Editorial

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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 fibrilla-
tion 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 rela-
tion. 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 con-
ventional 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. Cramp-
ton, 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
men, 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 con-
currence 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 retro-
spective 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 im-
portant 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 recom-
mend 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 defibril-
lation.'

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,

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.

References


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