Evaluation of body weight as a predictive factor for transvenous ventricular defibrillation characteristics

J.R. Paisey*, T. Betts, S. Allen, J.M. Morgan, P.R. Roberts

Wessex Cardiothoracic Centre, Southampton, UK

Submitted 31 July 2002, and accepted after revision 13 September 2003

Abstract
Aims To investigate the correlation between body weight and defibrillation threshold (DFT) for transvenous lead systems using a porcine model.

Methods and results Twenty-eight pigs were anaesthetised and DFTs assessed in single and dual coil configurations using a four-reversal binary search method. DFT was correlated with body weight in the RV/Can and RV/SVC/Can configurations. A Pearson correlation coefficient and a two-sided p-value were calculated. A positive correlation exists between body weight and DFT in RV/Can (r = 0.66, p < 0.000) and RV/SVC/Can (r = 0.44, p = 0.018).

Conclusion There is a significant correlation between body weight and DFT in swine. This tends to be greater in the two-electrode than in the three-electrode configuration. With these and previous human observations, one may predict a higher DFT in heavy individuals and make appropriate procedural adjustments.

© 2003 The European Society of Cardiology. Published by Elsevier Ltd. All rights reserved.

KEYWORDS
implantable cardioverter defibrillator; defibrillation threshold; ventricular arrhythmia; fibrillation; body weight

Introduction
While several variables have been identified that correlate with transthoracic defibrillation threshold (DFT) [1–3], no clear predictors of transvenous (or epicardial) ventricular defibrillation characteristics have been found. Observational studies have suggested that body size, left ventricular dimensions [4–6] and antiarrhythmic therapy [7] may correlate with defibrillation threshold.

Rigorous defibrillation threshold testing in humans is difficult as multiple ventricular fibrillation inductions are required.

Identification of predictive factors of DFT prior to implantable cardioverter defibrillator (ICD) implantation would allow individual tailoring of device selection and electrode configuration [8].

In this study we evaluate the correlation of body weight with a number of defibrillation characteristics in a pig model.

* Corresponding author. C/O Dr Morgan’s Secretary, Mailpoint 46, Southampton General Hospital, Tremona Rd, Southampton SO17 1SX, UK. Tel.: +44-2380-798676; fax: +44-2380-798942.
E-mail address: johnpaisey@doctors.org.uk (J.R. Paisey).
Methods

Animal preparation and monitoring

Twenty-eight female pigs of the same crossbred variety (Landrace and Large white parentage) weighing 30–70 kg (mean 43.8 ± 11.7 kg) were anaesthetised with a continuous intravenous infusion of alphaxalone (9 mg/kg/h) and alphadolone acetate (3 mg/kg/h) (Saffan, Mallinckrodt Veterinary, Uxbridge, Middlesex, UK). This anaesthetic has been reported to have minimal cardiovascular effects [9–11]. The animals were intubated with a cuffed endotracheal tube and ventilated using room air supplemented with oxygen. The tidal volumes and respiratory rates were adjusted depending on arterial blood gas concentrations. The femoral artery was cannulated for continuous arterial blood pressure monitoring and sampling. Arterial blood samples were analysed hourly for pH, PCO₂, PO₂, HCO₃, and K⁺. All these variables were maintained within normal limits for the duration of each study. Arterial pressure, ECG, and rectal temperature were monitored continuously throughout the study.

Instrumentation

The right external jugular vein was cannulated and an Angeflex defibrillation electrode (Angeion Corporation, Minneapolis, MN, USA) was advanced to the right ventricular apex (RV) under fluoroscopic guidance with the proximal defibrillation electrode located in the superior caval vein. Its stability in this position was ensured with repeated fluoroscopy. An active housing (AH) Can electrode (43 ml) was implanted into a pocket fashioned in the subcutaneous tissue of the left pectoral region of the chest wall.

Shock waveform

The pigs were defibrillated with a biphasic rectangular waveform with a phase 1 duration of 4.8 ms and a phase 2 duration of 2.4 ms, with 0.2 ms between phases. The leading edge voltage of phase 2 was 50% of the amplitude of phase 1. The waveform was delivered by an external research defibrillator (ARD9000, Angeion Corporation) that operates as a high voltage, linear amplifier. A rectangular waveform (zero tilt) was selected to maintain a constant waveform duration and constant voltage during each phase. Ventricular fibrillation was induced using 60 Hz alternating current of 10 V for 1 s delivered after 10 s of ventricular fibrillation.

