Increased Transient Outward Current in the Subepicardial Region Is Sufficient to Explain the Slurring of the QRS. A Simulation Study.

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BACKGROUND. QRS slurring was statistically associated with a recent history of sudden death and malignant arrhythmias. Clarification and differentiation between possible mechanisms of this easily detectable feature is needed to increase its predictive value.

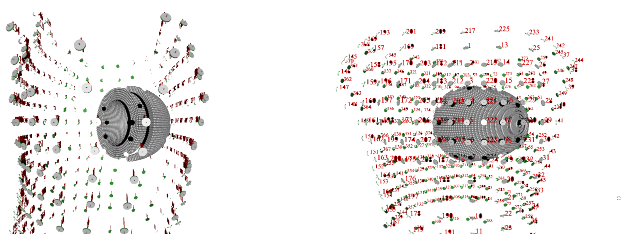

Figure 1. Anatomic model and placement in the thorax-shaped electrode system.

METHODS. We built a finite element model of the ventricles with 27000 elements organised in six myocardial strata for both the left and right ventricle (figure 1). The shape of the action potential was computed for the elements in each stratum using a modified Luo Rudy dynamic model that includes parameters extracted from the literature for the human myocardium. Activation times were assigned with a cellular automaton model and tuned to reproduce the well known recordings of Durrer D. at al. Electrograms were computed for 370 electrodes positioned on a surface with the shape of a human thorax in a uniform volume conductor around the ventricle (electrode positions were kindly provided by R. Macleod from University of Utah, USA).

A pair of simulations were compared, one without an Ito current and one with a maximum transient outward conductance $\mathbf{g}_{to}$assigned randomly in the 0.076–0.190 nS/pF interval in the subepicardial layer. All other parameters were identical between the two simulations.

The J point was taken as the instant where activation ended in the simulated myocardium. It was identical for all simulations, as activation was identical.

QRS slurring was measured by considering the decrease of the second derivative of the electrical potential in time on each lead at the instant when the last myocardial element was activated between the $\mathbf{g}_{to}$=0 and the $\mathbf{g}_{to} > 0$ cases.

1000 such pairs of simulations were run, with maximal conductances for the rapid and slow K, the ATP-dependent K, plateau K, T and L-type Ca, Na/Ca exchanger currents in a range of 40–160% of the reference value from the literature.

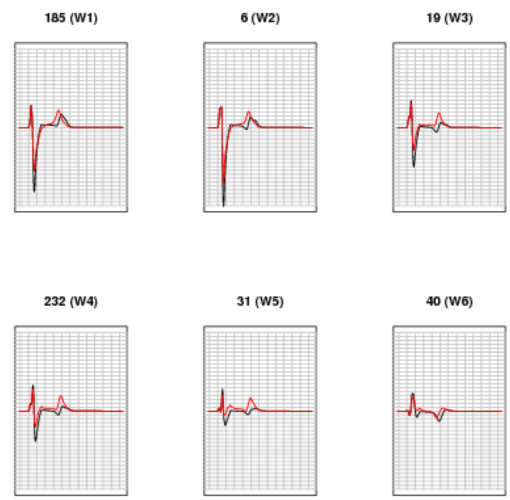

Figure 2. Simulated body surface electrograms without (black) and with (red) an I_{to} component, in one of the scenarios. The leads used are approximations of the precordials (identified with a corresponding 'W' instead of 'V'). In all leads either a degree of QRS slurring or a J wave is observed.

RESULTS. Adding the I_{to} current produced a QRS slurring effect in 322±2.4 of the 370 leads.

current	non-I_{to} J point ECG ampl.	I_{to} J point ECG ampl.	QRS slurring magnitude	QRS slurring prevalence
I_{to}	—	0.95	-0.74	-0.06
I_{K_r}	-0.04	-0.08	-0.05	-0.33
I_{K_s}	0.03	-0.24	-0.18	-0.43
$I_{Na/Ca}$	0.01	0.00	-0.02	-0.01
I_{Ca_T}	0.88	-0.02	-0.02	-0.02
I_{Ca_L}	-0.01	-0.06	0.04	0.03
$I_{Na/K}$	0.00	-0.05	-0.03	0.00
I_{Kp}	0.43	-0.15	0.37	0.32
$I_{K_{ATP}}$	-0.05	0.00	0.04	0.00

Table. Pearson correlation coefficients between current densities and ECG variables. Values above 0.1 and below -0.1 are rendered in color.

CONCLUSION. The QRS slurring aspect on the electrocardiogram could be obtained by the isolated increase in the maximum density of the transient outward current in the subepicardial region.