BIPHASIC DEFIBRILLATION: PEAK CURRENT PREDICTS SURVIVAL WHILE HIGHER ENERGY AND AVERAGE CURRENT INCREASE MYOCARDIAL DYSFUNCTION

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BACKGROUND

Relatively low-energy (150 J) biphasic waveforms are more effective than higher-energy (200 J-360 J) monophasic waveforms for successful defibrillation [1], and have been demonstrated in a swine model to improve post-resuscitation myocardial function [2]. It is unknown whether the same benefits may accrue as compared to higher-energy biphasic waveforms. We examined a low capacitance waveform typical of low-energy application (BTEL, 100 µF, 50/50 phase, = 200 J) and a high-capacitance waveform typical of high-energy application (BTEH, 200 µF, 60/40 phase, = 200 J) (Figures 1 & 2).

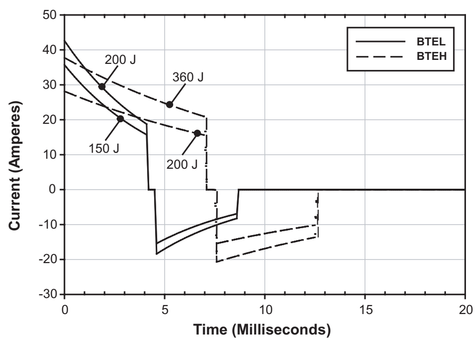

Figure 1. Biphasic waveforms utilized for the present study. BTEL uses a 100 µF defibrillation capacitor, while BTEH uses 200 µF.

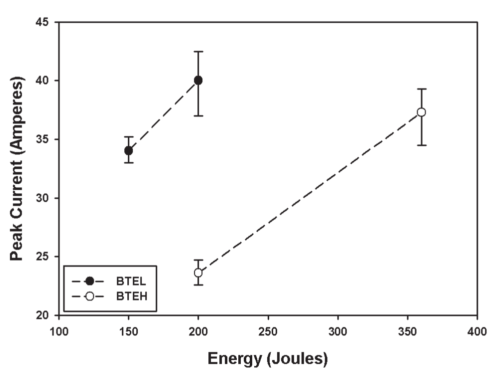

Figure 2. Energy versus peak electrical current relationships for the therapies used in the study.
Circles and whiskers indicate median and interquartile range.

METHODS

Four groups of anesthetized 40-45 kg pigs were investigated. Following 7 minutes of electrically induced VF, a 15-minute BLS resuscitation attempt was made; using sequences of up to three defibrillation shocks followed by 1 minute of mechanically delivered CPR. Animals were randomized to BTEL at 150 J or 200 J, or BTEH at 200 J or 360 J. Hemodynamic performance was monitored for four hours pos-resuscitation via transesophageal echo-Doppler technique.

All outcome variables were tested for significance of overall therapy effect using exact non-parametric methods. The Fisher-Freeman-Halton test was employed for tables of counts, while the Kruskal-Wallis test was used for continuous variables. If a significant overall effect was identified, between-group comparisons were performed using Fisher's exact test for the counts, and exact Wilcoxon-Mann-Whitney tests for the continuous data, with time stratification for repeated measures. Multiple linear regression was employed to identify waveform design effects.

RESULTS

Resuscitation was unsuccessful for 3 of 5 animals treated with BTEH 200 J. All other attempts were successful. Significant therapy effects were observed for survival, left ventricular ejection fraction, and stroke volume (Figures 3-5). Hemodynamic outcomes were negatively associated with energy and average current, but positively associated with peak current (Figure 6). Animals treated with 150 J shocks exhibited significantly less hemodynamic compromise immediately following resuscitation (EF, SV) compared to higher energy shocks ($p < 0.001$). For higher energy shocks, partial hemodynamic recovery was evident over the 4-hour period following resuscitation, but not to levels observed with 150 J shocks. With either waveform (BTEL or BTEH), hemodynamic performance was degraded by increased dose. Peak current was the only significant predictor of survival ($p < 0.001$).

