Electrical energy requirements for ventricular defibrillation

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Deaths from coronary attacks constitute one of the major problems in medicine in the western world. The majority of such deaths are sudden and occur outside hospital (Bainton and Peterson, 1963; Gordon and Kannel, 1971). More than 90 per cent of sudden coronary deaths result from ventricular fibrillation (Adgey *et al.*, 1969). The prevention of ventricular fibrillation is associated with many problems. No ideal long-term oral antiarrhythmic agent is available for the patient with known coronary artery disease. Furthermore, ventricular fibrillation may be the first manifestation of ischaemic heart disease. However, in 1966, it was shown for the first time that the correction of ventricular fibrillation outside hospital is possible (Pantridge and Geddes, 1966, 1967). This led to an explosive proliferation of mobile coronary care units, particularly in the USA. Paramedical personnel operating these units concentrate on resuscitation of patients with cardiac arrest. It has become clear that involvement of the public in the technique of cardiopulmonary resuscitation is a necessary part of any pre-hospital coronary care scheme (Thompson *et al.*, 1977). Unfortunately, the limitations of cardiopulmonary resuscitation have not been sufficiently recognised. External cardiac massage and ventilation will maintain the viability of the cerebrum for 20 minutes or longer (Kouwenhoven *et al.*, 1960). However, Kouwenhoven *et al.* (1960) showed that the arterial pressure during chest compression is of the order of 80 mmHg and between compressions 10 to 20 mmHg. Thus, the mean coronary perfusion pressure is less than 70 mmHg. Even a highly sophisticated mechanical device with a duration of compression 50 per cent of cycle time will not produce a mean arterial pressure of 70 mmHg (Taylor *et al.*, 1977). A mean pressure below 70 mmHg is unlikely to be associated with perfusion of ischaemic areas of the myocardium. Thus, progression of myocardial injury may explain the inverse relation between the duration of cardiopulmonary resuscitation and the chance of survival.

Aware of the limitations of cardiopulmonary resuscitation and aiming at the immediate correction of ventricular fibrillation, Pantridge has concentrated on the development of small, inexpensive and, therefore, readily available defibrillators. In the investigation of the miniaturisation of defibrillators and in the quest for a pocket defibrillator, Pantridge considered it imperative to determine whether the 400 watt seconds stored energy currently advocated was necessary. Thus, in 1974, a prospective study of the efficacy of low energy shocks was initiated. Preliminary data indicated that 98 per cent of episodes of ventricular fibrillation might be removed by a delivered energy not greater than 165 watt seconds (Pantridge *et al.*, 1975b).

Animated controversy now exists regarding the energy requirements for successful defibrillation. The majority of workers advocate the use of the maximum stored energy of the defibrillator, usually 400 watt seconds (Green *et al.*, 1971; Dunning, 1972; Standards for Cardiopulmonary Resuscitation (CPR) and Emergency Cardiac Care (ECC), 1974; Benson *et al.*, 1975; Duggan and Barrett, 1975). The maximum energy delivered through a resistance of 50 ohms by most commercially available defibrillators varies from 270 (American Optical) to 330 watt seconds (Pantridge Portable) (Campbell *et al.*, 1977). Workers at Purdue claim that one-third of patients cannot be defibrillated by the conventional devices (Tacker *et al.*, 1974). Tacker *et al.* (1974) state that maximum energy delivered from the usually available defibrillators is inadequate to defibrillate 35 per cent or more of subjects weighing over 50 kg and ineffective in 60 per cent of patients weighing 90 to 100 kg. They, therefore, recommend that defibrillators should be capable of delivering 500 to 1000 watt seconds and presumably storing 600 to 1200 watt seconds (Ewy and Tacker, 1976). These devices would, therefore, be much larger, less portable, more expensive, and less readily available.

The recommendations of Ewy and Tacker (1976)

