Energy Requirement for Defibrillation of a Markedly Overweight Patient

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SUMMARY Recommendations have been made recently that the energy output of present-day defibrillators be increased above the 400 wsec limit. These recommendations are based largely on experimental studies in animals. We report a case of a man weighing 190.1 kg (418.2 lb), successfully resuscitated with a single 400 wsec shock after a prolonged episode of ventricular fibrillation. The observation in this patient as well as data derived from cardiovascular experience indicates that weight is not a significant factor in the successful outcome following defibrillation in adults. Many variables primarily related to the clinical condition of the heart influence the results of countershock. There are no valid studies at present to support the claim that high-energy defibrillators are necessary. In fact, implementation of such a recommendation is premature and possibly dangerous.

DIRECT CURRENT DEFIBRILLATION of the heart is a standard method promoted by its procedural simplicity and sanctiond by its high success rate. Recently, Tacker, Geddes and coworkers1-3 presented data in both animal and man indicating that the standard instruments in current use provide insufficient energy for heavy subjects. They concluded that presently available devices are inadequate for defibrillating 35% or more of patients weighing in excess of 50 kg.4-5 This has led to the recommendation that defibrillators be manufactured capable of delivering larger electrical energies.1-3 The very opposite point of view has been reached by Pantridge et al.4-6 and Crampton et al.,5 7 who have counseled the use of lower energies for cardiac resuscitation. The issue is of great importance. If Tacker and coworkers are correct, heavy subjects are denied the chance of resuscitation. On the other hand, if the claims relating to the need for more energy are insubstantial, numerous patients will be subjected to injurious currents, and in some the chance of successful resuscitation will be jeopardized. Because information on the energy requirements for defibrillating patients weighing in excess of 150 kg is not available, we report the following pertinent experience.

Case Report

A 30-year-old white male with acromegaly for six years and atypical chest pain for two years, noted occasional dizzy spells associated with palpitation. He was on hormonal replacement therapy, and warfarin. He was admitted to the Peter Bent Brigham Hospital for weight reduction prior to cardiac catheterization and coronary angiography. He was massively obese, weighing 198.5 kg (436.7 lb) and 175 cm (68.9 inches) tall. Skull and acral enlargement was obvious. Pulse rate was 75 beats/min with occasional extra-systoles. Blood pressure was 120/80 mm Hg in the supine position. The cardiac findings were within normal limits. The electrocardiogram showed sinus rhythm at a rate of 56/min with frequent unifocal ventricular premature beats (VPBs). PR interval was 0.18 sec, QRS 0.09 sec and the axis was −30°. There were nonspecific ST and T wave abnormalities. Ambulatory monitoring for 24 hours demonstrated frequent unifocal VPBs, couplets and short runs of 3–5 beat ventricular tachycardia. A posteroanterior chest roentgeno-
Figure 1. Continuous strips. Monitor lead from 24-hour tape demonstrating salvos of ventricular premature beats and runs of accelerating ventricular tachycardia with occasional sinus beats. Ventricular tachycardia is initially self-terminating, but degenerates into course ventricular fibrillation in the last strip.

Figure 2. Continuous strips. Ventricular fibrillation, with artifacts produced by external cardiac massage, terminated by a single 400 wsec shock. A 3 sec pause is followed by idioventricular rhythm.

gram showed moderate cardiomegaly. Routine hematologic and biochemical studies were within normal limits.

A 300 calorie per day diet was instituted and body weight decreased to 190.1 kg (418.2 lb). Vasodilator drugs did not completely relieve chest discomfort. Antiarrhythmic therapy with conventional drugs failed to control high grades of ventricular arrhythmia. Addition of digoxin, 0.375 mg daily, suppressed ventricular tachycardia, but he developed symptomatic bradycardia with bigeminy and Wenckebach block.

