RESUSCITATION DURING ANÆSTHESIA AND OF THE NEWLY BORN.

By Sir Francis E. Shipway, K.C.V.O., M.D.

Senior Anaesthetist, Guy's Hospital.

(Abstract of a paper read before the Anaesthetic Section, Royal Society of Medicine).

ANÆSTHESIA is not sleep, but a state of unconsciousness brought about by the action of depressing drugs or conditions; at times there must be a danger of paralysis of the respiration and the circulation. The restoration of these vital processes is resuscitation. It must be recognised that there are desperate conditions aggravated by the shock of surgical interference which may be beyond the capacity of the anaesthetist to bring to a successful issue. But whilst this statement can be justified it must be conceded that many deaths are preventable; accidents arise partly from lack of proper knowledge of methods of resuscitation, and partly from delay in their application.

Resuscitation may be defined briefly as the restoration of the nervous and muscular activities of the body. These activities depend largely upon an adequate supply of oxygen and the removal of any excess of carbon dioxide. The exchange of gases may be interrupted in the following ways: (1) Temporary paralysis of the nervous system owing to lack of oxygen or the action of anaesthetics. (2) Paralysis of the muscles of respiration, generally secondary to paralysis of the nervous centres. (3) Failure of the circulation of the blood.

Artificial respiration will supply the needs of the nervous system and reduce the amount of the anaesthetic which is depressing the nervous centres; further, the alternate expansion and contraction of the lungs produce a mechanical effect by pumping the blood, and a respiratory reflex if the medulla
is excitable. This is the Hering-Breuer phenomenon, in which each expiration causes an inspiration.

If the medulla has been paralysed by lack of oxygen or excess of carbon dioxide this phenomenon can no longer be obtained by artificial respiration alone. This is quickly accomplished by artificial respiration combined with the administration of oxygen and of sufficient carbon dioxide to stimulate the centre.

The treatment of respiratory paralysis due to the action of drugs, volatile or non-volatile, which depress the centre is upon similar lines. If respiration has become very shallow oxygen alone is insufficient to supply the needs of the nervous system. As early as 1910 Levi used mixtures of carbon dioxide and oxygen for the purpose of stimulating the centre in cases in which the effects of anaesthetics, of operative shock, or a combination of these causes had temporarily paralysed its activity. He obtained the best results with a mixture containing 15 per cent carbon dioxide.

Henderson and Drinker, at the Centenary Meeting of the British Association for the Advancement of Science, stated that as a result of their wide experience in the resuscitation of newly born children and of persons suffering from carbon monoxide asphyxia a percentage of seven was often found to be effective when one of five had failed. In some cases a percentage of eight or even 10 was needed to stimulate an asphyxiated respiratory centre.

It is clear that for the mixture of five per cent or six per cent carbon dioxide in oxygen commonly used in this country, one containing at least seven per cent strength should be substituted, and a cylinder containing a mixture of this strength should be available in every operating theatre. Carbon dioxide, the natural stimulus of the respiratory centre, is easy to give and is more effective than artificial respiration. Further, it exerts a powerful influence upon the tonus of the skeletal muscles and thus, by augmenting the venous return to the heart, improves the circulation.

Care must be taken when using mixtures stronger than 10 per cent. A percentage of about 30 produces narcosis and death.
The importance of having available a supply of carbon dioxide was shown in my practice during an operation for the removal of tonsils. The patient was elderly and had suffered for many years from a severe degree of myocardial degeneration. During enucleation under ether and oxygen, the airway being completely free, the respiration began rapidly to fail, and the radial pulse could no longer be felt. The head was lowered and the chest squeezed, but the pupils continued to dilate. Carbon dioxide, from the portable sparklet apparatus suggested by Dr. Whitridge Davies, was then given whilst artificial respiration was continued, and almost immediately the breathing returned and the condition improved so rapidly that it was possible to complete the operation. It is highly probable that the prompt use of carbon dioxide will reduce the number of cases in which a fatal result has ensued in spite of what may be described as the more elaborate methods of resuscitation.

In children resuscitation should present no difficulties. Failure of respiration is best treated by lowering the head or partial inversion, and by rhythmical compression of the chest combined with the administration of carbon dioxide and oxygen. In the adult Sylvester's method often fails to restore respiration. It is particularly inadequate in the obese and the elderly, and it is very fatiguing if continued for more than a few minutes. Howard's method is more efficient and less fatiguing.

The prone-posture method of Schafer produces the fullest ventilation of the lungs, and is the official method of resuscitation from asphyxia due to drowning or other causes in nearly all parts of the world. Unfortunately, it is seldom applicable during an operation, as in the vast majority of cases it entails turning the patient into the prone posture, and imperils asepsis. Moreover, should it fail in restoring respiration and heart-beat, and should some form of cardiac stimulation prove to be necessary, still further delay would arise.