Defibrillation protocol

The defibrillation threshold was established for each randomised electrode configuration using a modified four-reversal binary search method. The starting energy was 16 J, with subsequent shock levels changed (increased/decreased) depending on the animals’ response (failure/success). The energy of subsequent shocks was increased or decreased in steps of 8, 4, 2, and 1 J, with all subsequent intervals at 1 J. When at the 1 J step size, the shock energy was increased/decreased until three successful shocks were obtained that were either preceded or followed by a failed shock. The defibrillation threshold was calculated as the mean of the three successful shocks. If any test shock failed, the animal was immediately rescued using a 40 J biphasic shock. The animal was allowed to recover haemodynamic function (return of heart rate and blood pressure to baseline level) between each fibrillation/defibrillation cycle, for a minimum of 3 min.

Data acquisition and statistical analysis

The DFT, impedance, leading edge current and voltage and weight of each animal were recorded prospectively and correlation coefficients were calculated for RV → Can and RV → SVC + Can between DFT and weight.

Results

There is a significant correlation between body weight and defibrillation threshold. This correlation tended to be closer in the two-electrode configuration RV → Can (Table 1, Figs. 1 and 2).

Five animals were more than one SD heavier than the mean. After excluding these animals,

| Weight (kg) | 43.8 ± 11.7 |
| RV → Can | 20.7 ± 8.8 |
| RV → SVC + Can | 17.7 ± 6.8 |
| RV → Can | 54.2 ± 6.9 |
| RV → SVC + Can | 49.1 ± 11.3 |
there remained a correlation between DFT and weight in the RV → Can configuration ($r = 0.56$, $p = 0.005$) but the correlation ceased to be significant in the RV → SVC + Can configuration ($r = 0.372$, $p = 0.081$).

The mean number of VF inductions in each animal was $19.9 \pm 3.4$. There was a non-significant negative correlation between number of VF inductions and DFT ($r = -0.24$, $p = 0.079$).

**Discussion**

Previous work has shown that both large body size and large heart dimensions are associated with a high DFT [12]. The effects of amiodarone on DFT are well known [12,13].

It has not previously been shown that there is a consistent positive correlation between body weight and DFT, neither has the interaction of body weight with DFT been assessed in the three-electrode configuration.

The findings of this porcine study are that body weight is positively correlated with DFT across a range of values. We also found that the correlation tended to be stronger in the two-electrode than in the three-electrode configuration.

The positive correlation between DFT and body weight is likely to be explained by one of two mechanisms. Either the larger extracardiac tissue volume is affecting current distribution within the

**Figure 1**  Defibrillation threshold vs. weight for the RV → Can configuration showing $r = 0.66$, $p < 0.000$.

**Figure 2**  Defibrillation thresholds for the RV → SVC + Can configuration ($r = 0.44$, $p = 0.018$).
myocardium thus altering defibrillation efficacy, or body weight acts simply as a marker of cardiac dimensions.

The trend to a greater increase in DFT with weight observed in the two-electrode configuration compared with the three-electrode configuration may be explained by the hypothesis that more non-cardiac structures are involved in the vector of RV → Can. This approach to explaining increasing DFT with weight puts more emphasis on the increased extracardiac tissue with body weight.

The alternative interpretation that DFT increases with body weight due to increased cardiac dimensions is also likely to play a role. In this hypothesis the additional electrode may be offsetting the loss of efficacy of defibrillation by increasing the proportion of myocardium in the shocking vector.

Porcine cardiac anatomy equates closely with humans, differing mainly in angulation within the mediastinum. The extramediastinal thoracic tissue distribution varies greatly and thus may have an effect on the correlation observed in this study. These findings, however, in conjunction with the analysis in humans previously referenced [12] provide a compelling case that body weight is a significant factor in DFT determination.

Predicting which individuals are likely to be affected by above average DFT should assist clinicians with device and configuration selection. Options such as subcutaneous arrays and novel configurations to reduce DFT should be considered in heavier individuals.

Most clinical patients have only device based testing so if DFTs are close to programmed therapies, this may not be known in advance. Extra caution should be exercised when commencing weighty patients on drugs such as amiodarone which increase DFT.

Further work is required to assess the best defibrillation configuration for high body mass individuals.

Limitations of the study

Whilst this study proves a correlation between DFT and body weight, it does not establish a causal link. Data on cardiac dimensions were not obtained as controlling this would further clarify the relative contributions made by LV size and extrathoracic tissue.

Conclusion

There is a positive correlation between DFT and body weight in swine.

There is a trend to a higher correlation in the two-electrode configuration than the three-electrode configuration.

References