Making More of Electrogram Morphology: Direction and Speed

D. Curtis Deno[1], Steven Kim[1], Patrick Kasi[1], Caleb Fick[1], Nicholas Ambrosius[1], Taras Rafa[1], Joe Rippke[1], Stéphane Massé[2], and Kumaraswamy Nanthakumar[2]

[1]Abbott Laboratories, Cardiac Electrophysiology, St. Paul, MN, USA
[2]University Health Network, Toronto General Hospital, Toronto, ON, Canada

Background

High density catheters with grid-like electrode arrangements enable more complete utilization of the information contained in electrograms. Recently, effort is being devoted to directly observing wavefront speed and direction. Omnipolar technology (OT) using electrogram morphology has recently been devised as an alternative method to conventional local activation timing (LAT) for instantaneously extracting speed and direction.

Objective

Determine the degree of agreement between OT and LAT methods of estimating local direction and speed from in vivo data.

Methods

Signals from identical 3-electrode cliques of Abbott's Advisor™ HD Grid Mapping Catheter Sensor Enabled™ were acquired from a pool of 10 maps and a total of 58,532 points in a variety of rhythms (SR, paced, AFL, AF) and chambers. Automated LAT determinations were made from unipolar dVdt timing whereas OT determinations were from unipole and bipole electrogram waveforms, ignoring activation timing. Clique signals were automatically scored for similarity to traveling waves (fixed shape, speed, direction) using OT Certainty, a machine learning derived index. Results are all mean ± standard deviation unless otherwise noted.

Results

In vivo, true directions and speeds are not known so accuracy could not be assessed. Wave directions were generally in agreement, correlated with R = 0.89 across all maps and points, rising to R = 0.97 when restricted to the 23% of points with OT Certainty > 0.7. A scatterplot of directions (not shown) revealed points clustered about the line of identity from 0-360°. Pooled angular discrepancies were often low, 0.6°±55.7° (median 0.0°, IQR 38.3°).

However, wave speed values across all maps and points were only modestly correlated, R = 0.34. Correlation improved to R = 0.41 with OT Certainty > 0.7. Pooled LAT speed was slightly less than OT speed (1.03±1.27 vs 1.15±0.74 m/s) though its variance was 3.0 times greater (1.61 vs 0.54 m^2/s^2, $p < 0.001$) as suggested in Figure 1.

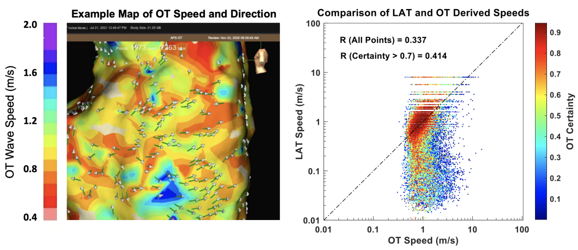

Figure 1: **Left**: Example map of OT speed and direction from a subject's RA during sinus rhythm. **Right**: Scatter plot of both LAT and OT speeds from all maps revealing widely distributed LAT speeds and greater agreement when OT Certainty was high.

Discussion

Mapping systems that display local direction and wave speed are under development and are hoped to contribute clarity to arrhythmia mechanisms and therapy options. This work compared two disparate approaches from 3 electrode cliques: LAT reflecting a detected instant and OT processing signals from a whole depolarization.

Both LAT and OT approaches produced plausible directions that were often in agreement. However, LAT derived speeds exhibited 3 times more variance than OT speeds. Wave speed 90^{th} percentile values ranged from 0.10 to 3.84 m/s for LAT and 0.50 to 2.10 m/s for OT. This appeared to reflect LAT sensitivity to timing differences compared to OT which does not involve timing. Wave speed variation may also reflect challenges from ignoring transmural conduction and surface irregularity.

As high-density catheters evolve to shorter inter-electrode spacings, increasingly local signals may better approximate traveling waves, favoring OT and becoming increasingly demanding of LAT. Both approaches may benefit from averaging over a larger number of electrodes, but at the expense of map resolution. Clinical requirements and benefits for accuracy and resolution from these new indices and grid-like catheters remain to be defined as a new era of mapping is beginning.