Section of Anæsthetics

President R W Cope FFA RCS

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Papers

Electroencephalographic Studies after Cardiorespiratory Resuscitation

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The concept of resuscitation is certainly not new, but it is only in the last few years that this phenomenon is no longer considered a miracle. An increasing number of reports appear in the popular press and in the medical literature, describing the successful re-establishment of a heart beat in somebody who seemed quite dead. At the same time, there has been an increase in the number of doctors going around with a knife in their pockets in the hope of resuscitating somebody.

The re-establishment of 'adequate' circulation and respiration, however, does not mean that clinical recovery might be complete. Although optimism may prevail after resuscitation, it is usually difficult to predict from the common clinical signs in the early stages whether a given patient is going to recover fully or whether irreversible cerebral damage has occurred.

It seems probable, as I mentioned to the Pædiatric Section of this Society (Pampiglione 1960), that the improvement in nursing and anæsthetic techniques coupled with a widespread knowledge of resuscitation techniques, might keep 'alive' an increasing number of patients with severe cerebral lesions. Resuscitation may become sufficiently common to constitute, with its sequelæ, a major problem in the organization of hospitals of any size.

The study of the electrical activity of the brain has been found helpful in the investigation of patients in particular conditions when the more usual clinical examination might present considerable difficulties.

In this connexion, I shall discuss the information obtained from systematic EEG studies in a group of 20 children resuscitated with cardiac massage in the wards or in the anæsthetic room. To this material, I shall add the neurophysiological studies of some 40 other patients, whose cerebral circulation was interrupted for a few minutes during operations on the heart and main vessels. Finally, I shall briefly mention the use of the EEG as a possible biological monitoring system of the adequacy of mechanical ventilation after resuscitation.

In all our observations the EEGs were recorded through silver-silver chloride electrodes stuck to the scalp with collodion in predetermined positions. On occasions, I have used small needle electrodes (stainless steel Lane's cleft palate needles), but these in general are unsatisfactory if the patient moves at all, because of their high contact resistance. Together with the EEGs usually recorded on 7 channels, an electrocardiogram was also recorded (lead 1) in order not to miss sudden, or gradual, changes in the function of the heart. A number of apparently minor technical details have been found relevant to obtaining satisfactory EEGs in the operating theatre or at the patient's bedside in the wards, or in the anæsthetic room. In view of the difficulties at both technical and interpretation levels, I wish to emphasize that simultaneous information must be obtained from a minimum of four to five different regions of the brain if any sense is to be made out of a method of investigation which is still in its adolescence, and is tested in strenuous conditions in emergency work of this kind.

The EEG changes during cerebral ischæmia and during alterations in venous and arterial pressure, as may often occur in cardiothoracic operations, have been described by several authors (Arfel *et al.* 1961, Pampiglione & Waterston 1961, Brazier 1961, Storm van Leeuwen *et al.* 1961, Thies-Puppel & Wiemers 1961). The recovery of cerebral function as detected by EEGs after re-establishment of circulation depends on a number of factors, amongst which the most important are the total duration of inadequate blood supply to the brain, the patient's body temperature, and the adequacy of ventilaton. As an introduction to the problem, Fig 1 shows how precarious may be the condition of the brain during intermittent cardiac massage in a child whose body temperature had been reduced to 29° C.

This child, operated on by Mr David Waterston, recovered fully. The low body temperature and the prolonged though intermittent cardiac massage saved his brain. There is little doubt that the best place to have a cardiac arrest is in the operating theatre when the chest is already open.

When, however, a patient is found pulseless in the ward or in the anæsthetic room, and is rapidly resuscitated, it is usually impossible to evaluate exactly the total duration of inadequate blood supply to his brain. In the first few hours after resuscitation, when the patient is still unconscious, the risks of respiratory difficulties, of metabolic complications and of seizures are great. The efforts and attention of the resuscitation team are heavily tested during this period and it is

