THE MANAGEMENT OF ACUTE HYPOXIA¹

GORDON M. WYANT, F.F.A.R.C.S.

ACUTE HYPOXIA may develop in a large variety of medical and surgical conditions. It may range from relatively mild or short-lasting episodes to the ultimate in severity as exemplified by ventricular fibrillation and cardiac standstill. The subject of acute hypoxia has been dealt with extensively in the literature, but the main emphasis usually has been laid on cardiac arrest. Yet, any condition or event, affecting *either* respiration *or* circulation *or* both, which acutely leads to suboxygenation of tissues constitutes acute hypoxia.

While it can be readily appreciated that the diverse causes of acute hypoxia and their combination are legion, it is equally clear that, either because of the mild degree or because of extremely short duration, obvious clinical signs and sequelae may be entirely absent or at least they cannot be detected with the diagnostic means at our disposal. Hence, from a practical point of view, such hypoxic events are of little significance.

On the other hand, cardiac arrest is by no means the only acute hypoxic episode in which sequelae of hypoxia are present and need vigorous treatment. All too often treatment for one of the less dramatic hypoxic events is not instituted and the fact is accepted that the patient will regain consciousness less promptly than might be expected otherwise, that he will be confused, nauseated, or restless. This applies equally to anaesthesia, diverse states of unconsciousness, and hypoxia not associated with coma. It behoves us then in all cases of acute hypoxia to weigh the severity and duration of the event and decide whether for a particular patient under the particular circumstances prevailing the hypoxia was severe enough in degree and duration to merit active treatment.

An attempt will be made to describe the management of severe hypoxia.

TREATMENT

(a) It is a general principle that whenever an untoward reaction occurs from whatever cause, the first step must be to correct that cause if it is known. This same principle applies to the management of acute hypoxia. If at all possible the aetiological factor responsible for the hypoxia must be identified and corrected and a determined effort must be made to provide adequate tissue oxygenation.

(b) Because of its great intolerance to deprivation of oxygen, the central nervous system, and in particular the brain, present the most formidable obstacle to satisfactory recovery from acute hypoxia. The crudeness of our tests prevents us from ascertaining minor degrees of cerebral impairment while in extreme cases

¹From the Department of Anaesthesia, University of Saskatchewan and University Hospital, Saskatoon, Sask. Presented at the Meeting of the Western Divisions, Canadian Anaesthetists' Society at Victoria, B.C., April 28-30, 1960.

the clinical picture is one of coma, convulsions, periodic breathing or complete apnoea. Between these two extremes all grades of intermediate stages exist.

It must be accepted as axiomatic that "nervous tissue once destroyed does not regenerate and cannot resume function." Hence, depending upon the duration and severity of the hypoxic episode, there will be a degree of morphological damage which is irreparable. This in itself may be sufficient to cause death or irreversible coma, leading ultimately to a fatal outcome.

Just as oedema will occur anywhere in the body where hypoxia has interfered with tissue integrity, so also will cerebral oedema supervene if the brain has been exposed to abnormally low oxygen tensions. Indeed the brain is more likely to be affected by oedema since it reacts in this fashion to a slightest insult. While in many parts of the body, with the exception of the lungs, the oedematous reaction is of little immediate consequence, it is of grave significance when it affects the brain. This is largely due to the fact that the organ is enclosed in a bony casing and once displacement of cerebral spinal fluid has allowed for maximum expansion the organ then becomes compressed upon itself. This places the brain into triple jeopardy. First, the blood supply is impeded through external compression of the cerebral vascular bed; second, nerve cells are mechanically compressed; and third, gas exchange between capillaries and cells is impeded through the interposition of oedema fluid.

It is reasonable to assume that, while some cells or groups of cells have been damaged beyond repair and others are entirely unaffected, there will be some nervous elements which have not been sufficiently injured by hypoxia to cause their immediate death and under proper management may be able to recover. However, the recurrence of a restricted oxygen supply may be sufficient to inflict a final insult upon these elements, converting reversible into irreversible damage. In this way a vicious cycle of hypoxia, oedema, more hypoxia is initiated and this will continue, unless treated, despite the fact that the original hypoxic episode may have been brought under complete control. Thus originally limited damage may assume fatal proportions at a time when it would appear that the crisis has passed.

