

The effects of biphasic waveform design on post-resuscitation myocardial function

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“...survival was maximized and myocardial dysfunction minimized using a waveform that simultaneously delivered higher peak current while minimizing energy and average current.”

Objective

The authors examined a low-capacitance waveform typical of a low-energy/high peak current commercial application (100µF capacitance, ≤ 200 Joules) and a high-capacitance waveform typical of a high-energy/lower peak current commercial application (200 µF capacitance, ≥ 200 Joules). The objective was to determine which design results in greater defibrillation success, better resuscitation and survival outcome, and lower myocardial dysfunction.

Methodology

Ventricular fibrillation (VF) was induced in anesthetized 40-45 kg pigs. After 7 minutes in VF, resuscitation was attempted using a sequence of up to three defibrillation shocks followed by 1 minute of CPR, and repeated if necessary for up to 15 minutes. Animals were randomized to one of four groups:

1. Low capacitance shocks at 150J
2. Low capacitance shocks at 200J
3. High capacitance shocks at 200J
4. High capacitance shocks at 360J

Results

- Resuscitation was successful in just two of the five animals treated with high-capacitance 200J therapy (40% survival). The other three groups achieved 100% resuscitation.
- Significantly more shocks and more CPR were required for the pigs resuscitated with the high-capacitance therapy.
- Significantly higher post-resuscitation myocardial dysfunction was observed with the high-capacitance therapy.

The authors observe, “Higher peak current is associated with improved survival, whereas higher energy and higher average current are associated with increased post-resuscitation myocardial dysfunction...Post-resuscitation myocardial dysfunction has been associated with early death after initial successful resuscitation.”

Group	1	2	3	4
Capacitance	100µF	100µF	200µF	200µF
Energy	150J	200J	200J	360J
Median Peak Current	34A	40A	24A	37A
Survival (to 72 hours)	100%	100%	40%	100%
Median Number of Shocks to Resuscitate	1	3	5	4
Median CPR Duration (seconds)	106s	83s	909s	218s
Median Total Energy Required	155J	563J	994J	1440J
Median Ejection Fraction (% of baseline)*	95%	75%	62%	53%

*A representative measure of dysfunction. A lower number compared to baseline means more dysfunction.

Conclusions

The authors conclude, “With respect to patient outcome, these results suggest that peak current is a more appropriate measure of defibrillation dose than either energy or average current and that toxicity may be minimized by simultaneously reducing both of the latter...survival was maximized and myocardial dysfunction minimized using a waveform that simultaneously delivered higher peak current while minimizing energy and average current.”

Philips Commentary

The Philips waveform maximizes peak current for shock efficacy while minimizing energy to limit toxicity and dysfunction for an already compromised heart. The study demonstrates that this is a beneficial combination. It means Philips can deliver its most potent therapy from the very first shock. There is no need to hold back for fear of compromising an already fragile heart.

Philips' use of low capacitance, similar to that seen in the low capacitance arm of this study, enables Philips to use less (toxic) energy to deliver more (therapeutic) current. At every energy level, Philips delivers higher peak current, demonstrating true efficiency.

By contrast, the high capacitance therapy requires a lot more energy to achieve the same resuscitation benefits, bringing along toxic side effects. Manufacturers employing high capacitance start with their weakest shock. If it fails, they escalate energy to

drive higher current once, maybe twice, with long CPR intervals between each shock. It may take several minutes to reach the shock strength required for that patient.

The American Heart Association and European Resuscitation Council have made similar statements that current is the appropriate measure of shock strength, not energy (joules). The 2005 AHA Emergency Cardiac Care Guidelines state: "Energy is a nonphysiologic descriptor of defibrillation despite its entrenchment in traditional jargon...Transition to current-based description is timely and should be encouraged."¹ ERC guidelines make a similar statement. "Although energy levels are selected for defibrillation, it is the transmural current flow that achieves defibrillation. Current correlates well with successful defibrillation and cardioversion. Future technology may enable defibrillators to discharge according to transthoracic current: a strategy that may lead to greater consistency in shock success."²

References

¹ American Heart Association Guidelines 2005. Circulation 2005; 112.

² European Resuscitation Council Guidelines 2005. Resuscitation 2005; Vol 67 Supplement 1.



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