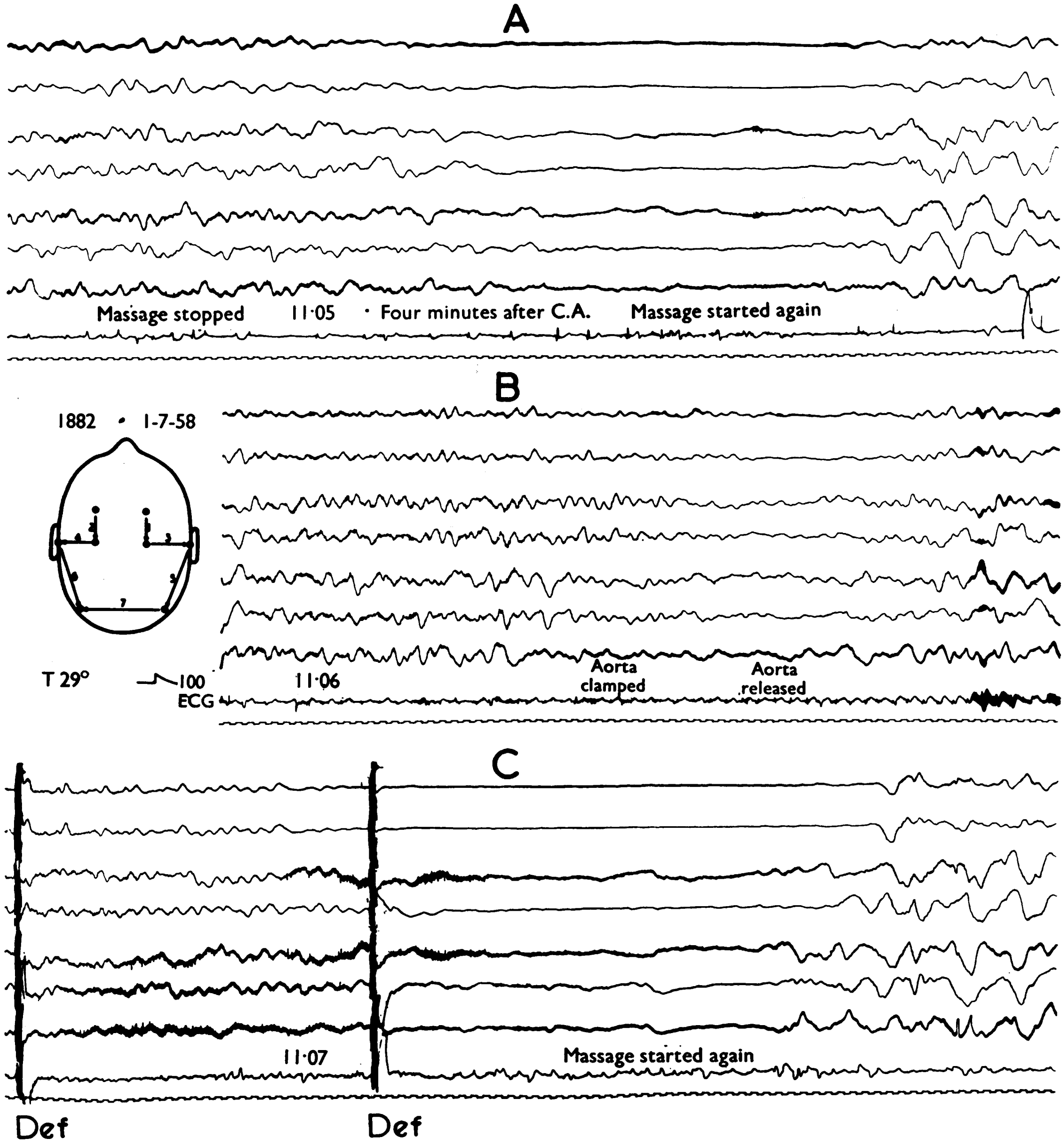

Fig 1 *During a chest operation, on a boy aged 5, a cardiac arrest occurred and cardiac massage had to be carried out for over twenty minutes. The EEG was recorded throughout from various regions of the brain* (see *head diagram*). *The 8th channel records the ECG (occasional irregular complexes and periods of ventricular fibrillation).* A, *EEG changes a few seconds after interruption of cardiac massage with flattening of the traces. Return of slow waves a few seconds after restarting the cardiac massage.* B, *similar EEG changes after a short-lived occlusion of the aorta during continued cardiac massage to ensure good flow in the coronary circulation.* C, *defibrillation* (Def) *applied twice, the first time during cardiac massage, the second time when massage had stopped; return of slow activity after restarting cerebral circulation with the cardiac massage*

particularly difficult to predict, from the clinical examination alone, either the chances of survival, or the chances of good or poor survival. The EEG studies performed early after resuscitation appeared to offer considerable help in this connexion.

Thanks to the co-operation of my colleagues at Great Ormond Street, I was notified soon after successful resuscitation at any time of day and night. The first EEG was taken in most patients two to five hours after the cardiac arrest, although in some cases the first record could begin in less than one hour and in a few others with a greater delay. The prognostic criteria derived from these early EEG observations are usually easy to apply. In our Hospital the anæsthetists are well acquainted with the information that might be obtained from the EEG in the first few hours after resuscitation (*see* Fig 2). A portable 8-channel EEG apparatus was essential as none of the patients could be moved, some being cooled and/or placed in an oxygen tent; others with their chest still incompletely closed, and others with a tracheotomy tube attached to a mechanical respirator. Subsequent EEGs were taken at intervals of hours, days, or weeks in an attempt to evaluate the course of cerebral events. The following patients have been selected to illustrate the range of cerebral complications that might be met after an apparently successful resuscitation.