While speaking with a visitor one afternoon, he felt dizzy, lost consciousness and became cyanotic. He was found to be in ventricular fibrillation. Cardiopulmonary resuscitation was performed for approximately six minutes. Defibrillation was successfully accomplished with a single discharge at an energy setting of 400 wsec by means of an American Optical Model 10645 DC defibrillator utilizing the Lown waveform. One electrode was placed over the second right interspace and the other at the fourth interspace at the left lower sternal border. The chest diameter was 123 cm (48.4 inches) at the second and 132 cm (52 inches) at the fourth interspace.

The entire sequence was fortuitously recorded on a monitor tape. During the course of the day, ventricular ectopic activity increased progressively in frequency, multiformality and repetitive pattern. The onset of fibrillation was preceded by longer runs of ventricular tachycardia of the vulnerable period (Fig. 1). After the single 400 wsec shock, there was a pause of three seconds, followed by idioventricular rhythm for one minute before resumption of sinus rhythm (Fig. 2). The duration of ventricular fibrillation was 10 minutes and 15 seconds (Fig. 3).

Following resuscitation, lidocaine 2-4 mg/min suppressed all ventricular ectopic activity. Serum potassium was 3.8 mEq/L. Cardiac enzymes showed a greater than twofold elevation transiently, but serial electrocardiographic tracings remained unchanged. Cardiac catheterization showed slightly increased left ventricular end-diastolic pressure, an ejection fraction of 0.64 and normal coronary arteries.

Discussion

Few reports have been published on resuscitation of very heavy subjects. One female, weighing 237 lbs, was reverted with 300 wsec;9 while a man, weighing 319 lbs, was successfully defibrillated with 400 wsec of stored energy.10 Despite a more massive body weight of 418 lbs and chest diameter ranging from 48 to 52 inches, our patient was defibrillated with a single discharge. The setting was 400 wsec and the delivered energy through a 50 ohm resistance was 340 wsec. A factor limiting the delivered energy to this
patient was the position of the electrode paddles. Because of massive girth, electrodes were placed on either side of the sternum thereby possibly reducing effectiveness of the delivered pulse. It has been recommended that one electrode be placed in the second right intercostal space and the other just below the angle of the left scapula as this electrode configuration is known to reduce electrical energy requirements for cardioversion by about 50%.\(^\text{11}\)

Clinical experience indicates that many variables other than body weight affect the ease of defibrillation. Among these are the state of the myocardium, the size of the heart, precipitating factors such as myocardial infarction, primary electrical failure, and drug intoxications, the duration of ventricular fibrillation, the presence and extent of hypoxia, acidosis, and electrolyte imbalance, and the amount of circulating catecholamines. The methods employed, specifically the size of electrodes, their positioning, firm skin contact and the adequacy of conductive paste also influence the outcome. The very nature of the dire emergency under which defibrillation is effected and the realization that delay brooks failure have precluded the acquisition of meaningful information bearing on the determination of precise energy requirements under diverse clinical circumstances.

What then is the evidence purporting a relation between discharge energy and body weight? In various animal species, requirements for defibrillation increase seemingly as a function of body weight.\(^1\) Rabbits weighing 2.3 kg (5 lbs) require much less energy than horses of 340 kg (750 lbs). These findings provide little information whether the smaller variability in body mass of the adult human is a pertinent determinant of energy needs for defibrillation.

The role of body weight in man in relation to requirements of electrical discharge was examined by Tacker et al.\(^2\) They retrospectively analyzed hospital records of resuscitated patients. The weights of these subjects ranged from 3.2 to 126 kg (277 lbs). They impute a relationship between weight and energy setting for defibrillation. Their data permit no such interpretation since critical information such as the nature of underlying heart disease, the duration of cardiopulmonary resuscitation and electrode placement is not provided. Their data are based on three populations: eight subjects of less than 50 kg in weight; 97 patients, varying in weight from 50 to 90 kg, only 70% of whom were reverted at the highest energy setting; and six patients weighing in excess of 90 kg, only two of whom were successfully defibrillated. The most logical conclusion, based on these limited data, is that children without coronary heart disease require less energy than a diverse group of middle-aged and elderly adults. These investigators\(^3\) also compared weights of 13 patients in whom failure to defibrillate at one energy setting was followed by success at a higher setting; this subgroup included three infants, three children, and seven adults. A straight line is drawn between these few values and this becomes the energy dosage reference per kilogram of body weight. Based on their limited data, Tacker and colleagues\(^4\) maintain that with available defibrillators one third or more of patients weighing over 50 kg cannot be reverted from ventricular fibrillation.

