A Novel Combination of Ionic Computing Models to follow the Propagation of Electrical Activity of Atrial Fibrillation in the Left Atrium.

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1 Introduction:

The prominence of Atrial Fibrillation (AF) is on the incline in the UK, with roughly 1.3 million diagnosed [3,4]. Therefore, the need for research to investigate methodology to streamline current treatment methods is paramount. Currently, catheter ablations are most commonly used in clinical practise as a non-pharmacological approach [4]. This method uses 3D electroanatomic geometry created from electrocardiograms collected via electrophysiology studies. This approach is prone to a high level of subjectivity, specifically in determining where an ablation point should be made. Previous research has shown evidence through frequency analysis of dominant frequency (DF) patterns that implied evidence of re-entry circuits and phase patterns [12,17,18]. Alongside these measures, computer model simulations can further track the propagation of electrical activity in the left atrium (LA) during AF. Increasing the overall strength of objectivity during ablation procedures. Components of 3 computing models are combined, they are: Fenton & Karma, Courtmanche *et al.* and Simitev-Biktashev [6,9,13]. This paper aims to investigate whether such a combination can follow the spread of AF in simulation form in the LA and be generalisable, using a larger set of parameters. Potentially, supporting the degree of efficiency in trailing the propagation of AF in the LA in an individualised manner for each patient. The second aim of the paper is investigating if the results from the latter stage agree with phase analysis and DF maps.

2 Methodology:

2.1 Subject Recruitment

The retrospective data used to test the computer model was via the following subject recruitment. This investigation enlisted 10 PersAF patients from Glenfield Hospital (University hospital of Leicester). All of whom had not undergone catheter ablation (with a 2048 node detection catheter) in the LA beforehand. The ages of the recruited patients ranged from 36 to 76. Ethical requirements and formal ethical approval were fulfilled with the support of the local trust ethical committee. For each patient individual informed consent was sought before each procedure.

2.2 Electrocardiogram Data Acquisition

The instrument used to collect electrocardiogram data during the ablation procedure is a high-density non-contact mapping multi-electrode array catheter. The data collected from the mapping catheter via the commercial system forms 3D LA geometry maps in real time. Specific anatomic points are labelled for objectivity, these are left atrial appendage, atrial roof, anterior wall, posterior wall, pulmonary vein, mitral valve and septum. The data collected was bipolar EGM recordings at baseline and post procedure. With a band pass filter of 30-250 Hz and notch filtered at 50 Hz the EGMs were taken at 50 seconds. The use of clinical retrospective data is facilitated by the license the University of Leicester holds with Ensite at Glenfield hospital.

2.3 Computation of Data

Data collected from the virtual electrograms via the catheters is exported in 5-minute segments from the commercial system into MATLAB (R2018a: MathWorks). To this data QRST subtraction is conducted via the platform (USURP [19]) created by the Bioengineering research group at the School of Engineering at the University of Leicester. The same platform with applied formulation in MATLAB is used to gain HDF and phase analysis maps [12,17].

2.4 Combining Ionic Computer Models

3 different Action Potential Ionic computer models chosen are:

- Courtemanche et al 1998 [6]
- Fenton & Karma 1998 [9]
- Simitev & Biktashev (A variation of Courtemanche et al’s model) 2006 [13]

The development of the computer algorithm is completed by merging the algorithms of the latter three models into one with the efficiency of the three combined. This is coded into a MATLAB script that can then be run on ECG & EGM retrospective data. It is the merging of the differential equations each model is comprised of. 3D simulations are produced via a simulation program that works cohesively with MATLAB. The program is called Simulink.

2.5 Statistical Analysis

Statistical Analysis was performed using Windows software ‘Graph pad Prism’ (V7.04)
It was used to compare the data from generated HDF & phase analysis values in comparison to the values generated via Simulink.

3 Results:

Using code combining the 3 models[1] on MATLAB retrieved 3D simulations for all 10 patients, with 3 patients data simulations successfully following the trail of electrical activity propagation at 79±5%. Propagation route coincided with HDF regions in 66% of patient data. Phase analysis maps compared over simulations showed 57% of expected re-entry wavelets at points of heightened electrical activity. Results imply widening parameters of each individual computing model [1]and combining them can successfully create a criterion to follow propagation of AF in the LA.

4 Discussion:

This study is a snapshot into the potential modelling techniques that can be developed to better tailor ablative strategies. From all previous work done by the research group on ablative procedure a key limitation has consistently been the high level of subjectivity on determining which area to ablate. Regardless of whether phase analysis or DF maps were produced as validating factors. Thus, such work on modelling can create an additional verifying factors increasing the degree of objectivity.

A lot of work does need to be completed to make the algorithm in the independent study more robust. For example, propagation trailing via Simulink only occurred around 80%. Although this percentage seems high the number of actual patients is only 10. Thus, more work needs to be done to refine parameters and catch anomalies. Also, the results show that validating factors of comparisons to phase analysis maps and DF maps show mutually around 60% which suggests that other electrophysiological anomalies may also contribute to electrical activity. It may be worth looking into fibrosis as derived from studied literature to explain this in future work.

A benefit of this study is that it used popular AP computer models which can be easily applied, and their parameters changed. This can help in making the model more robust in future work. A drawback of this work is that the participant pool is so small (only 10 patients) which reduces its validity. However, this will be addressed in future research because patient recruitment and trials have already begun for further studies.

5 Conclusion:

The study addresses the gaps in current research on AP modelling in AF, from lack thereof to execution. The study takes a novel approach by merging popular computer models into one algorithm and with the assistance of clinical data shows the importance of its further development to reduce subjectivity in ablation procedures. Making the treatment of AF via catheter ablation more efficient. With potential applications to other forms of AF therapy too.

6 References:

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