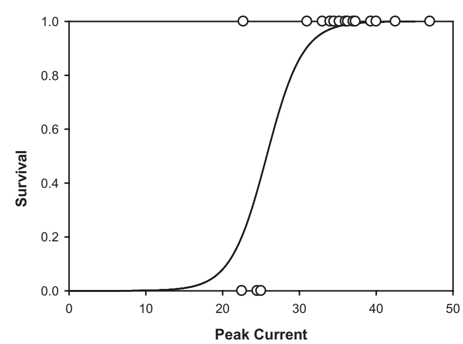

Figure 3. Logistic regression for survival versus peak current ($p < 0.001$).

References on reverse.

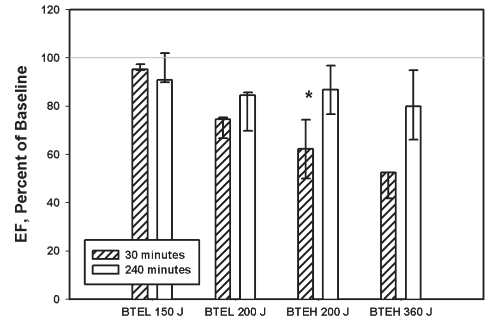

Figure 4. Ejection fraction versus therapy at 30 and 240 minutes post-resuscitation, shown as median and interquartile range.
*BTEH 200 J data excludes 3/5 animals that failed resuscitation, and is therefore biased high.

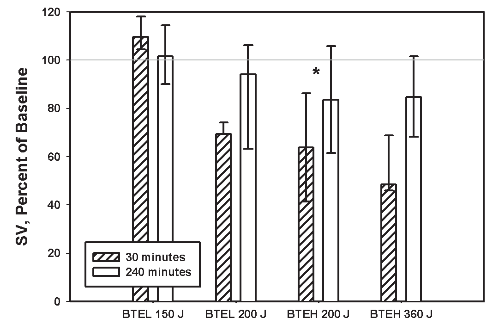

Figure 5. Ejection fraction versus therapy at 30 and 240 minutes post-resuscitation, shown as median and interquartile range
*BTEH 200 J data excludes 3/5 animals that failed resuscitation, and is therefore biased high.

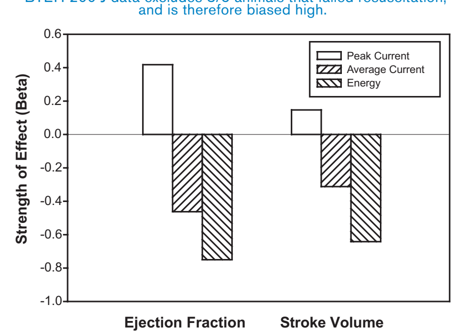

Figure 6. Normalized multiple regression coefficients. Positive value implies beneficial association and vice versa. $R^2 = .75$, $p = 0.002$ for EF, $R^2 = 0.57$, $p = 0.032$ for SV.

DISCUSSION AND CONCLUSIONS

The results of this study contradict the notion that peak current is the primary correlate of myocardial injury/ dysfunction.

The positive association between peak current and survival combined with the negative association between energy, average current, and hemodynamic performance, argues for a biphasic waveform that maximizes (within the limits of this study) the ratios of peak current to energy, and peak current to average current.

This is most readily accomplished via the use of lower-value defibrillation capacitors and shorter duration waveforms.

REFERENCES

1 Martens PR, Russell JK, Wolcke B, et al. Optimal Response to Cardiac Arrest study: defibrillation waveform effects. *Resuscitation* 49:233-243.

2 Tang W, Weil MH, Sun SJ, et al. The effects of biphasic and conventional monophasic defibrillation on post resuscitation myocardial function. *J Am Coll Cardiol* 1999;34:815-822.