Case 1 M N, male, aged 2½ (Mr Henry Sharpe's patient) This child, with a congenital stridor, had a laryngoscopy on 10.11.60 which was followed by some respiratory difficulty. The next day a tracheotomy was performed, but in the evening there were again some respiratory difficulties. At 9 p.m. a first cardiac arrest occurred, lasting probably less than one minute. The heart restarted spontaneously. Later in the night a second cardiac arrest occurred. The chest was opened and the heart restarted with direct cardiac massage.

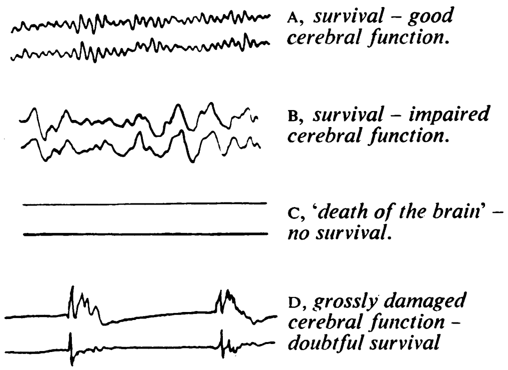

Fig 2 *Schematic and simplified comparison of EEG features* two to fifteen *hours after cardiac arrest and resuscitation in children (from 3 months to 12 years of age) in relation to the final outcome. These criteria have doubtful validity in the first hour or two.*

The patient remained unconscious with intermittent gasping, but of good colour. His body temperature was lowered to 30° C and 15 g of urea were given intravenously. The EEG was taken three hours after resuscitation (Fig 3). The child was dead by next day.

Case 2 P E, female, aged 7 (Dr R E Bonham Carter's patient), had a ventricular septal defect and was slightly backward. During cardiac catheterization on 14.11.60 there was a hæmorrhage from the femoral artery. After transfusion the child was noticed to be pulseless and the chest was soon opened. The heart restarted with cardiac massage. The EEG was taken three hours after the cardiac arrest (Fig 4), while the child was still unconscious. The moderate amount of slow activity and the considerable amount of rhythmic 6–12 c/s activity indicated that the cerebral damage, if any, was minimal. On the third day the child was well and was fairly alert, able to talk and to move her limbs. Unfortunately, a second cardiac arrest occurred a few days later and the heart then could not be restarted.

Case 3 V N, male, aged 7 months (Dr R Lightwood's

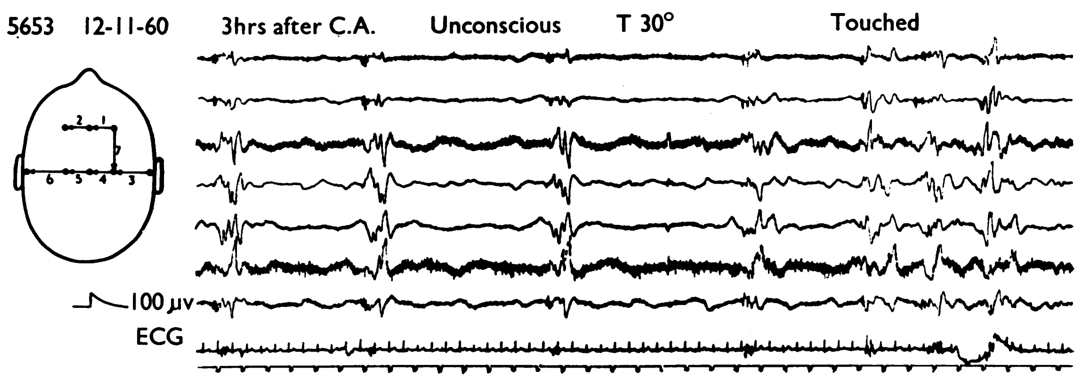

Fig 3 **Case 1** *The EEG was taken three hours after the circulatory arrest. The occurrence of large periodic irregular discharges is of bad prognosis. The child died next day. When the child was stimulated (touch) the discharges became more irregular. A considerable amount of muscle action potentials is seen superimposed upon the EEG, particularly from the electrodes in both temporal regions (channels 3 and 6). In addition,* short *bursts of muscle action potentials are seen also from the arms superimposed upon the ECG in connexion with periodic gasping movements. The movements became irregular after a tactile stimulus on the patient's lips*