Clinical experience is at variance with this opinion. A recent and more detailed retrospective study showed no relation between body weight and energy requirement for defibrillation. Kerber and Sarnat,\(^9\) in studying 52 patients with ventricular fibrillation, showed that higher energy shocks per kilogram of body weight were not more effective for defibrillation and, in fact, may have actually been deleterious. They conclude that the other factors they examined such as hypoxia, acidosis and prolonged delay before defibrillation may be more important than body weight in influencing success of defibrillation. Indeed, Pantridge and coworkers\(^6\) have provided evidence in support of the contention that 400 wsec may be excessive for most patients. They found that a single 200 wsec shock reverted 73 of 82 episodes of ventricular fibrillation and a second discharge at the same setting restored sinus rhythm in an additional seven, yielding a success rate of 98%. There was no correlation between ease of reversion and body weight. The recent findings of Crampton,\(^4\) using single and repeated shocks, are quite similar. In 86 episodes of prospectively assessed ventricular fibrillation, 100–250 wsec proved consistently effective. The average energy requirement was 47% of that recommended by Tacker et al.\(^9\)

The issue of energy for defibrillation is not a trivial one.

Figure 3. Continuous trendscription record of the entire sequence of ventricular fibrillation and subsequent defibrillation. There are increasing salvos of ventricular premature beats followed by ventricular tachycardia and ventricular fibrillation. The arrow indicates the time of capacitor discharge terminating ventricular fibrillation. Defibrillation is followed by a brief asystolic period after which a 1 min period of idioventricular rhythm occurs. Sinus tachycardia supervenes thereafter.
Electrical discharge can injure even when delivered transthoracically. Such myocardial injury may prevent successful resuscitation. The decision to limit electrical discharge to 400 wsec in DC defibrillators was not an arbitrary one, but was based on the fact that even the highly damped sine wave current of the defibrillator may cause injury to cardiac and subjacent muscle resulting in ventricular arrhythmias in dogs.\textsuperscript{14, 15} The critical factor determining the occurrence of injury and arrhythmias is the energy setting. Thus while only 3\% of dogs exhibited ventricular tachycardia after a single transthoracic discharge of 100 wsec, 25\% showed arrhythmia after 200 wsec, and 65\% after 400 wsec.\textsuperscript{15} Several studies confirm these earlier observations.\textsuperscript{12, 16-19} After 10 transthoracic shocks at 400 wsec, Warner and coworkers\textsuperscript{16} found epicardial and myocardial injury and transmural necrosis. When sacrificed at 3 to 14 days, these dogs also showed fibrotic scarring and mineralization of the myocardium. DiCola and coworkers\textsuperscript{17} showed by scintigraphy that the extent of damaged tissue was directly related to the magnitude of applied energy. More recent studies have shown that morphologic, biochemical, functional, and electrophysiologic derangements occur and these are related to the level of the shock intensity.\textsuperscript{18, 19} Furthermore, use of high energies for defibrillation may result in asystole following termination of ventricular fibrillation. Such an outcome is undesirable as fibrillation may recur in the absence of resumption of a stable rhythm.

The weight of evidence indicates that presently used defibrillators have adequate energy stores for defibrillation in the clinical setting. What is required is not an increase in the potential hazard of these devices but the opposite: to define the clinical circumstances wherein lesser energies would suffice.

Acknowledgment

We wish to thank Dr. William Branch for referring the patient to us and Mrs. Claudia Kenney for her secretarial assistance.

References

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Circulation. 1978;57:827-830
doi: 10.1161/01.CIR.57.4.827

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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