On the other hand, Schafer's method can be performed by one person, it removes obstruction caused by the relaxed jaw muscles and tongue, and allows free drainage of mucus or fluids which may have gained access to the air passages. Its use, therefore, should be borne in mind in the event of
acute respiratory obstruction arising under anaesthesia and dependent upon the presence of a foreign body. It is hardly necessary to point out that occasions may arise on which laryngotomy or tracheotomy may have to be performed and air forced into the lungs by inflation.

Caution must be exercised against the use of undue violence during the performance of any of these methods of artificial respiration, for many cases of fractured ribs and damage to the internal organs have been reported.

Should the heart cease to beat, attempts to revive it must be made by massage, intracardiac injection of a drug, or puncture of the auricle or ventricle. Massage has been practised for many years. Its function is to stimulate the heart muscle by creating an artificial circulation in the coronary arteries, and to supply the central nervous system with blood. The route which is commonly employed is the subdiaphragmatic, and the heart is either rubbed or kneaded. Many successful cases have been reported. Unfortunately, the majority of attempts at resuscitation by this method are unsuccessful. The route does not give good access, except perhaps in the case of the child, as only the apex is reached, and the heart tends to slip away from the hand in spite of counterpressure by the other hand upon the chest. Bost restored the heart's action, after subdiaphragmatic massage had failed, by incising the diaphragm, passing his hand into the left pleural cavity and grasping and squeezing the heart. Coleman succeeded in producing a response by this method after subdiaphragmatic massage for half an hour had failed to elicit a beat. He states that the heart "could not be grasped or moved at all through the diaphragm because it was small . . . and lying against the back of the chest wall." Norbury was unable to restore cardiac pulsation in thirteen out of a total of sixteen cases of subdiaphragmatic massage deliberately performed. On the other hand, immediate massage when the abdomen was open was quickly followed in several cases by pulsation.

The movements of the hands when the heart is directly grasped are those of compression, and not of massage; they effect two purposes, stimulation of the heart by pressure upon the nerve ganglia at the base, and the emptying of the ven-
tricles, the blood being thereby propelled with more force and efficiency than by the subdiaphragmatic method. In order to prevent pneumothorax the parts are pressed round the wrist. Levy suggests that to prevent this risk whilst artificial respiration is being carried on perfusion of the lungs should be carried out, either by intubation or by the passage of an intratracheal catheter, through which a controlled stream of oxygen is passed.

The rate of kneading or of compression should not exceed thirty or forty to the minute, as the heart usually recovers slowly in the case of an overdose, the first beats being feeble; there must be brief intermissions to allow it to recover. The first beats are, as a rule, not only feeble but irregular, and as a regular rhythm may not be established immediately, the heart should be stimulated from time to time until the beats become strong and regular. Most observers are agreed upon the necessity of continuing massage at intervals until the maximal contraction has been obtained. In a case reported by Ogilvie, massage was continued for seventy-five minutes before spontaneous beats could be obtained.

Artificial respiration must be maintained throughout until natural breathing is resumed. Success has occasionally been obtained without artificial respiration, but it is desirable to ensure the circulation of oxygenated blood.

Intracardiac injection of a drug has frequently been practised. A review of the literature reveals the fact that a correct aim is difficult: the right ventricle has often been punctured in an attempt to reach the left. Bodon and others recommend puncture in the fourth left intercostal space, close to the sternal border; the heart is most safely and easily reached by this route.

Many drugs have been used for injection—caffeine, camphor, digitalis, strychnine, strophanthin, adrenalin, pituitrin, metrazol, sodium thiosulphate. Bolton restored pulsation after cardiac arrest under ether by the injection of ether. Imerman revived an elderly patient who was moribund from insulin hypoglycaemia by the injection of a twenty per cent dextrose solution; recovery was immediate.

Adrenalin is the drug advocated strongly by the physiologists. It stimulates the muscles of the heart by its action
upon the sympathetic neuro-muscular junction. Gunn has shown that the mammalian heart, arrested by chloroform, can be restored by perfusion with adrenalin. It produces also a temporary rise in the blood pressure, which assists the recovery of the vaso-motor centre and the heart.

The injection of adrenalin has often been practised by both physicians and surgeons. It would not, however, appear to be without danger. Johnson and Siebert, repeating the work of Fleisher and Loeb, have shown that myocarditis can be produced in rabbits by intravenous injection of adrenalin. Smirnow states that histological examination of the hearts of dogs, given intravenous adrenalin during chloroform anaesthesia, showed marked destructive changes in the bundle of His. Cleghorn and also Crile state that the injection of adrenalin into a cavity or into the muscle may produce fibrillary contractions.

