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Non-Contact Mapping Accurately Defines Endocardial Pattern of Repolarisation-Validation Using MAP Recordings

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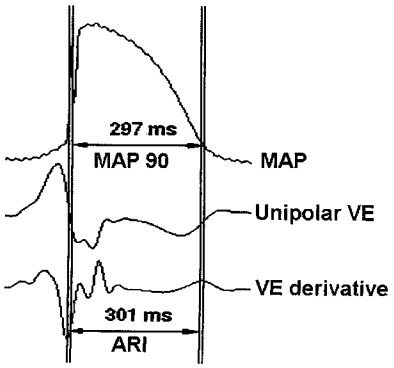
Background: Non-contact mapping (NCM) has not been validated as a determinant of endocardial repolarisation patterns. Global high density endocardial repolarisation maps may help identify proarrhythmic repolarisation syndromes. We validated use of NCM to determine repolarisation characteristics by analysis of virtual electrograms (VEs) at sites of MAP recordings (MAPS). Methods: MAPS were made from a total of 24 sites during constant pacing at 600 milliseconds DCL, with and without introduction of ventricular extrastimuli during restitution curve construction in patients undergoing NCM guided ablation of VT. Enguide was used to document MAP locations on the endocardial geometry. MAPs were measured at 90% repolarisation and correlated with same site 90% VEs repolarisation phase (recorded at filter settings of 0.1–300 Hz, with no adaptive, notch or spatial filters) Results: repolarisation times closely correlated with MAP-determined repolarisation times during steady state and premature extrastimulation (correlation coefficient, $r = 0.94$; $p < 0.001$). MAP and VE restitution curves exhibited the same characteristics. Conclusion: NCM is an accurate determinant of steady state and dynamic endocardial repolarisation patterns; NCM data could be used to characterise features of abnormal repolarisation.



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Cardiac Memory Accumulation on Dynamic Restitution of Action Potential Duration

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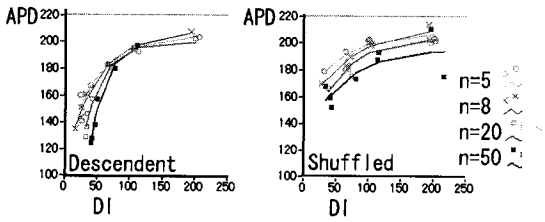
We tested dynamic electrical restitution property of cardiac cells by optical measurements of 6 Langendorff-perfused intact rabbit hearts stained with di-4-ANEPPS (0.3 μM) and cytochalasin D using the S1S1 method. Laser induced optical images from the left ventricle were recorded (490fps) during stimulation of the right ventricular endocardium at variable cycle length(CL). In a n-beats sequence, n basic beats (S1) were applied at a basic cycle length (BCL) before switched to next n-trains at new BCL. Transitions between BCL were varied as follows: Protocol 1: Gradually decreasing BCL typically from 350, 300, 250, 200, 180, 160, 150, 140. Protocol 2: 3 different sets of the randomly shuffled transition of 8 BCLs used in protocol 1 were tested on the same hearts after protocol 1 to minimize the possibility of the memory effect from the descending order. Dynamic restitution curve was obtained by plotting 90% of repolarization (APD90) of the last S1 activation against the preceding diastolic interval (DI) unless the heart failed to be activated with every beat or ventricular fibrillation occurred for the BCL. With increasing numbers of S1 stimuli, APD shortened and DI prolonged at BCLs <200 ms to make curves shift downwards for both protocols. Slopes of restitution curves also became steeper at longer DIs for protocol 1. In protocol 2, 2:1 activation were induced at BCLs at which had succeeded to 1:1 activation in protocol 1 when it applied after a short period of BCL. Conclusion: APD for same DI can vary due to the memory effect. Accumulation of rapid activation makes wave fronts blocked or break with longer DI, which play important roles on induction of ventricular fibrillation (VF). The results suggest that to remove cardiac memory effect will help organizing pacing rate and avoid VF induction.



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Excitation Under a Patch Electrode in the Heart

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Membrane excitation under patch electrodes used for defibrillation has not been optically mapped due to blockage of light by electrodes. We hypothesized excitation is produced under the electrode where the current density is high or where the shock-induced transmembrane voltage change (ΔVm) is positive. To test this, we used transparent electrodes and optical mapping in which light passed through the electrode. METHODS: Transparent electrodes 1 cm in diameter were fabricated from indium tin oxide sputtered onto glass and patterned. Electrodes were placed on ventricles of 4 warm perfused rabbit hearts to apply unipolar stimulation (3 ms, 5–100 mA). Stimulation was given during the action potential plateau to determine ΔVm or during diastole to determine excitation with no pharmacologic motion inhibition. Nonratiometric optical mapping of light transmittance through the electrode with a 128-spot laser scanner indicated distribution of current density at the electrode surface. Simultaneous ratiometric optical mapping with di-4-ANEPPS indicated Vm at the spots under the electrode and outside of electrode edges. RESULTS: For stimulation strengths greater than 8 times threshold, early excitation occurred under the cathodal electrode where positive ΔVm was found and at the edge and outside of the anodal electrode along fibers where positive ΔVm was found. When stimulation strength was reduced to 1–3 times threshold with either polarity, stimulus-excitation delay increased to 16 ± 11 ms and anomalous early excitation sites occurred under the electrode in 75% of trials. Anomalous sites did not correspond to regions of highest current density or positive ΔVm. CONCLUSIONS: Early excitation for strong cathodal and anodal stimuli occurs under a patch electrode and outside the electrode along fibers consistent with regions of high current density and positive ΔVm. Early excitation sites under the electrode for weak stimuli are not explained by electrode current density or ΔVm. This suggests other factors, such as myocardial heterogeneity, influence excitation for weak stimuli delivered from a patch electrode.

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Restitution Curves Can Not Predict the Dynamics in a Numerical Model of Reentry in a Ring

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Background: Action potential duration (APD) restitution is thought to play an important role in the formation of alternans and reentry; however, recent data suggest this link is uncertain. Methods: Stability of propagation and APD restitution were studied using numerical simulations in a ring of cardiac tissue represented by 2 ionic models (A & B) with different AP shape but the same APD and CV restitution curves (S1-S2 protocol) based on isolated rabbit heart data. The dynamics of all model parameters were analyzed as the ring perimeter was successively shortened. Results: Different propagation dynamics were observed in the models. Propagation was unstable for ring lengths of 7–9cm before propagation failed for model A and 5.9–7.5cm for model B. In the 8 cm ring where diastolic intervals (DIs) were very short, alternans was observed for A but stable propagation occurred for B. APD and DI along the ring for 2 beats are shown in Figure. Conclusions: Differences in electrotonic effects and gating variable dynamics for the 2 models resulted in the different regimes of stability. Therefore APD/DI values in small rings differ from those predicted by the restitution curve. In fact stable propagation in a ring occurred at DIs much shorter than the DI where the slope becomes >1 in the APD restitution curve (model B). In some cases the restitution relationship cannot predict reentry dynamics.