Spectral Analysis for Slow Pathway Characterization in Atrioventricular Nodal Reentry Tachycardia

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Aims: Despite significant technological advances in supraventricular arrhythmias mapping, the procedure for ablating atrioventricular nodal reentrant tachycardia (AVNRT) still relies on a qualitative and experience-based identification of the slow pathway (SP) potentials described by Jackman and Haissaguerre. This study aims to characterize the SP signal in the frequency domain, trying to identify one or more parameters to make the mapping more objective and effective than current techniques.

Methods: The study analyzed 355 atrial signals from 42 patients undergoing AVNRT ablation (using the CARTO 3 system, version 7.5). In particular, 123 signals were target signals recorded from the regions of Koch's triangle where junctional rhythm appeared during radiofrequency delivery, and 232 signals were from non-target regions. A multiparametric analysis was performed on these signals, utilizing 10 spectral (Figure 1, panel A) and 1 temporal parameters (Figure 1, panel B) in 2047 combinations to find the best set of parameters for distinguishing target signals from non-target ones, using ROC curve analysis.

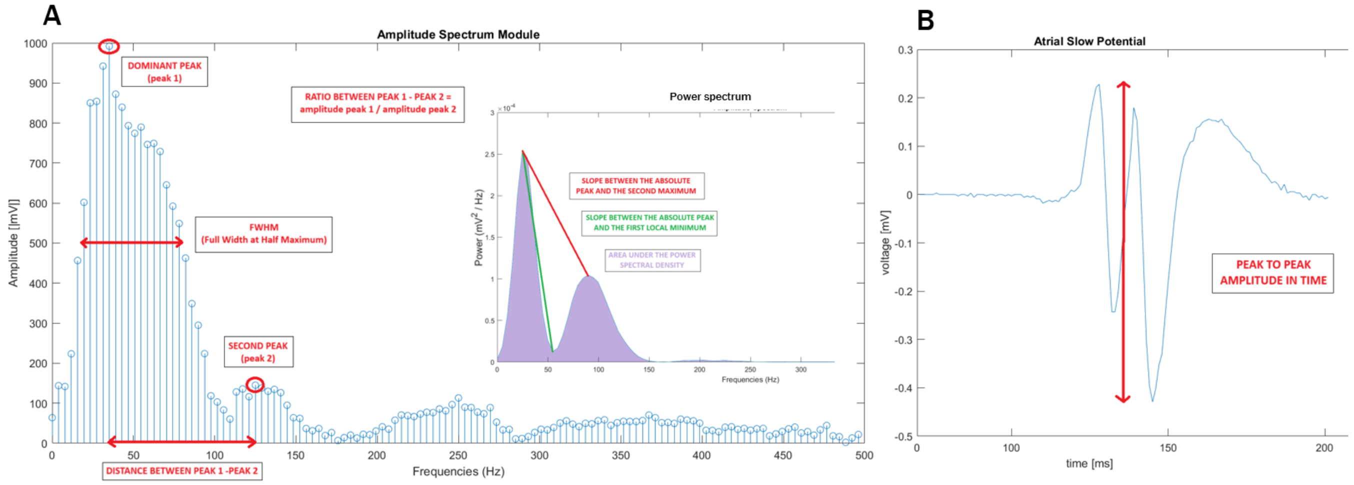

Figure 1: (A) Schematic depiction of the parameters extracted from the spectrum: the dominant peak, indicating the frequency with the highest amplitude, second peak representing the next most significant frequency component, the FWHM, showing the bandwidth over which the signal's amplitude is greater than half the amplitude of the dominant peak, the ratio between dominant and second peak, comparing their amplitudes, and the distance between the two peaks indicating the frequency interval between the two peaks and offering insight into the spectral distribution of the signal's energy. In addition, the power spectrum graph is shown with 3 additional parameters describing how energy is distributed throughout the signal and providing insight into its frequency components; (B) an example of a time-domain waveform of the atrial component of a target signal and the "peak to peak amplitude in time" defined as the maximum voltage fluctuation within the signal, marking the difference between the highest and lowest points of the waveform.

Results: The findings indicated that the best performance in terms of discrimination was achieved by combining the amplitude of the second peak with the power spectrum density slope between the dominant and secondary peaks (AUC 0.63), achieving 80% sensitivity and 55% specificity. This represents a 50% reduction in false positives compared to operator experience-based evaluations.

Conclusions: Enhancing accuracy and automating the SP signal mapping is essential to avoid multiple non-target radiofrequency deliveries. Based on our results, a shift from the time to the frequency domain seems necessary to improve SP signal characterization. Interestingly, the amplitude of the second peak might represent the fast component described by Jackman in the temporal domain. Overall, frequency domain signal analysis could be a valuable tool and, following a comprehensive validation on a larger dataset, its development and integration in current mapping systems could support ablation strategy planning.