be done by air, and he made a transit of 9,850 miles by this means. A year later, except for a little weakness, he was keeping reasonably well.

Case 29.—A girl of 19 was first seen in 1949, when she had an extensive rheumatic heart disease. The history suggested the possibility of pericarditis 18 months previously, and physical examination showed very great enlargement of the heart, auricular fibrillation, and systolic and diastolic murmurs at the apex. Broadbent's sign was positive in the interspaces behind on the left. The *x*-ray film (Fig. 3) showed that the heart was enormous; the transverse diameter of the chest was 23.5 cm. and that of the heart, by orthodiagraph, was 19.5 cm. In spite of the extent of organic change she has remained symptomatically remarkably well, and flew with her father from San Francisco to Australia via the Philippines without symptoms. In recent years she has flown more than 13,000 miles.

Case 30.—A woman aged 41 with mitral stenosis, normal rhythm, and pulmonary hypertension had had increasing shortness of breath with several attacks of severe paroxysmal dyspnoea before her journey from Singapore to London. She was found to have a severe degree of narrowing, the mitral orifice measuring 1.5 by 0.5 cm. at the time of operation. She has now returned to her home in the Far East.

Comment

These examples from many different varieties of cases of organic heart disease would seem to show that flying is perfectly safe when the heart is well compensated, and that it is a reasonable risk in patients whose state of compensation is not perfect, provided that the journey is necessary, or provided it is of such personal importance to the patient that he is prepared to take what can accurately be described as a very moderate risk. Generalizations as to suitability or unsuitability for flying cannot be made. Every case must be considered on its merits.

This opinion is confirmed by figures obtained from a recent survey carried out by the Medical Committee of the International Air Transport Association, which includes figures from 13 different air lines. It seems that on a five-year average one cardiac death has occurred per 1,113,000 passengers carried, and that one cardiac death has occurred per 800,000,000 passenger miles.

Conclusions

Thirty individuals, all with organic cardiovascular disease, are shown to have been able to undertake journeys by air successfully. They comprised most of the common varieties of severe organic heart diseases. In all cases the state of cardiac compensation was good at the time of flying, and in no patient did such air travel deleteriously affect the heart or the hypertension, either at the time or subsequently.

Adequate pressurization of the aeroplane must be assured in such cases. This point must be confirmed with the airport officials as an essential preliminary.

The benefit of the short air journey must be set against the disadvantage of the longer sea transit in such patients as may require to be in close contact with specialized medical care for therapeutic or other purposes, and who yet need, perhaps for personal reasons, to make a long journey.

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The establishment of the "American College of Angiology" is announced. This new organization has been formed by physicians and surgeons interested in diseases of the blood vessels. The College, whose official journal will be *Angiology*, is "dedicated to the teaching, research, and dissemination of knowledge concerned with the science and practice of angiology."

GASES ADMINISTERED IN ARTIFICIAL RESPIRATION

WITH PARTICULAR REFERENCE TO THE USE OF CARBON DIOXIDE

A Report to the Medical Research Council by its Committee* for Research on Breathing Apparatus for Protection against Dangerous Fumes and Gases

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John Hunter suggested, in 1776, that inflation of the lungs with oxygen would be a valuable procedure in resuscitation. In 1780 Chaussier (see Hahn, 1899) administered oxygen in asphyxia of the newborn and later devised a laryngeal tube for this purpose. Early in the present century oxygen was being used increasingly in attempted resuscitation. However, in 1920, Henderson and Haggard reported that 90% oxygen and 10% carbon dioxide caused more rapid elimination of carbon monoxide in experiments on dogs. In later papers they recommended a mixture of 95% oxygen and 5% carbon dioxide for carbon monoxide poisoning, ether or alcohol intoxication, or for respiratory failure due to any cause. These workers also made a great contribution by persuading the authorities concerned that there was no efficient apparatus generally available for the administration of oxygen or other gases and that there was an urgent need for portable apparatus with properly fitting masks. Nicloux *et al.* (1925), Walton *et al.* (1926), and other workers could not confirm the great increase of carbon monoxide elimination with added carbon dioxide reported by Henderson and Haggard, and continued to support the use of pure oxygen only. Nevertheless, mixtures containing carbon dioxide were adopted almost universally for use in resuscitation.

Since this time evidence has accumulated against the use of carbon dioxide for this purpose, and recently the Medical Research Council Committee for Research on Breathing Apparatus for Protection against Dangerous Fumes and Gases recommended (unpublished memorandum) that, in first-aid practice, pure oxygen and not oxygen and carbon dioxide (carbogen) be administered to persons suffering from respiratory failure or respiratory depression and requiring manual artificial respiration. This recommendation was stated in simple terms, and it is now considered desirable that the reasons for abandoning "carbogen" should be given in greater detail. It is to be emphasized that the recommendation applies only to the resuscitation of subjects suffering from respiratory depression or failure and requiring immediate manual artificial respiration.

The urgent decision on whether artificial respiration is required may be very difficult. It is often hard to assess the degree of respiratory failure by looking at the movements of the chest or the colour of the patient.

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First-aid workers rightly err on the side of safety, and artificial respiration may be given to patients who are not in respiratory failure.

Causes of Respiratory Failure

The various types of respiratory failure seen by first-aid workers are as follows :

1. There are those persons who have become unable to ventilate their lungs because of drowning, asphyxiation, or strangulation and are suffering from severe oxygen lack and carbon dioxide retention.

2. There are those subjects who have been breathing an atmosphere deficient in oxygen and who have been able to increase their ventilation in response to increasing anoxaemia, thus washing out a considerable amount of carbon dioxide. However, in any dangerous atmosphere, anoxia will subsequently cause central respiratory depression, and these subjects will ultimately suffer from reduced ventilation and carbon dioxide retention.

