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Discrimination of atrial flutter on simulated 12-lead-ECG signals by applying biosignal processing

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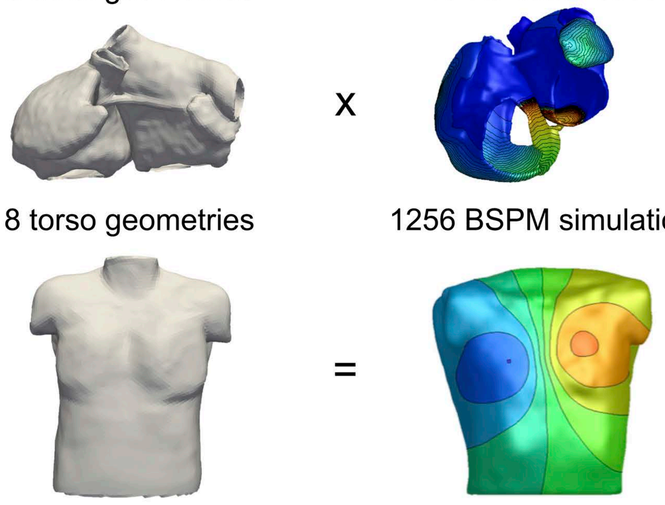
Motivation

Atrial flutter (AFl) is a common reentrant arrhythmia, characterised by a self-sustainable mechanism and an electrical signal that propagates along pathways different from physiological excitation propagation. Although AFl is not a direct cause of death, it can lead to fatal complications, such as stroke or heart attack. For this reason, it is essential to identify and recognise this condition, so that it can be promptly treated. So far, invasive methods of signal acquisition are required to reliably discriminate which type of AFl a patient suffers from[1]. To the best of our knowledge, this work is the first study that applies different biosignal processing tools on a large dataset of simulated 12-lead electrocardiogram (ECG) signals, looking for quantitative features that efficiently discriminate different types of AFl. In future clinical practice, the results of this study could avoid the use of invasive methods or decrease the procedure time of the ablation therapy.

Models & Methods

Simulated signals

8 atrial geometries x 19-20 flutter cases x 8 torso geometries x = 1256 BSPM simulations



- Fast Marching simulations
- Courtemanche action potential of atrial electrophysiology [2]
- Boundary element method (BEM) to solve the forward problem of electrocardiography [3]
- Extraction of the 12-lead ECG from the BSPM

Features evaluation

- Principal component analysis (PCA) on the 12-lead ECGs
  - Principal components (PCs)
  - Principal components scores
- Temporal recurrence quantification analysis (RQA) of the first two PCs scores

Statistic analysis

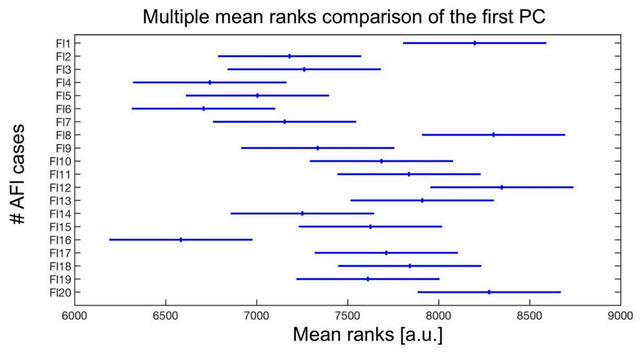
- Kruskal-Wallis, multiple comparison, area under the receiver operating characteristic (AUROC) curves on the PCs
- Wilcoxon test on the PCs scores correlation coefficients
- AUROC on the RQA parameters

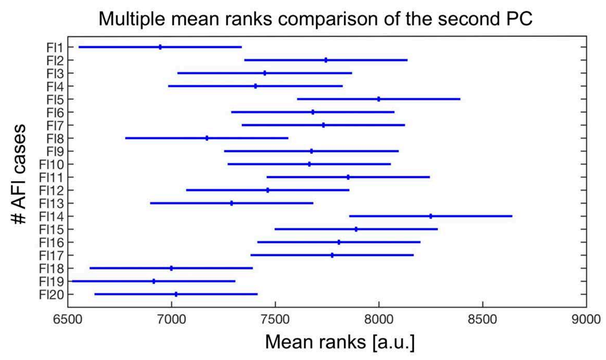
Conclusions

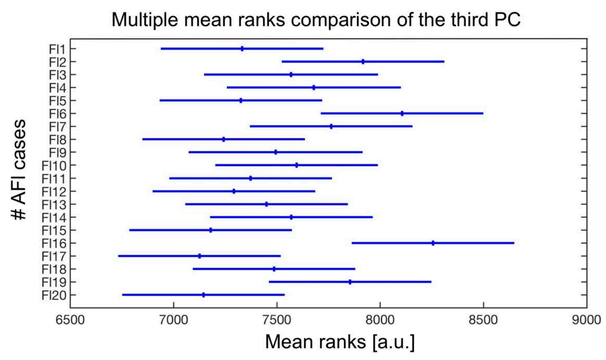
- The first three PCs are unsuitable discriminators for all the cases, but they can discriminate subgroups of cases (especially the first and second PCs).
- The first three PCs scores could be good discriminators, having significantly higher correlation coefficients within cases than between cases.
- The RQA parameters evaluated on the first two PCs scores, taken individually, can moderately discriminate the cases of AFl.

Results

Principal components





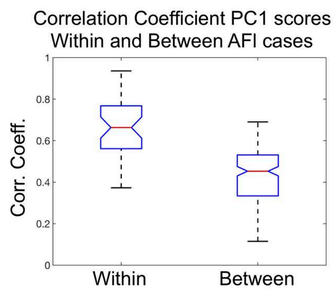


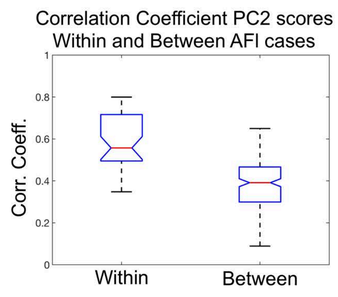
- 31.6% of the pair-wise combinations of the cases have significantly different first PC ($p<0.05$)
- 14.7% of the pair-wise combinations of the cases have significantly different second PC ($p<0.05$)
- 7.9% of the pair-wise combinations of the cases have significantly different third PC ($p<0.05$)

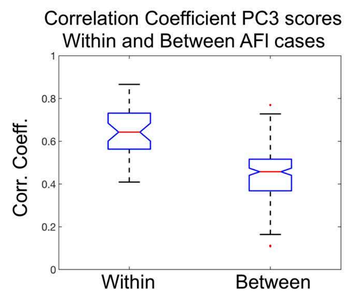
	AUROC [%]
First PC	56,92
Second PC	56,04
Third PC	55,22

- The area under the receiver operating characteristic (AUROC) curve shows how the respective PC can discriminate the cases.

Principal components scores







- For all the first three PCs scores, the correlation coefficients within and between cases are significantly different ($p<0.01$).

Temporal RQA

AUROC [%]	Determinism	Laminarity	Entropy diagonal lines	Entropy vertical lines	Trapping time	Recurrence rate
PC1 scores	67.4	73.9	67.9	73.5	69.5	64.9
PC2 scores	67.9	73.2	67.8	72.4	71.1	65.7

- The AUROC calculated for all the parameters extracted with the RQA, indicates the goodness of these parameters in discriminating the different types of AFl.

Outlook

- Other features will be identified and evaluated.
- The combination of the best features will be used to train a classifier. This will be subsequently tested on clinical data.

Acknowledgment

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