It would seem unwise to inject it when chloroform has been administered, owing to its tendency to cause fibrillation in the presence of this anaesthetic. In making this statement I am aware of the view advanced by Levy that adrenalin is not dangerous in the presence of deep chloroform anaesthesia, but only in the initial stages and during recovery from this anaesthetic. The experience of Jones contradicts this view; there can be no doubt that in his cases anaesthesia was of a depth which Levy has pronounced safe.

Since success has been attained with each of the drugs already mentioned, the question arises whether the result is due to the drug. There must be something more than the action of the drugs, which are numerous and widely different in their actions, which has produced a response from the arrested heart, more particularly as arrest has usually been caused by the depressant action of chloroform and the heart itself has been proved to be the seat of disease. Is it possible that this "something more" is the mechanical stimulation of the needle? Some observers have noted a movement of the needle as it entered the heart. Rodon looks upon this as a good augury of success.

Watson demonstrated in 1887 that in twenty-two out of a total of sixty experiments on dogs killed by chloroform, puncture of the heart alone was sufficient to start the beat.
Resuscitation During Anaesthesia

Hyman, acting upon the view that the success of intracardiac injection depends upon the irritant action of the needle-puncture of the heart rather than upon any specific drug action, succeeded in reviving a patient, who had collapsed during ether anaesthesia, by puncture of the ventricle after all other methods had failed. He states that the arrested heart tends to become irritable, and responds readily to any strong stimulus. The first beats are extrasystoles, which are usually succeeded by normal rhythm, but if the myocardium has suffered much damage during the period of anoxæmia, arrhythmia may persist and develop rapidly into ventricular fibrillation. He suggests that the onset of ventricular fibrillation is the explanation of a secondary collapse after successful resuscitation.

Extrasystoles arising in the auricles followed by auricular fibrillation are compatible with life. Further, the auricles are known to be more sensitive to stimulation than the ventricles. Reasoning upon these lines Hyman punctured the auricle in four cases of patients who had died from various diseases. In two the results were successful, the heart-beat being restored, in one for a period of seventeen minutes after complete standstill for nine minutes, and in the other, a case of mitral stenosis, for a period of eight days. Hyman has now collected forty-four cases in which auricular puncture has been performed. It is carried out by a curved needle inserted in the third right intercostal space, close to the sternum.

Perhaps the most weighty reason for the large number of reported failures in resuscitation generally is delay. Failure does not arise because of inability to restart the heart-beat, although this is sometimes difficult. It is known that the beat may be restored after many hours of cardiac immobility; the heart retains its irritability and excitability for a prolonged period. It was shown many years ago that the heart of a dog could be revived by massage after being placed in snow for as long as eighteen hours. Failure arises because of damage done to the cortical cells through prolonged interference with their oxygen supply. It is more than probable that if the beat has not been restored within five minutes systemic death will almost certainly occur.
British Journal of Anaesthesia

Cases of successful resuscitation after periods of apparent standstill of ten, eleven, and even fourteen minutes' duration have been reported. The time of cardiac arrest, however, is difficult to determine with exactitude; the absence of pulse and the impossibility of hearing the heart-beat do not necessarily mean that its action has ceased. Whatever the facts may be, the conclusion is irresistible that the patient must be given the benefit of the doubt, and that unnecessary delay in taking active measures to restore an effective circulation must be avoided, especially if chloroform has been used or the myocardium is known to be degenerated.

Since the restoration of activity of patients moribund from some grave condition such as toxæmia and haemorrhage seldom meets with a favourable result, there is no object in prolonging attempts in these cases.

In Petty's case of resuscitation after arrest of six and three-quarter minutes, recovery was marked by somnolence lasting twelve hours; in others, consciousness has never been regained, although respiration and circulation were restored for a considerable time. The case reported by Mollison also enforces the lesson of the danger of prolonged interference with the cerebral blood-supply. The patient, a child, recovered after a period of cessation of the heart's action of at least thirteen minutes, and probably longer, but the subsequent history showed that serious damage had been caused to the cortical cells. Mollison states that for some moments after starting cardiac massage "there was no response, then some respiratory movements began and continued intermittently; the boy's colour improved and pupils contracted . . . . still there was no attempt at heart-contraction." He suggests that this attempt at respiration was due to the slight artificial circulation produced, blood being driven to the medulla and stimulating the respiratory centre. This observation of his and a similar observation by Fisher agree with the statement of Gunn that, for the purpose of deciding whether the cells of the central nervous system are capable of complete restoration or not, the time can be calculated, not as from the start of spontaneous heart-beats, but as from the time of beginning massage. It must be remembered in this connexion that massage, to be effective, must drive blood
Resuscitation During Anaesthesia

to the central nervous system. Proof of success in this direction is given by improvement in the colour and by contraction of the pupils.

