Principal Component Analysis Identifies Hidden Electrogram Features that Predict Outcomes From Atrial Fibrillation Ablation

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BACKGROUND

Prior studies have attempted to predict long-term outcomes from atrial fibrillation (AF) ablation using clinical variables or intracardiac electrograms (EGMs), but have produced modest results.

OBJECTIVES

We hypothesized that explainable machine learning – using principal component analysis (PCA) combined with unsupervised clustering of EGMs may reveal novel features that predict arrhythmia freedom after AF ablation.

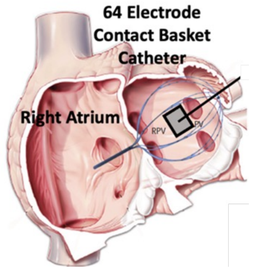

Figure 1: Method allowing to recover the electrical signals of the heart in the form of 64 channels

METHODS

We studied N=309 AF patients (64.9±10.5 yrs, 25.5% female) in whom unipolar EGMs were recorded at 64-sites.

Figure 2: BSK sensors signal for a specific patient with recurrence

We applied PCA to 70% of the dataset for training, and tested the ML model on a 30% hold-out set. We probed the model by analyzing variances of PCA of eigenvector projecting more than a fixed threshold of the global variance (15%). We clustered eigenvectors to find common projection axis among them using k-means algorithm.

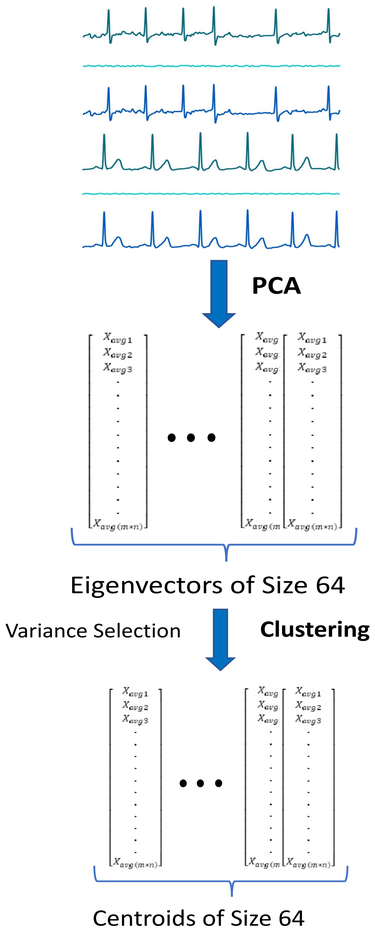

Figure 3: Method to extract the common axis of projection from the data of multiples patients using Singular Value Decomposition

The real challenge here is to select the eigenvectors with the most information right after the PCA. In order to do so, a threshold is put to select only eigenvectors explaining 15% of global variance.

RESULTS

N=218 had freedom from arrhythmia (AF and AT) for <1 year after blanking period (“Freedom” group), and N=91 had recurrence (“Recurrence” group). The results plots show the projected variance from PCA of AF EGMs in Recurrence and Freedom groups respectively.

Figure 4: Proportion of the projected variance for an eigenvector of the Freedom group

By looking at the projected variance for a Freedom group, the variance was higher in Freedom group than in Recurrence group (μ = 37.6 %, σ = 18.4% vs μ=26.9%, σ = 12.9% of the global variance, median p-val = 0.2 for KS2) by looking at the average distribution.

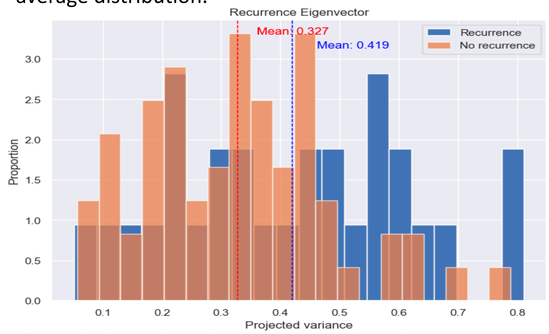

Figure 5: Proportion of the projected variance for an eigenvector of the Recurrence group

If we look at the projected variance for a Recurrence group, the variance was higher in Recurrence group than in Freedom group (μ = 41.9 %, σ = 19.7% vs μ=32.7%, σ = 15.5% of the global variance, median p-val = 0.2 for KS2) by looking at the average distribution.

Small clusters of Recurrence/Freedom patients also appears in the projected variance distribution and allow us to potentially use this projection axis as a relevant input for a neural network to predict the state of a patient

CONCLUSION

- Singular Value Decomposition and unsupervised ML of EGMs alone revealed novel features that predicted AF ablation outcomes.
- This approach allows us to obtain essential information about underlying clusters.
- These projection axis could be used as an input to ML algorithms like a neural network.
- This approach to dimension reduction could be extended to non-linear methods to improve prediction and come closer to providing a perfect binary classification on AF recurrence.

REFERENCE

- J. Fan, Y. Liao and W. Wang (2016), **Projected Principal Component Analysis in Factor Models** , The Annals of Statistics

ACKNOLEDGEMENT & CONTACT

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DISCLOSURES

Dr. Narayan reports consulting from Abbott Inc., Uptodate Inc., LifeSignals Inc and TDK Inc. Dr Narayan reports intellectual property owned by University of California Regents and Stanford University. Mr. Clopton reports consulting at American College of Cardiology. Dr. Rogers reports grants from NIH (F32HL144101), NIH LRP, and Stanford SSPS. Drs Ganesan, Deb, Feng, report no disclosures.