TIMING DEFIBRILLATION SHOCKS
IMPROVES DEFIBRILLATION SUCCESS

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BACKGROUND

Although cardiac electrical activity in ventricular fibrillation (VF) is apparently highly disordered, Damle et al.[1] and Bayly et al.[2] found strong evidence for local spatial organization, paving the way for extensive further investigation. Garfinkel et al.[3] characterized VF as spatio-temporal chaos, finding underlying dynamic order. Gray, Pertsov and Jalife[4] and Witkowski et al.[5] demonstrated the existence of multiple spirals in VF. More recently, Bayly et al. quantified[6] spatial correlation in VF by demonstrating a correlation length of 4-10 mm.

If a degree of organization and periodicity exists during VF, perhaps the current required to defibrillate could be reduced if the shock were delivered at an optimum point in the fibrillatory cycle. Perhaps if the shock were delivered during a during a time period when a large portion of the myocardium is depolarized or refractory, then less current would be required to depolarize an additional portion of the myocardium to reach a critical mass for defibrillation. Finally, defibrillation at such a time in the cardiac cycle might minimize the chances that VF would reinitiate following defibrillation (cf. refs 7,8).

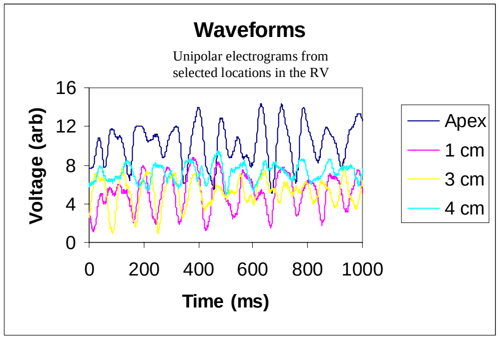
PURPOSE AND HYPOTHESIS

Purpose: reduce defibrillation threshold for practical, implantable defibrillators

Hypothesis: defibrillation threshold can be reduced by timing with respect to spatio-temporal data

Limitations imposed in clinical practice:
Small number of allowed sensing electrodes
Limited computational power
Structure of waveforms - see below
    Baseline variability and drift
    Amplitude variability

TYPICAL WAVEFORMS (unipolar electrograms)



SUMMARY

Study Goals

To determine whether success of defibrillation can be improved by suitably timing defibrillation shocks. Current internal defibrillators synchronize the shock to an activation measured from an RV tip bipole.

Methods

In a prospective study directed by Teri Whitman of Medtronic, four isoflurane-anesthetized pigs were instrumented with a Medtronic 6944 true bipolar lead in the RV apex, a diagnostic catheter in the great cardiac vein, and a subcutaneous patch in the pectoral region. In addition, a 2-8-2 mm diagnostic catheter was placed along the RV free wall for the retrospective study described herein. Fibrillation was induced with a T shock and defibrillation was attempted after 10 seconds of VF using one of four synchronization methods: 1) asynchronous, or synchronized to the first sensed activation from 2) RV tip/ring electrogram (EGM), 3) RV coil/ sub-cutaneous patch EGM, or 4) LV bipolar EGM. Twenty sets of 4 shocks were given at energies stepping around the overall 50% successful defibrillation dose. The retrospective study analyzed voltages and slew rates recorded by the RV diagnostic catheter in order to determine whether success of defibrillation can be improved by suitably timing defibrillation shocks. 317 of the 320 recordings were usable.

Results

The number of sites in the repolarizing state was correlated with defibrillation success (success: 1.66±0.08; failure 1.38±0.08 (mean ± SEM), p=0.016, paired t-test). Moreover, defibrillation was significantly more successful when the both the apex and most distant site were in the repolarizing state (65% vs. 51%, chi-squared = 4.88, $p < 0.05$). This criterion was met 26 % of the time. Finally, in a preliminary estimate with logistic regression, applying this criterion appears to reduce defibrillation energy by 19 (+12, -9) %.

Conclusions

Retrospective analysis indicates that defibrillation success could be significantly improved by sensing two sites in the RV and delivering shocks when both sites are in the the repolarizing state.

The future

Modeling study to optimize criteria of this type in two ways: maximizing the reduction in defibrillation energy and minimizing the expected waiting time until the criterion is met. Design a prospective animal experiment aimed at a 40% reduction in defibrillation energy, and perform that animal experiment.

Selecting a criterion

Look at successes and failures
Study behavior of electrograms

Unipolar electrograms at the apex and 4 cm distal
Average number of sites in depolarization

	Average	Standard dev	SEM
Failures (n = 143)	0.196	0.340	0.029
Successes (n = 174)	0.305	0.460	0.035
Difference	0.109		0.045

t = 2.41, p = 0.016

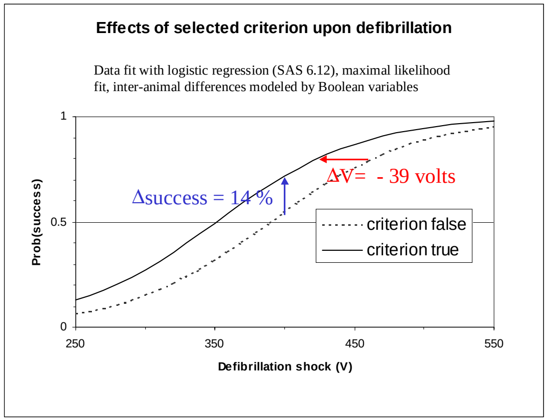
Evaluating the criterion

Consider how often criterion met
and effect upon defibrillation success
Criterion: Apex and 4 cm distal both repolarizing
How often met ? 26 % of time

Criterion met ?	Successes	Failures	Trials	Prob of success	Std Error
No	121	115	236	51.3 %	3.3 %
Yes	53	28	81	65.4 %	5.3 %
Total	174	143	317	54.9 %	2.8 %

Chi-squared = 4.84, $p < 0.05$

IMPROVED DEFIBRILLATION SUCCESS



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