are not supported by the data of other workers (Pantridge *et al.*, 1975a, b; Crampton and Hunter, 1976; Kerber and Sarnat, 1977; Campbell *et al.*, 1977; DeSilva and Lown, 1978). The Belfast data which involved 394 episodes of ventricular fibrillation among 214 patients showed that shocks of 100 watt seconds stored energy were successful in 81 per cent of episodes of ventricular fibrillation (Campbell *et al.*, 1977). A single shock of 100 watt seconds stored energy succeeded in 67 per cent. Shocks of 200 watt seconds stored energy succeeded in 95 per cent and a single shock of 200 watt seconds succeeded in 85 per cent. Body weight was not related to the chance of successful defibrillation with 200 watt seconds stored energy. Among the few patients in the Belfast study who failed to be defibrillated by low energy shocks, there was not a single example of failure with 400 watt seconds stored—the maximal delivered energy was 330 watt seconds. Workers in the University of Virginia obtained similar results. Experience of 11 patients with ventricular fibrillation showed that 100 to 250 watt seconds stored energy consistently removed ventricular fibrillation (Crampton *et al.*, 1977). These workers failed to find a relation between body weight and success of defibrillation. Kerber and Sarnat (1977) were also unable to find such a relation. The lack of a relation between the energy required for defibrillation and the body weight is apparent from other reports. There are many records of successful defibrillation of heavy patients by conventional defibrillators. Ventricular fibrillation complicating acute myocardial infarction was removed in a pregnant woman weighing 108 kg by 1 shock of 300 watt seconds (Curry and Quintana, 1970). Men, weighing respectively 145, 225, and 190 kg, were defibrillated by a single shock of 400 watt seconds stored energy (Lappin, 1974; R. S. Crampton, 1978, personal communication; DeSilva and Lown, 1978).

The views of Tacker *et al.* (1974) are, therefore, directly at odds with those of other observers. This requires explanation. B. Lown and R. A. DeSilva (1978, personal communication to the Editor, *British Heart Journal*) comment that Tacker *et al.* (1974) and Geddes *et al.* (1974),

‘... demonstrated that small animals can be defibrillated with less energy than large animals. In these experiments heart weight ranged from 5 gm to 2500 gm or varied by a factor of 500. In adult man, heart weight varies at most by a factor of 4. Other determinants are of more decisive importance, such as the duration of ventricular fibrillation, the cause of fibrillation, whether primary or secondary, the presence and extent of heart disease, the concurrence of metabolic, acid base and electrolyte

derangements, electrode position, and no doubt, many other variables. The studies, therefore, have very little bearing on human adult defibrillation.’

‘Tacker *et al.* (1974) also showed in a retrospective study of 111 adults that increasing body weight was associated with decreasing success in defibrillation attempts.’

Lown and DeSilva go on to say,

‘The authors merely gathered from patient charts the notes of house-officers and correlated success or failure of defibrillation with body weight. Absolutely no information is supplied regarding the several important factors which determine the outcome of cardiac resuscitation. We did a statistical analysis of their data using the Chi-square method. This analysis showed that the relationship between success and failure as a function of body weight in the 111 patients was not significant at a 5 per cent level.’

‘The same authors also used their retrospectively collected data in 13 patients to plot an energy dosing curve as a function of body weight. A line was drawn between energy requirement in 3 infants, 3 children, and 7 adults, and from this they recommend the dose of energy should be 3.5–6.0 wsec/kg for humans. The data are inadequate for a line to be drawn between the three groups of bunched points and it is neither statistically nor logically valid. Equally disquieting is that these investigators did not employ a homogeneous population and patients differed only as regards one variable under study, namely body weight. The comparison of infants to adults is improper, for the differences between them encompass a multiplicity of cogent factors (other than body weight) which affect the ease of defibrillation.’

The controversy is of considerable importance. Apart from the disadvantages of reduced portability and availability, larger defibrillators carry the risk of cardiac damage. In experiments, increasing the energy of DC shocks was associated with increasing frequency of arrhythmias (Lown *et al.*, 1962; Gold *et al.*, 1977). The higher the energy level, the greater the amount of myocardial damage (DiCola *et al.*, 1976). Clinically, there was a direct relation between the energy used for synchronised DC conversion and the incidence of post-conversion arrhythmias and ST displacement (Resnekov and McDonald, 1967; Lown, 1978).

It has been argued that when the initial shock is of low energy, it may require to be repeated and that 2 low energy shocks cause more damage than a single shock of identical total energy. Animal experiments do not support the latter proposition. When a given amount of energy is delivered by high energy shocks, the resultant myocardial damage is

greater than when the same total energy is delivered by twice the number of low energy shocks (Pantridge, 1978).

The Belfast data do not support the proposition that defibrillators should store more than 400 watt seconds. Indeed, the data suggest that this energy level is, for the majority of patients with ventricular fibrillation, grossly excessive. Urging the FDA to prohibit the manufacture of defibrillators storing more than 400 watt seconds, Lown (1978) stated that absence of such action would result in a tragedy greater than the thalidomide catastrophe.

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