Can Sequentially Collected Electrograms Be Effectively Used for Dominant Frequency Mapping During Persistent AF?

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Abstract

Sequential electrogram collection using multipolar catheters (Pantaray, HD Grid, etc.) is increasingly used in persistent atrial fibrillation (persAF) mapping. However, it is unknown whether sequential mapping is suitable for dominant frequency (DF) mapping, as DF tends to be spatiotemporally unstable. We aim to model and compare simultaneously and sequentially collected EGMs for DF mapping.

1. Introduction

In clinical practise, atrial fibrillation (AF) is the most prevalent cardiac arrhythmia, affecting 1-2% of the general population [1]. In AF patients, a lack of efficient atrial contraction may result in blood clots in the atria, which raises the risk of stroke fivefold [2]. Despite the increasing use of catheter ablation procedures to treat AF patients, the fundamental pathophysiological processes of persistent atrial fibrillation (persAF) is still currently unclear [3]. Atrial areas containing electrograms (EGMs) with fast activation rates and high dominant frequency (DF) may be crucial sites for the maintenance of AF [4]. As DF is spatiotemporally unstable, it may be more difficult to determine the proper target when the DF value changes over time, and DF mapping algorithms must take this into account [5]. Sequential electrogram collection employing multipolar catheters (Pantaray, HD Grid, etc.) is becoming more popular in the mapping of persAF. Since DF has been demonstrated to be spatiotemporally unstable with simultaneous EGMs [5]. Therefore, it is worth investigating whether sequential mapping is suited for DF mapping.

In this study, we aim to investigate the feasibility of using sequential mapping for DF mapping. This will be achieved by modelling the process of the sequential ECG collection from simultaneous data.

2. Methods

2.1. Electrophysiological Study

Ten patients with persAF (**Table 1**) who were undergoing their first left atrial (LA) catheter ablation were included [6]. To guide ablation targeting high DF, up to 300 seconds of LA noncontact EGMs (Ensite Array, St Jude Medical) were exported to our Matlab platform [7]. As previously mentioned [8], high DF zones in the LA were discovered. Four out of ten patients had their AF terminated (3 flutter, 1 sinus rhythm) by high DF ablation prior to pulmonary vein isolation (PVI). None of the 10 patients had any adverse consequences.

Table 1. Patients' clinical characteristics

	Median	Min	Max
Male (n)	10	-	-
On amiodarone (n)	2	-	-
Age (years)	57.8	36.1	76.4
Days in AF pre-procedure	219	132	848

2.2. Signal Pre-processing

2048-channel virtual EGMs (EnSite Array, Abbott; 5 min) were analysed. The 5 min-long EGMs were sampled at 2034.5 Hz and then re-sampled to 512 Hz using the cubic interpolation method to save processing time and conserve storage. As ventricular far field activity in EGMs might appear as misleading frequency components on the atrial

frequency spectrum, affecting DF identification accuracy, therefore QRST subtraction was conducted as reported in our earlier work (**Figure 1**) [9].

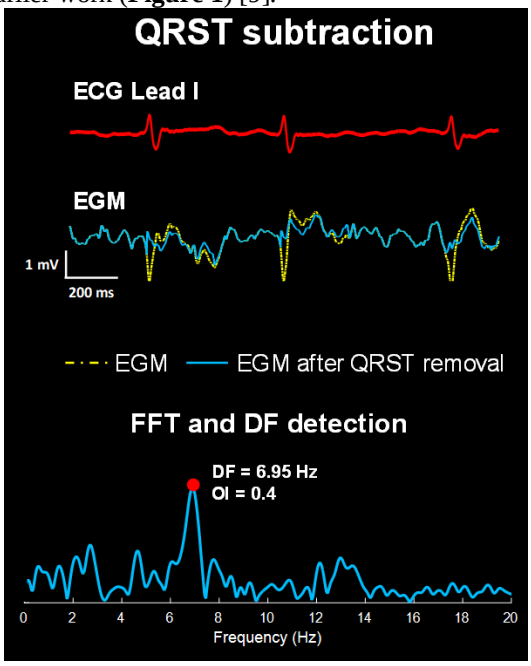

Figure 1. illustration of the QRST subtraction in noncontact EGMs. Bottom: FFT-estimated frequency spectrum of a noncontact EGM after QRST subtraction, with annotated DF and organisation index (OI). Adapted from [10].

Following QRST subtraction, spectral analysis was performed on the EGMs using fast Fourier transform (FFT) with 4-s sliding windows (2-s overlap). When performing the FFT, a zero-padding factor of 5 was used, resulting in a frequency step of 0.05 Hz. The amplitude of the side lobes surrounding the DF peak in the power spectrum was reduced by using a Hamming window. The frequency of the peak in the power spectrum within the physiological range of 4-10 Hz was defined as the DF.

2.3. Left Atrial Mesh Segmentation

LA meshes were automatically segmented into 20 random-selected captures (**Figure 2** left) to model multipolar catheter captures. Sequential maps were generated altering time delay (gap) between captures and compared with the simultaneous map (**Figure 2** right).

