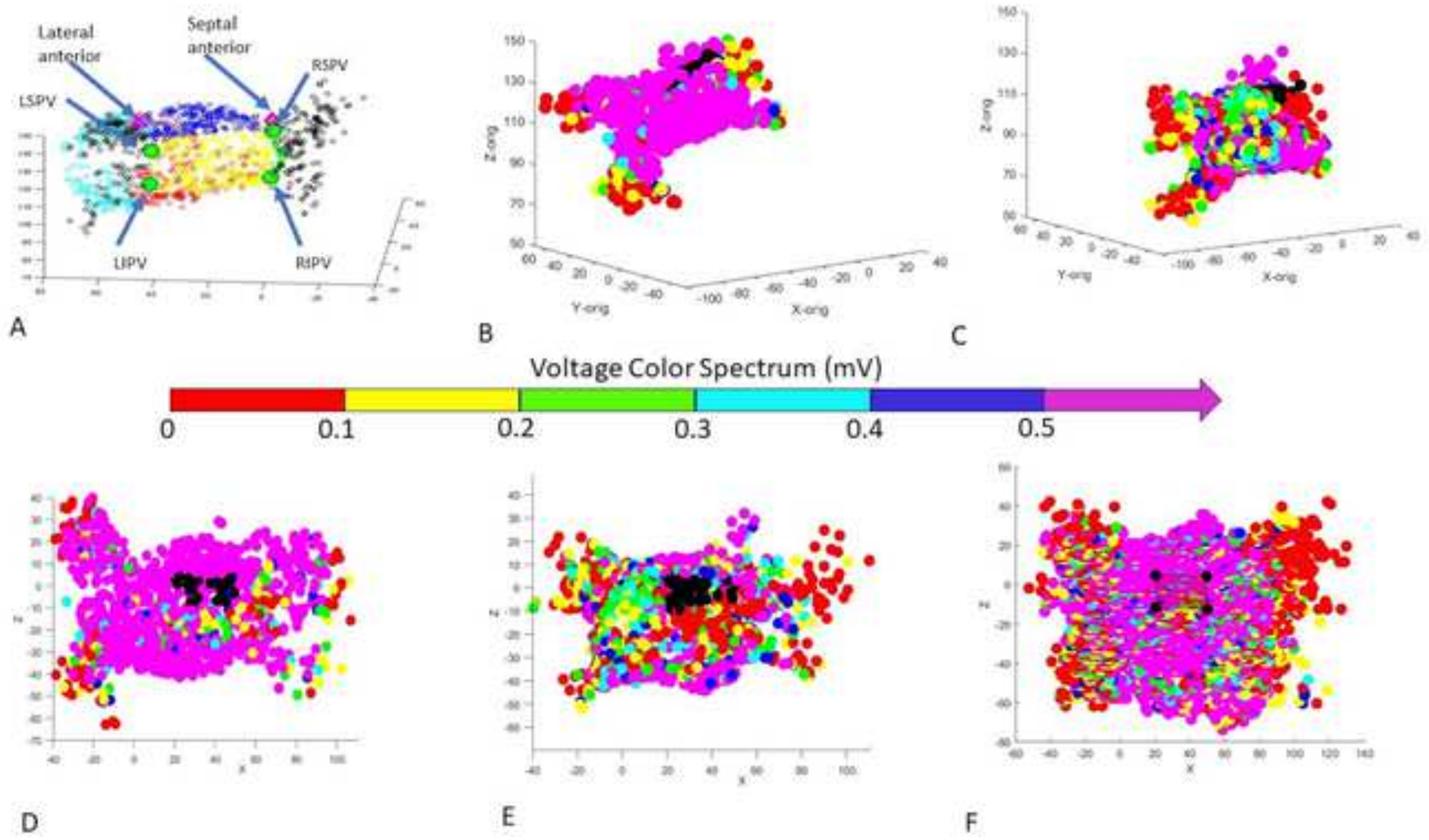
89

90

91 Figure Legend

92 Figure 1: The algorithm assigns points to pulmonary veins (black), roof (blue), posterior
93 (yellow), anterior (red), anterior-lateral (cyan) and septal (green) walls based on
94 proximity to reference points (A). Voltage color maps are shown for two subjects, in
95 original coordinates (B and C) and, respectively, in an anterior view after a scaled
96 coordinate transformation is performed (D and E). A composite map from N=13 patients
97 is illustrated (F) with a region of interest (ROI) drawn on the anterior wall. Points within
98 the ROI are shown in black in panels B,C,D and E.

Click here to access/download;Figure;Figure.jpg



Graphical Abstract

To study left atrial voltage distributions in patient cohorts requires an ability to compare similar regions of interest (ROI) among patients, despite atria of different sizes and orientations.

To achieve this efficiently requires a computational platform able to automatically and efficiently scale and align multiple atrial maps to a standardized set of coordinates.