Maximum entropy accurately predicts the distribution of phase singularity lifetimes in atrial fibrillation: implications for the AF mechanism

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Background: Maximum entropy (MaxEnt) is a statistical inference technique allowing selection of the optimal distribution for a given data sample. The key idea behind MaxEnt is that the least biased and best choice for a sample's distribution is one with the highest uncertainty. MaxEnt permits inferences to be made about the underlying data generating process. We hypothesized MaxEnt would provide insights about the generating process underlying the lifetime of phase singularities (PS), which occur at wavebreaks and rotors, and are believed critical to AF.

Objective: To study PS formation/destruction using a MaxEnt approach in: i) human (H) ii) sheep (S), and iii) computer simulated (SIM) AF.

Methods: Long duration basket recordings (H: 43 epochs ; S: 7 epochs) and SIM AF were studied. Phase maps were constructed using the Hilbert transform. PS destruction/formation was quantified by fitting PS lifetime and formation time data to an exponential distribution using non-linear least squares regression. Observed and predicted λ was compared using MaxEnt constrained by each epoch's sample mean.

Results: PS lifetime distributions for PS destruction returned similar experimental λ and MaxEnt derived λ in both humans and sheep (Human: 4.9%/ms (95%CI, 4.6, 5.3); Sheep: 4.6%/ms (95%CI, 4.2, 5.0)) (S7), which were strongly correlated (Human R^2: 0.99; Sheep R^2: 0.99). PS formation demonstrated similar results (Human: 4.3%/ms (95%CI, 4.0, 4.5); Sheep: 3.7%/ms (95%CI, 3.3). Similar results were seen in SIM AF ($R^2 > 0.97$).

Conclusion: The accurate prediction of PS lifetime distribution by MaxEnt principles in multiple systems implies that although AF may appear spatiotemporally random, the underlying aggregate process responsible for generating AF at the macro-scale is stable, deterministic, and predictable. MaxEnt is a new framework to understand AF generating mechanisms, that in future may be useful to the development of new AF treatments.

MaxEnt Predicted and Fitted λ are Highly Correlated