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LINEAR RELATIONSHIP BETWEEN DISTANCE AND ECG SIMILARITY DURING ENDOCARDIAL AND EPICARDIAL PACING: APPLICATION IN A NOVEL MAPPING ALGORITHM FOR THE REAL-TIME PREDICITON OF THE SITE OF ORIGIN OF VENTRICULAR ARRHYTHMIAS

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Introduction: Pacemapping (PM) is an established method for localising the site of origin (SO) of ventricular arrhythmias (VA). Currently, there is no system to indicate where subsequent PM will result in a better match to the clinical VA. We investigated the relationship between the change in ECG and distance between PM points and developed a novel navigation algorithm which was tested prospectively.

Methods: Digitised ECGs and Cartesian catheter coordinates were extracted from prospectively collected PM points across the endocardial (endo) surface of both ventricles and epicardial (epi) where possible, along with geometry from a 3D mapping system used in patients who underwent ablation of VA. Using custom software, a similarity metric was calculated using the root mean square error sum (RMSE) for each ECG between pairs of PM points (myocardial voltage $>$ 0.5 mV) and plotted against Euclidian distance and linear regression through origin performed to examine the distance similarity relationship (DSR). For the navigation concept, custom 3D mapping software was developed to run in parallel with the EnSite Velocity System (St Jude Medical, MN). For each study, a patient specific DSR was created initially from 3 widely spaced PM points and RMSE calculated between the VA and PM points. Using the DSR, the distance between VA and each PM point was extrapolated and visualised as 3 overlapping circles converging on a target superimposed on the 3D geometry (Figure). If the target was large, the PM point furthest away was substituted with a PM point predicted to be closest to the VA and this process repeated iteratively until the target area reduced to a minimum.

Results: From Oct 11-Jun 14, we enrolled 64 patients, 43 Male, median age 56 (IQR 26) who underwent 70 procedures (40 VE, 30 VT, 65 Endo, 5 Epi approach). 30 had normal hearts (NH), 19 ICM and 15 NICM. Median LVEF was 55% (IQR 22). A total of 861 PM points were analysed (mean 12.3 $\pm$ 4.4 PM points per patient). Distance and ECG similarity were strongly correlated, median correlation coefficient R 0.937 (IQR .044). There was no difference in strength of correlation or gradient of the slope between scarred vs NH or between NH vs ICM vs NICM.

We performed real time SO prediction on 25 prospectively enrolled patients (18 male; age 52 $\pm$ 15 yrs; median LVEF 57% (IQR 15); 15 VE, 10 VT; 11 NH, 4 IHD, 10 NICM; Epi approach in 3). SO prediction was performed on 32 distinct VA (12 LV, 4 LVOT, 3 RV, 11 RVOT, 2 Epi LV). The system correctly identified the SO (as identified by conventional means) in 31/32 instances with a mean target area of 208 $\pm$ 185mm2 range (40-708mm2) requiring 7 $\pm$ 3 PM to build the relationship. In one case, the system correctly identified the area of best PM match but was discordant with activation mapping.

Conclusion: There is a strong linear relationship between change in ECG morphology and distance using PM points from myocardium $>$0.5 mV that does not appear to be significantly different between scar and non-scar aetiologies. Using this novel system, it is possible to correctly identify a clinically useful target area in real time to identify the SO of VA in patients with structural heart disease and normal hearts. Further work is needed to confirm its usefulness in VA of epicardial origin.