In 1953, Sadove *et al.* (1) described their concept of a "dehydration therapy" which had been worked out by that group. They had found that the administration of hypertonic 50 per cent dextrose solution did in fact accelerate the waking-up process of patients who had been in cardiac arrest. However, they found that this state was not a permanent one, and that "rebound oedema" usually caused some regression in the state of consciousness following initial improvement. They were able by repeated administrations to maintain consciousness and obtain a high percentage of recoveries.

The basic concept of reducing cerebral oedema by the administration of hypertonic solutions is not new. Following the work of Weed and McKibben (2) as early as 1919, many attempts have been made to reduce intracranial pressure by use of hypertonic solutions. Among the agents tested at one time or another were sodium chloride, sodium sulphate, sodium bicarbonate, magnesium sulphate, sucrose, dextrose, and others. While sodium chloride and 50 per cent dextrose are followed by the so-called "rebound oedema," 50 per cent sucrose which does

not show rebound oedema to the same degree is more damaging to renal function. In later years, quadruple concentrated plasma, plasma volume expanders, in particular high molecular-weight dextran, and serum albumin were added to the list of substances capable of influencing brain oedema. With all these agents adequate kidney function was maintained by the administration of diuretics while recurrence of the oedema was further prevented by rigid control of fluid and electrolyte administration, the correct balance of which in turn depended upon adequate and well-controlled renal function.

The introduction of *urea* in a clinically useful solution for parenteral administration has revolutionized the treatment of cerebral oedema. It had been found in 1927 that urea was effective in reducing cerebral spinal fluid pressure in animals (3, 4), but it was not until 1956 that Javid and Settlage (5) first reported on its effect on cerebral spinal fluid pressure in man. However, one disadvantage of the parenteral administration of urea was the occasional occurrence of haemoglobinuria. Only recently has this difficulty been overcome by the preparation of lyophilized urea dissolved in invert sugar. This agent has the added advantage of being a diuretic in its own right. Anyone who has observed the effect of this therapy in neurosurgical procedures must be impressed by its performance.

(c) A further valuable adjunct to the management of the sequelae of acute hypoxia is *hypothermia*. There are three basic reasons for its efficacy. One is the reduction of the tissue oxygen demand and thus the provision of further protection of partially damaged brain cells; secondly, hypothermia assists in the control of cerebral oedema and, lastly, it controls the hyperpyrexia so often associated with severe brain damage. Cooling may be done by any of the accepted methods and a temperature of between 30 and 32° C. is aimed at. It is, of course, important that shivering be controlled and that both the body temperature and the electrocardiogram be continuously monitored. Oesophageal temperature readings are preferable to rectal temperatures.

If prolonged maintenance of hypothermia is needed an attempt might be made to maintain the lowered temperature by the use of fans or, if available, in a cold-room. There are some definite nursing difficulties, especially with regard to skin care, when the patient is maintained in hypothermia blankets for any length of time.

(d) As in all cases of coma, meticulous attention must be paid to the airway and to adequate tidal exchange. Repeated tracheobronchial toilet is mandatory and, if necessary, artificial respiration is carried out by means of a mechanical ventilator or inadequate spontaneous respiration is assisted using an assistor. If coma is prolonged beyond 24 hours, tracheostomy should be considered.

(e) Vital signs are continuously monitored and treatment for cardiovascular embarrassment is symptomatic. Digitalization may be required, the electrolyte balance must be maintained in the presence of a regime of dehydration and an adequate caloric intake must be assured. An indwelling catheter serves as a means of observing and recording urinary output. Antibiotics are administered prophylactically. If the coma is prolonged beyond a few days tube feeding may have to be instituted.

(f) If hypoxia has not resulted in coma but only in post-hypoxic restlessness

as is seen not infrequently in the immediate postoperative period, this must not be interpreted as a manifestation of pain. Hence, narcotics are not indicated in the majority of cases. In these instances it is well to administer high concentrations of oxygen, check tidal and minute volumes, and remember the possibility of diffusion hypoxia. Assistors may again be indicated.

PROGNOSIS

In all cases of very severe and prolonged hypoxia the prognosis should be guarded. Following cardiac arrest, in particular, it is most unrewarding to prognosticate. However, three groups of observations can be of assistance in this regard.

(a) *Electroencephalogram*. If following severe hypoxia no electroencephalographic activity is discernible, the prognosis is grave indeed. On the other hand the presence of electroencephalographic activity does not assure recovery.