2.4. Minimum Time Duration Required per Capture for Sequential Mapping

The minimal time period required each capture must be acknowledged in order for sequential mapping to be accurate and reproducible while still being fast and reliable. To investigate this, a 5-minute average DF map was generated. This was regarded the 'gold standard' mapping result since it is the most summative map showing the major activities. Then, from all patients, averages for DF mapping with shorter time durations per capture (from 0 to 5 minutes) were constructed and compared to the gold standard. Correlation coefficients (CCs) and absolute differences (in Hz) between each map were generated and plotted on a graph. This approach allows us to visualise the moment at which the data no longer match the gold standard, allowing us to define a minimal time period. This will assist to minimise the amount of time sequential mapping takes and, as a result, boost the efficiency of the process without reducing the quality and robustness of the maps created.

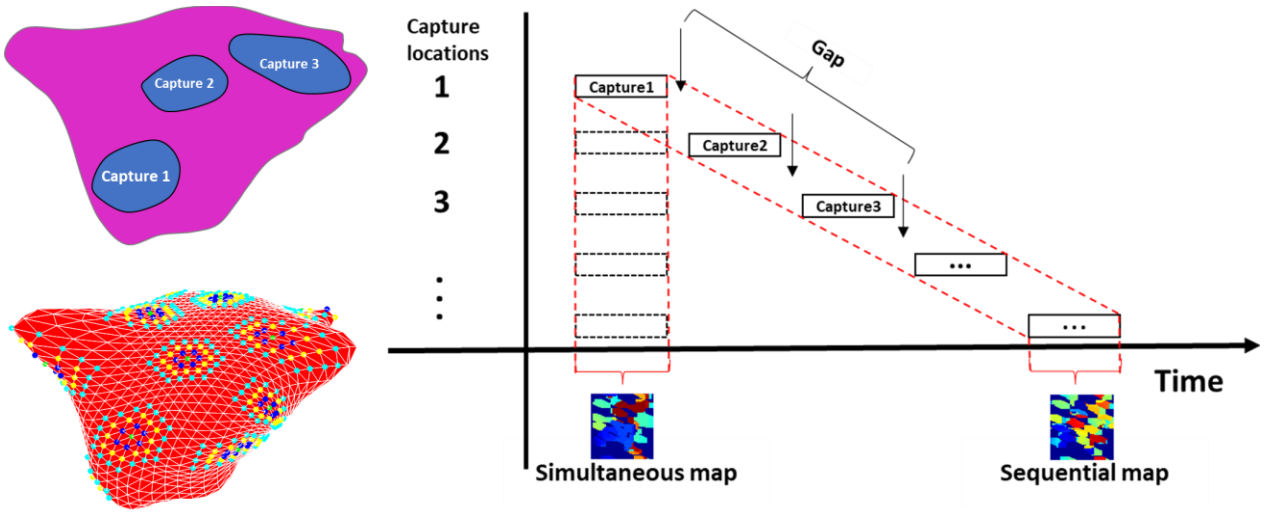

Figure 2. Graphical diagram illustrating the difference between simultaneous and sequential map generation. Left: the purple diagram at the top of the picture depicts the location of each capture (blue circles with the capture number labelled inside as it relates to the mesh plot (red and white diagram with cyan, yellow, blue, and green points) below it. The graph

on the right indicates that a simultaneous map is created from a single capture in a single time instant with no gaps, whereas a sequential map is created by taking many captures with gaps between each capture.

3. Results

3.1. Sequential and Simultaneous Mapping

With a value of 0.13 ± 0.12, the correlation coefficient between the sequential and simultaneous maps was poor. The correlation coefficient between the varied capture delays, however, showed significant differences ($p<0.05$), as shown in **Figure 3**. Furthermore, there is a DF difference of 0.61 ± 0.22Hz at each node (as shown in **Figure 3**), which is significant. **Figure 4A** depicts the difference between simultaneous and sequential mapping. It shows how the frequency of each capture changes once a gap is created, providing a more accurate picture of DF during persAF. The presented simultaneous maps only allow for one view at a single time instant, however the sequential maps show changes in DF frequency over time.

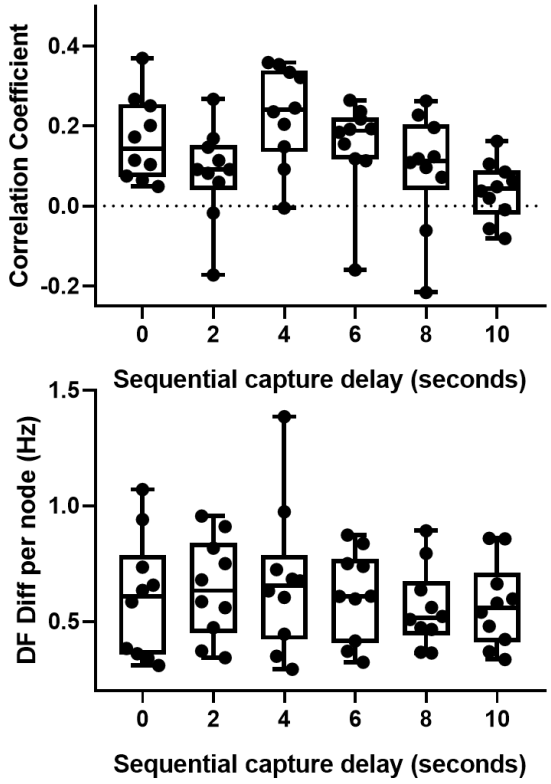

Figure 3. Top: Correlation coefficients between simultaneous map and sequential maps with different delays; Bottom: absolute DF difference per node between simultaneous map and sequential maps with different delays.