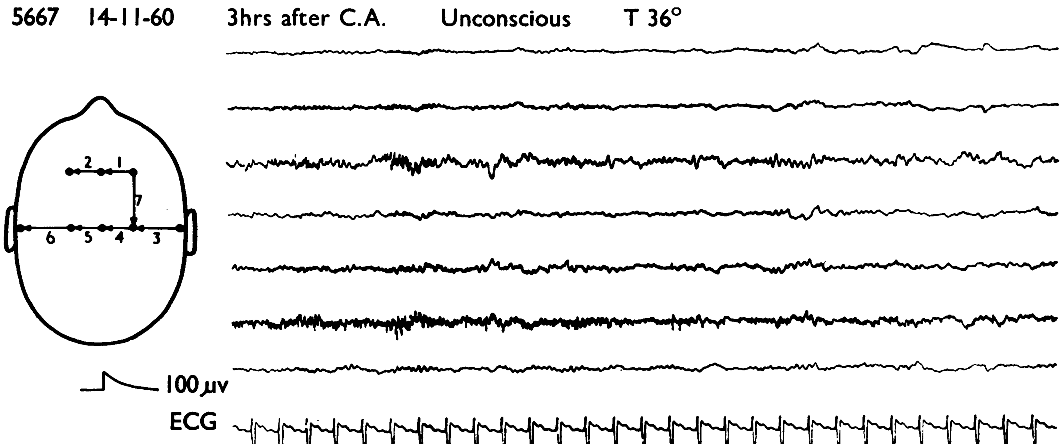

Fig 4 **Case 2** *The EEG was taken three hours after resuscitation, the patient being still unconscious with medium-sized pupils. In addition to a fairly regular 6–12 c/s activity, prolonged runs of muscle action potentials appeared superimposed upon the EEG (? shivering)*

patient) had a long history of eczema and a short history of some possible neurological illness; he had a circulatory arrest after a lumbar puncture on 11.12.61. He was promptly resuscitated, but no objective timing of the events was available. The child remained comatose and the first EEG was taken two and a half hours after resuscitation and was repeated daily (Figs 5 & 6). The child improved slightly on the third day and could breathe spontaneously. On the fourth day there was some deterioration, breathing became irregular and a chest complication became apparent. Through a tracheotomy, mechanically assisted breathing began, and we were very fortunate to have the expert opinion of Dr A Swensson, here on a short visit from Sweden. Eventually the child improved and a week later he could be disconnected from the respirator. He appeared blind and his motor control was poor, but later, vision returned. The first EEG (Fig 5), two and a half hours after the cardiac arrest, was compatible with a good chance of survival and the rapid improvement seen in a few hours suggested that the cerebral damage was only of moderate severity. From the fourth day, however, the EEG follow-up indicated a deterioration of cerebral function with an increase in irregular slow activity (Fig 6A, B). He improved on 16.12.61, but as soon as he was disconnected from the mechanical respirator, the rapid increase in slow waves in the EEG indicated the inadequacy of spontaneous breathing (Fig 6C, D). A few days later, however, the EEG pattern had improved and there were no longer any gross changes after short periods of unassisted breathing. In spite of the apparent blindness of the child, there were clearly recognizable EEG responses to visual stimulation (flashes of light) and it was very gratifying when, a few weeks later, the child's vision returned.

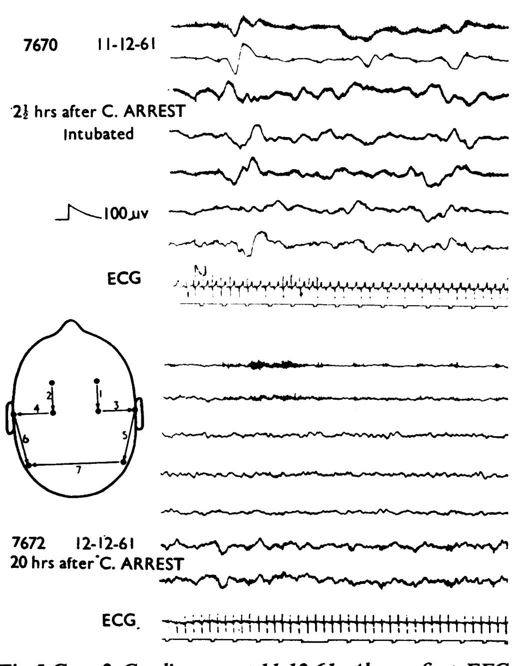

Fig 5 **Case 3** *Cardiac arrest 11.12.61. Above, first EEG taken two and a half hours after resuscitation. There is a considerable amount of slow activity but this activity is continuous and there are no discharges. Below, rapid improvement of EEG features on the next day. There is still an excess of slow activity over the posterior temporal regions*

With the exception of studies during cardiothoracic operations, there is little information in the literature about the prognostic value of *early* EEG studies after cardiorespiratory resuscitation in children. Although observations on small groups of patients (for bibliography *see* Turinese 1957 and Fischgold & Mathis 1959) have been reported, this is the first attempt at a systematic EEG study on a fairly large group of cases.