(b) *Respiration*. If following a severe hypoxic episode respiration ceases and does not resume within half an hour or thereabouts, the outlook is again grave. Patients whose respiration has never ceased have a much better prognosis.

(c) *Cardiovascular function*. The outlook is grave if cardiovascular function cannot be maintained and if prolonged intractable hypotension ensues.

However, it is important to emphasize once again that these signs are guides only and are not of absolute prognostic value.

SUMMARY

The management of acute hypoxia in its more severe forms is based primarily upon the control of cerebral oedema. With the advent of a clinically useful form of urea, all agents previously employed for this purpose have become obsolete. The control of cerebral oedema shortens coma and increases survival. Hypothermia is a further valuable adjunct which supplements the action of urea, reduces oxygen demand by injured tissues, and controls hyperpyrexia. In all other regards the management of the patient, unconscious from hypoxia, is identical to that which applies generally to the care of the unconscious patient. If hypoxia has not resulted in coma, care must be taken to interpret correctly post-hypoxic restlessness, and depressant drugs must be avoided.

The prognosis should always be guarded. The electroencephalogram is a valuable aid in assessing the extent of cerebral impairment. Early resumption of spontaneous respiration and stability of cardiovascular function in the post-hypoxic period are favourable signs, but are not of absolute prognostic value.

RÉSUMÉ

L'hypoxie aiguë peut survenir dans une grande variété de cas de médecine ou de chirurgie et cela ne se limite pas aux cas où il s'est produit un arrêt complet de la circulation.

Le traitement efficace de l'hypoxie aiguë tient, pour une grande part, au

contrôle de l'œdème cérébral. Ce contrôle est devenu plus facile grâce à l'apparition de l'urée qui, en même temps, a apporté plus de sécurité et permet de prévoir les résultats. L'œdème cérébral, après que la crise aiguë d'hypoxie a été vaincue, cause des dommages cérébraux additionnels et, ainsi, il peut rendre irréversibles des lésions qui étaient réversibles.

Un autre précieux adjuvant dans le traitement de l'hypoxie aiguë est l'hypothermie. Non seulement l'hypothermie aide à contrôler l'œdème cérébral mais elle réduit en plus la demande d'oxygène de la part du cerveau et elle prévient l'hyperpyrexie.

Les malades qui demeurent comateux doivent être traités par ailleurs de la même manière que le sont tous les malades inconscients. En d'autres termes, il faut leur assurer une fonction respiratoire adéquate, supporter leur système cardiovasculaire et, si nécessaire, contrôler leur équilibre hydrique et électrolytique; il faut alimenter ces malades soit par tubes, soit par voie parentérale.

Il peut arriver qu'un malade ne soit pas comateux à la suite d'une hypoxie aiguë, mais qu'il demeure agité. Cette situation commande une oxygénation adéquate et, peut-être, une respiration assistée plutôt que des narcotiques et des sédatifs qui seraient susceptibles d'accroître l'agitation et de déprimer la respiration.

L'électroencéphalogramme, en ces circonstances, peut devenir précieux pour établir un pronostic. Si l'apnée persiste ou si l'hypotension n'est pas corrigible, le pronostic est mauvais. Toutefois, aucun de ces signes ne peut prendre une valeur absolue de pronostic et ils ne peuvent servir que comme indices de l'issue probable.

REFERENCES

1. SADOVE, M. S., WYANT, G. M., & GITTELSON, L. A. The Acute Hypoxic Episode. *Brit. Med. J.* *II*: 255-257 (Aug. 11, 1953).
2. WEED, L. H., & MCKIBBEN, P. S. Pressure Changes in the Cerebrospinal Fluid following Intravenous Injection of Solutions of Various Concentrations. *Am. J. Physiol.* *48*: 512-530 (May, 1919).
3. FREMONT-SMITH, F., & FORBES, H. S. Intra-ocular and Intracranial Pressure: Experimental Study. *Arch. Neurol. & Psychiat.* *18*: 550-564 (Oct., 1927).
4. WOLFF, H. G., & FORBES, H. S. Cerebral Circulation: IV, Action of Hypertonic Solutions. *Arch. Neurol. & Psychiat.* *20*: 73-83 (July, 1928).
5. JAVID, M., & SETTLAGE, P. Effect of Urea on Cerebrospinal Fluid Pressure in Human Subjects: Preliminary Report. *J.A.M.A.* *160*: 943-949 (March 17, 1956).