Primary circulatory arrest due to ventricular fibrillation arises occasionally during light chloroform anaesthesia. This condition is entirely different from that of overdosage; it must be recognised at once, for the treatment is simple and effective if applied at once. The only occasion on which I have seen primary cardiac syncope due to ventricular fibrillation was towards the end of an operation, and as the details of these cases are of value they are given here:

A tall, overgrown youth of eighteen had been under chloroform for about thirty minutes for an operation on his nose; the anaesthesia had been of a medium depth and uneventful, circulation and respiration being satisfactory, although not strong. Towards the end of the operation the concentration of the vapour was diminished and the anaesthetic finally stopped, to prepare the patient for the removal of his tonsils. This case occurred in the days when the opinion was held that such an operation was more safely performed under very light anaesthesia. The first tonsil was removed by the guillotine; at this stage respiration was vigorous and a strong corneal reflex was present. The guillotine was then applied to the second tonsil, but during the course of avulsion the colour, which had been good, suddenly became pale, the pupils dilated widely, and three deep respirations of a gasping character were taken. Respiration then ceased. The sequence of events, namely, sudden cardiac failure, followed rapidly by respiratory failure, was so clear that the condition was recognised. The head was immediately lowered, and the chest squeezed vigorously. The pupils soon became smaller, and recovery was prompt. Jones has reported three cases in which recovery followed very quickly upon inversion.

The outstanding feature in these cases is sudden pallor. Death is obviously not preceded by respiratory failure. The heart has failed not because it is overdosed, but because fibrillation has been produced. There is a spontaneous tendency for it to recover, but it is advisable not to wait too long for this to occur, for if the heart has become asphyxiated it can then be revived only by direct massage.
The nervous system and heart of a child apparently still-born are more resistant to lack of oxygen and excess of carbon dioxide than is the case in the adult. Its lungs resemble a solid organ, and require inflating with air. The first essential before endeavouring to resuscitate a child suffering from asphyxia neonatorum, therefore, is to clear the air passages of fluid; pulmonary respiration can then usually be established. Fluid is best removed by means of posture or by suction. Mouth-to-mouth inflation supplies sufficient oxygen and carbon dioxide if it is successful in filling the lungs with air, but it is more likely to inflate the stomach. Its use should be reserved for emergencies. Following the clearing of the air passages the treatment differs according to the type of asphyxia from which the child is suffering. If blue asphyxia is present resuscitation should be easy owing to the vigour of the circulation. As warmth increases the metabolism and excitability of the nervous system, the child should be placed in a warm bath and time given to it to start spontaneous breathing. Should this be delayed cutaneous stimulation by cold water may be practised. It is erroneous to suppose that stimulation of the skin by douching is all-important; whether the child is born in arctic or tropical regions the tendency is towards spontaneous respiration. If douching fails, or if the heart-beat becomes feeble, artificial respiration by the method of Schäfer should be started.

In the case of a child suffering from white asphyxia the circulation is failing. The hold upon life of such an infant is feeble, and extreme gentleness in handling is essential. Warmth is even more important than in the case of the blue child; gentle artificial respiration and, if it is available, the administration of a mixture of oxygen and carbon dioxide may meet with a favourable response. If these fail in establishing respiration and the pulse becomes more feeble direct stimulation of the heart by auricular puncture should be attempted.

In some cases white asphyxia is dependent not upon an injury and interference with the placental circulation during a difficult labour, but upon absorption from the mother's blood of a drug which has been used to diminish the pains of childbirth. Morphia and hyoscine are often used to induce the
condition known as twilight sleep; chloroform, also, is given frequently for a prolonged period during labour. These drugs depress the respiratory centre both of the mother and of the child, with the undeniable result that the lives of some infants are endangered, for the resuscitation of a child born under these conditions may tax to the full the resources of the practitioner and his assistant, at a time when the demands of the mother upon their services may be imperative. To meet this emergency a mixture of oxygen and carbon dioxide should always be carried, or Davies's portable carbon dioxide apparatus.

To sum up: there are many causes of respiratory and circulatory paralysis. In general, the use of carbon dioxide and oxygen both for their prevention and, combined with artificial respiration, for their treatment is to be encouraged. Partial inversion is of use in the absence of asphyxia; it should be adopted at once for the treatment of primary circulatory syncope. If the action of the heart cannot be restored by these means, puncture of the auricle followed, if necessary, by direct massage should be performed. If the abdomen is already open subdiaphragmatic massage may be carried out; if not successful within two minutes direct massage must be undertaken. Artificial respiration must be maintained throughout until natural breathing is restored.

The time-factor is all-important. Circulation must be restored within five minutes of the time of arrest.

During all attempts at resuscitation the body-temperature of the patient must be maintained.