EEG changes in children are much more obvious and dramatic than in adults, but it seems

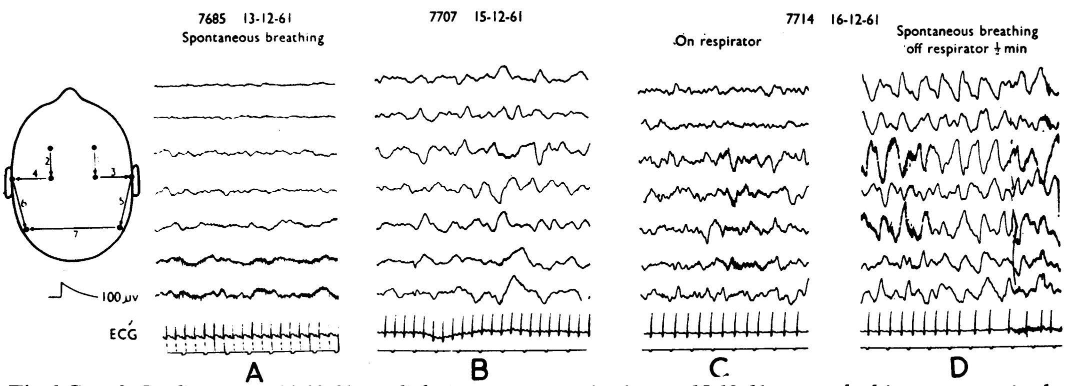

Fig 6 **Case 3** *Cardiac arrest 11.12.61.* A, *slight increase in slow activity on 13.12.61.* B, *further greater increase in the following two days, probably related to pulmonary complications. Irregular breathing required assisted respiration on 15.12.61.* C, *marked improvement in the EEG on the mechanical respirator.* D, *rapid increase in slow waves when the child was disconnected from the respirator for a forty-seconds test*

probable that careful and well-timed EEG studies would give precious information about the chances of survival, and of good survival, after cardiorespiratory resuscitation at any age. The probabilities of partial recovery of cerebral function in connexion with a variety of complications may be assessed in a way that is not possible by other methods of clinical examination.

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External Cardiac Massage

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The relative failure of open-chest cardiac massage has been the main reason for the search for a more effective method of emergency cardiac resuscitation and it was for this reason that Kouwenhoven, Jude & Knickerbocker (1960, *J. Amer. med. Ass.* **173**, 1064) introduced the method of closed-chest cardiac massage. Even with a properly organized service for open-chest cardiac resuscitation, failure is astonishingly common, even in those patients whose hearts have stopped for reasons other than cardiac disease. At the Hammersmith Hospital for the last three years there has been a Resuscitation Sub-Committee whose purpose is to organize emergency services throughout the hospital and to instruct residents, particularly those newly joining, in the methods of cardiac resuscitation. The emergency cardiac call has been used in approximately 50 cases annually since its inception and there are only 2 survivors annually by conventional methods. These figures refer only to cases outside the operating theatre.

To give more meaning to these figures cardiac arrest must be defined, for every man and woman ultimately dies from this cause.

The aim is to resuscitate patients falling into three groups: (1) Those whose hearts stop during the course of any surgical or medical operative procedure. (2) Those whose hearts stop on, or shortly after, admission to the Casualty Department. (3) Those designated by the consultant-in-charge as being a special risk.

Despite this very clear statement, the emergency cardiac call may be initiated by a nurse (perhaps a junior nurse at night) who finds a patient apparently dead and immediately summons assistance, not being willing to take on herself the responsibility of accepting death. The emergency team arrive, resuscitation is attempted, the patient is clearly suffering from cessation of heart beat and it is only when attempted resuscitation is well under way that the doctor learns that the patient is in fact 75 years of age and dying from carcinoma of the head of the pancreas, or some other terminal condition. While external cardiac massage is being performed the doctor has time to ascertain the diagnosis and the circumstances under which death has occurred and he thus avoids the trauma to himself, the nurses and the adjoining patients, of open-chest massage in the middle of a ward.

Group 1: The most favourable place to have