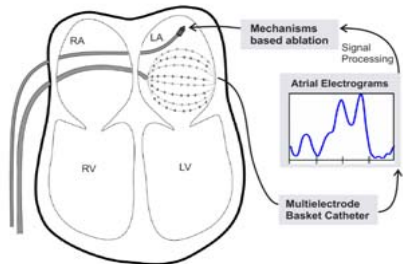


# An Integrative Framework for Processing Panoramic Electroanatomical Cardiac Electrograms

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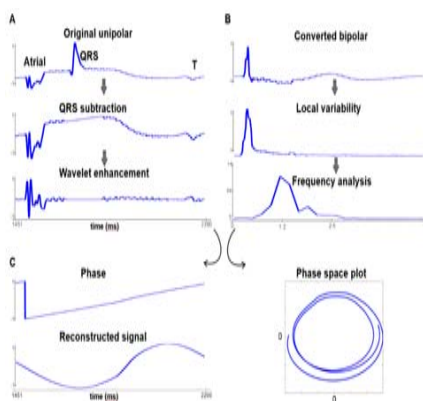
## Background

- Atrial fibrillation (AF) is the most common cardiac arrhythmia. Catheter ablation is widely used to treat patients with AF (Fig. 1). However, results for persistent AF remain disappointing. Narayan et al. have recently identified electrical rotors in patients with AF by using 64 electrode basket catheter in both atria in their FIRM trials and suggest that AF is characterized by a limited number of stable rotors and focal resources, which are disputed by others.<sup>1</sup>
- The **goal** of our study is to provide a standardized computational framework for processing panoramic atrial electrograms in order to reconcile and unify these current paradigms with regard to atrial drivers and improve the success rate of catheter ablation.<sup>2,3</sup>



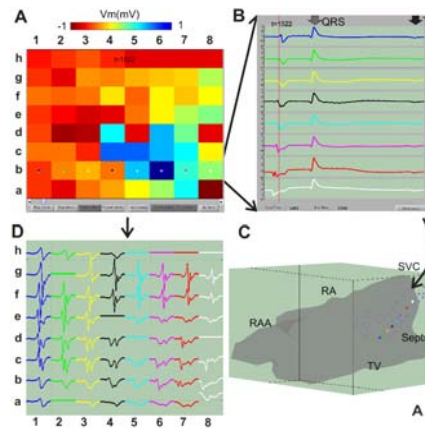
**Fig 1** Schematic of the heart with an ablation catheter and multielectrode basket catheter in LA to illustrate the concept of atrial panoramic mapping and mechanisms based ablation guided by signal processing tools. LA = left atrium; RA = right atrium; RV = right ventricle; LV = left ventricle.

## Signal processing approaches:



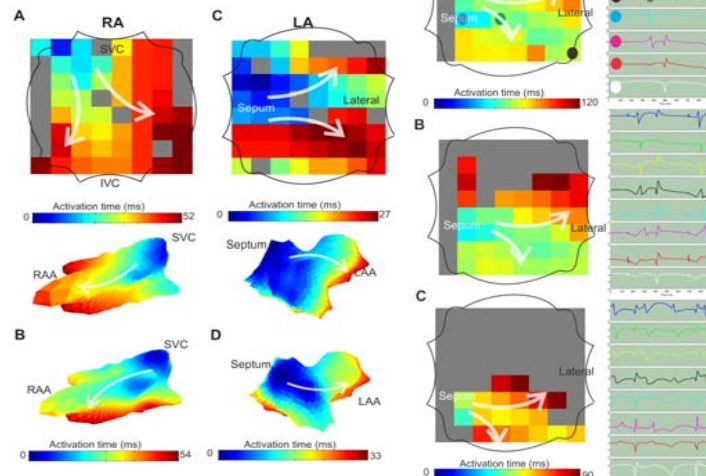
**Fig 2** Illustration of a suit of signal processing tools by employing the approaches on one segment of atrial sinus rhythm electrograms recorded in the right atrium (b7, Fig 3) during 1451-2200 ms. (A) Original unipolar electrograms with atrial complex, QRS and T wave was displayed at the top panel, then QRS subtraction and wavelet filter were utilized to enhance the high frequent component of the atrial electrograms. (B) An alternative approach to process the original unipolar signal is to convert unipolar to bipolar electrograms by subtracting its neighbouring unipolar electrograms along the same spline of the basket catheter. Then a local variability approach and subsequent Fast Fourier Transform were employed to estimate atrial frequency. (C) The enhanced unipolar electrograms and frequency obtained through A and B were used together to produce phase map and reconstructed sinusoidal wavelets.

## Graphical user interface



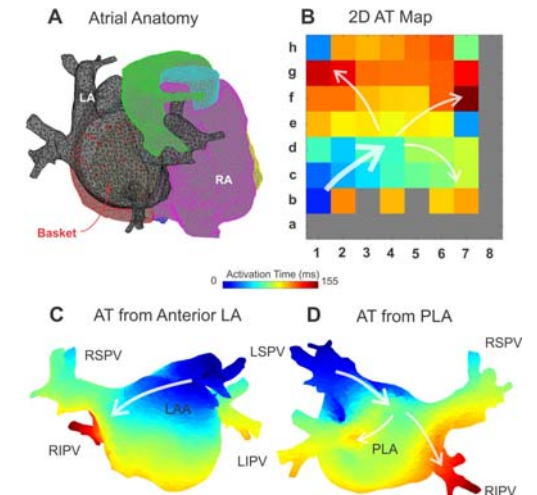
**Fig 3** Several key components of our custom developed GUI to process panoramic electroanatomical atrial electrograms interactively. (A) 64 potentials were recorded using a Constellation basket catheter in the RA during sinus rhythm are displayed at t=1522 ms. Eight potentials (b1-b8) were displayed at 1451-2200 ms at B and their locations in RA were indicated at C. (D) 64 channel potentials containing atrial activities (1451-1600 ms) were displayed side by side. Flat lines indicate channels are missing or broken. Here, RA = right atrium, SVC = superior vena cava, RAA = right atrial appendage, TV = tricuspid valve.

## Results



**Fig 4** Estimated activation times (ATs) of normal sheep #2 during sinus rhythm using Constellation basket catheter and ablation catheter. (A) Estimated ATs of the right atrium (RA) in 2D and 3D using the basket catheter. (B) Estimated RA ATs using a contact catheter. (C) Estimated ATs of the left atrium (LA) in 2D and 3D using the basket catheter. (D) LA ATs using the ablation catheter.

**Fig 5** Estimated activation times (AT) of LA in pacing induced AF studies (sheep #1) during sinus rhythm A, pacing B and atrial flutter C. Here eight original atrial electrograms are displayed at the right panel. Atrial frequency increased from 1 Hz, to 2 and 4 Hz. During atrial flutter, a ratio of 2:1 atria vs ventricle signals.



**Fig 6** A case study result from a left atrial (LA) chamber recorded in a patient using basket catheter prior linear line ablation (see Movies). (A) Registration of the 64 basket catheter and detailed atrial anatomy obtained using CT. (B) Activation time (AT) was estimated using our approach. (C/D) ATs were projected to LA using a radial basis function

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