13.4.4 - Device Treatment

QRS complex and T wave planarity for the prediction of death and appropriate shocks in recipients of prophylactic implantable defibrillators

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Background: Three-dimensional (e.g., vectorcardiography) loops of normal physiologic QRS complex and T wave are known to be planar. Non-planarity of these electrocardiogram (ECG) loops was described in cardiac patients, mainly in relation to ischemic heart disease, but predictive values of the extent of non-planarity of the loops have not been systematically researched.

Methods: Pre-implantation digital ECGs were collected in 1948 cardiac patients (381 females, median age 65, inter-quartile range 56 – 72 years, 62% ischemic heart disease) who obtained an implantable cardioverter-defibrillator (ICD) for primary prophylactic reasons. In each ECG, QRS and T wave 3-dimensional loops were constructed using singular value decomposition and the non-planarity of the loops was measured as the relative power of the 3rd, least significant decomposition component. The non-planarity (i.e., the spatial twist) of the loops was related to all-cause mortality and to appropriate ICD shocks that occurred during the first 5 years after device implantation. This predictive power was compared to that of age, heart rate, left ventricular ejection fraction, QRS duration, spatial QRS-T angle, QTc interval, and T-peak to T-end interval.

Results: Non-planarity of the QRS loop was significantly associated with follow-up deaths despite ICD protection ($p<0.001$ both univariably and in multivariable Cox regression analysis) but was less powerfully associated with appropriate ICD shocks. Non-planarity of the T wave loop was significantly associated with appropriate ICD shocks during follow-up ($p<0.001$ both univariably and in multivariable Cox regression analysis) but was not associated with mortality during follow-up (Table). This was also seen in significant separation of Kaplan-Meier event probability curves (Figure).

Conclusions: The analysed data of recipients of prophylactic ICDs suggest that non-planarity of QRS complex and T wave loops offers distinction between patients who are at greater risk of death despite ICD protection and those who are likely to utilize the defibrillator protection.

13.4.4 - Device Treatment

Table

	Univariable analysis			Multivariable analysis		
	Wald	p-value	HR (95% CI)	Wald	p-value	HR (95% CI)
Prediction of 5-year all-cause mortality						
Age [years]	48.9	<0.001	1.043 (1.031 – 1.055)	38.2	<0.001	1.039 (1.026 – 1.051)
Female sex	0.51	0.476	0.891 (0.648 – 1.224)			
Non-ischaemic HD aetiology	2.32	0.127	0.834 (0.660 – 1.053)			
Heart rate [bpm]	30.8	<0.001	1.019 (1.012 – 1.026)	24.2	<0.001	1.018 (1.011 – 1.025)
LVEF [%]	30.1	<0.001	0.959 (0.945 – 0.973)	12.3	<0.001	0.970 (0.954 – 0.987)
QRS duration [ms]	26.6	<0.001	1.009 (1.006 – 1.013)			
QTc interval [ms]	20.3	<0.001	1.006 (1.004 – 1.009)			
QRS-T angle [°]	26.1	<0.001	1.010 (1.006 – 1.014)	8.87	0.003	1.006 (1.002 – 1.010)
TpTe interval [ms]	1.09	0.296	1.002 (0.998 – 1.006)			
QRS loop twist	17.5	<0.001	1.329 (1.163 – 1.519)	16.8	<0.001	1.339 (1.165 – 1.540)
T wave loop twist	0.87	0.349	1.061 (0.938 – 1.200)			
Prediction of 5-year ICD shocks						
Age [years]	0.43	0.510	1.004 (0.992 – 1.016)			
Female sex	7.55	0.006	0.538 (0.346 – 0.837)	7.39	0.007	0.541 (0.348 – 0.843)
Non-ischaemic HD aetiology	3.97	0.046	0.751 (0.566 – 0.995)			
Heart rate [bpm]	1.73	0.188	0.994 (0.984 – 1.003)			
LVEF [%]	0.01	0.975	1.000 (0.985 – 1.014)			
QRS duration [ms]	0.23	0.879	1.000 (0.995 – 1.004)			
QTc interval [ms]	0.15	0.696	1.001 (0.997 – 1.004)			
QRS-T angle [°]	0.91	0.340	0.998 (0.995 – 1.002)			
TpTe interval [ms]	0.50	0.476	0.998 (0.992 – 1.004)			
QRS loop twist	6.61	0.010	1.233 (1.051 – 1.447)			
T wave loop twist	17.7	<0.001	1.364 (1.180 – 1.576)	17.7	<0.001	1.363 (1.180 – 1.575)

CI – confidence interval, HD – heart disease, HR – hazard ratio, LVEF – left ventricular ejection fraction, TpTe – T peak to T end, Wald – Wald test statistics. Multivariable analysis used stepwise backwards elimination.

Figure