Average DF map over 5 min were generated as 'gold standard'(**Figure 4B**) , average DF map using shorter time duration ranging from 0 to 5 min for all patients were compared with the 'gold standard' map (Figure 5).

3.2. Minimum Time Duration Required per Capture for Sequential Mapping

As expected, the CC was correlated with increased time for DF map calculation, while DF difference were inverse correlated (**Figure 5**). Using data for 84 s, CC of 0.91 ±0.06 and DF error of 0.065±0.023 Hz were achieved compared with full-length data (5 min). This was confirmed visually in **Figure 4B** with fully reproducible maps using 84 s.

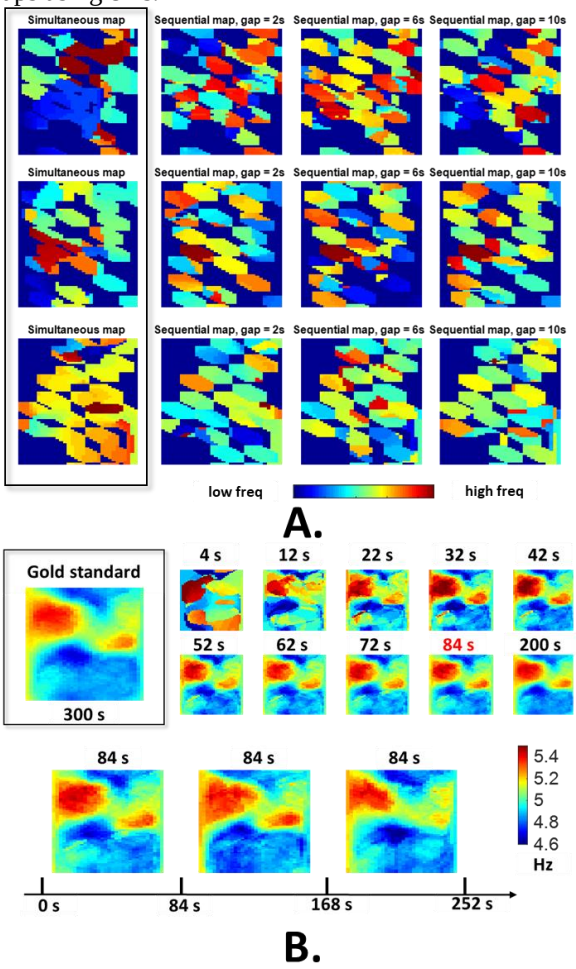

Figure 4. A. Examples of poorly correlated simultaneous map and sequential maps with different delays from 3 subjects; **B.** Top: examples of DF map with full length data and DF maps with shorter lengths, bottom: non-overlapping DF maps with recommended duration.

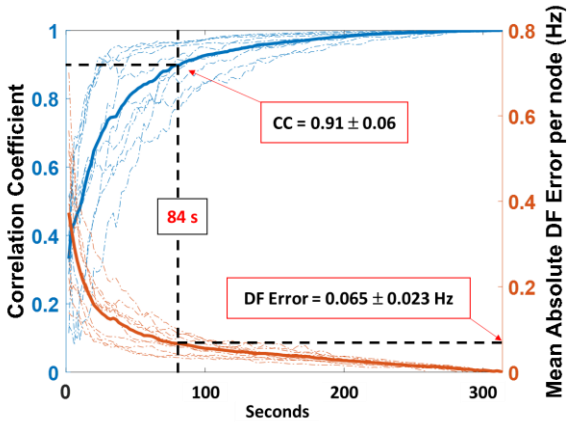

Figure 5. The Correlation coefficients and absolute DF difference per node between DF map with full length data and DF maps with shorter lengths.

4. Discussion and Conclusions

The results show that sequentially collected DF maps with short duration (4 seconds) captures generate distinct results from simultaneously collected maps. This was supported by the data as the low correlation coefficient of 0.13 means that the similarity between the two mapping techniques is low. As a result, the two mapping processes will provide two distinct representations of DF during persAF. In addition, we were able to reach a conclusion that the minimum duration required per sequential capture should be 84 seconds in order to generate a solid and reproducible DF map. This was supported by the fact that there was more than 90% similarity between the 84 second capture and the gold standard capture and that the DF error is less than 0.065 Hz comparing to the full data length. Our findings provide valuable insights for DF mapping using data collected sequentially, and it is vital for clinicians to accurately map DF with most recent preferred mapping tools.

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