3. There are those patients who have been able to ventilate their lungs freely with air but are rendered anoxaemic by the combination of haemoglobin with carbon monoxide, with resultant interference with oxygen transport. Animal experiments show that so long as the impaired oxygen transport has not caused respiratory depression there is little immediate danger (Schwerma *et al.*, 1948). But when respiratory failure supervenes, even the limited amount of available haemoglobin will no longer be oxygenated and very grave anoxaemia will occur. It is the first-aid treatment of such subjects requiring artificial respiration which is being considered here. The further treatment of surviving patients after first aid presents a special problem in so far as they may still have large quantities of carboxyhaemoglobin in the blood.

4. There are those persons who have been exposed to irritating gases and have developed pulmonary oedema. Cases of drowning may also have pulmonary oedema as well as water in the lungs. In such instances alveolar ventilation is grossly disturbed, and, added to this, the transfer of oxygen across the pulmonary membrane is impaired.

5. There are those subjects in whom electric shock or gaseous, volatile, or ingested poisons have caused acute central respiratory failure with consequent oxygen lack and carbon dioxide retention in an otherwise normal environment.

In all these instances there is cessation or severe depression of respiration, and urgent danger of permanent asphyxial damage to the vital centres even when the patients are returned to a normal environment. Unless artificial respiration is started very quickly they will die. (It is assumed in this discussion that irreversible circulatory failure has not occurred.) It must be emphasized here that it is *immediate* artificial respiration that is the major life-saving procedure ; and that if it is efficiently carried out it will save many lives whether air or oxygen is breathed. The administration of oxygen is a most important ancillary measure, and it is useful to discuss the advantages so obtained before considering the use of carbon dioxide.

Advantages of Oxygen Therapy in Resuscitation

In general terms, the immediate danger is the death or irreparable damage of vital structures (the medullary centres, brain, and myocardium) from lack of oxygen. Even the smallest rises of oxygen tension in the lungs and body must therefore have a favourable effect in the few critical minutes during which the damage may become irreversible.

The efficient distribution of the inspired air to the alveoli may be impaired by secretions, exudates, haemorrhages, or fluid in the air passages and air spaces. Further, the abnormal air movement in and out of the lungs produced by artificial respiration appears to cause serious deficiencies of the proper distribution of inspired air to the individual alveoli ; and oxygenation of blood flowing through the lungs may be subnormal even when normal or greater than normal ventilation is being induced (Gordon, Prec, *et al.*, 1951). The administration of high tensions of oxygen will go far to overcome the effects of poor gas distribution and to ensure that blood passing through the alveoli will be adequately oxygenated.

If there is oedema fluid in the alveoli or alveolar walls, then there will be considerable interference with the diffusion of oxygen from the alveoli to the venous blood flowing through the alveolar capillaries. The administration of oxygen will greatly increase the oxygen diffusion gradient, with resultant improvement in the transfer of oxygen to the blood.

Even if distribution and diffusion are not greatly impaired there will be a small but significant increase in the oxygen actually dissolved in the blood which will increase the initial oxygen diffusion gradient to the tissues. Although this effect cannot be great, it may turn the tide in favour of the survival of vital structures in the early critical moments of resuscitation. An extreme example of how small a quantity of oxygen may decide between death and survival is seen in Brucer and Swann's work (1950) on asphyxiated dogs, where 2% oxygen in nitrogen prevented the death of these dogs in the critical period following asphyxia.

In carbon monoxide poisoning, in view of the danger of anoxic brain damage even without respiratory failure, the administration of oxygen is often as urgent a necessity as artificial respiration. A further advantage of the increased tension of oxygen in the blood is that it will favour the dissociation of carboxyhaemoglobin.

The advantages of giving oxygen during resuscitation by artificial respiration are thus unqualified.

Carbon Dioxide Therapy in Resuscitation

Although carbon dioxide has been given with oxygen to subjects with respiratory failure during the last 30 years, there has been a great deal of uncritical thought concerning the use of this gas, and an attempt needs to be made to define with greater care the physiological situation involved. The main problem under consideration is whether the administration of additional carbon dioxide to persons with respiratory failure, who are being artificially ventilated, has any stimulant or other desirable effects.

The most straightforward view is that these subjects are suffering not only from profound anoxaemia but also from carbon dioxide retention ; that artificial respiration is instituted to ensure normal or high oxygen tensions in the lungs and to remove both the excess carbon dioxide and that being produced by body metabolism ; and that additional carbon dioxide is unnecessary because of the excess already present.

But this view has been questioned. It has been claimed that persons suffering from respiratory failure may have low body tensions of carbon dioxide and that this gas should therefore be administered to such cases. However, this has never been demonstrated under first-aid conditions, and it is clear that any subject who has remained capable of maintaining such efficient ventilation that it causes a lowering of the body pCO_2 is not in respiratory failure. Further, the postulated syndrome of respiratory failure with low levels of carbon dioxide in the living body, in which metabolism continues, implies the removal of carbon dioxide without breathing. There is, however, the remote theoretical possibility that the body metabolism and carbon dioxide production are so immediately and greatly reduced under extremely anoxaemic conditions that complete respiratory failure and abnormally low carbon dioxide levels can occur simultaneously. Reliable and precise evidence on this point is not available in the human subject, but clinical research has always shown normal oxygen uptakes and carbon dioxide production during fairly severe anoxaemia (Donald *et al.*, 1952).

Grodins *et al.* (1946) have studied this point with some care in dogs in which asphyxia was produced by tracheal obstruction or by the inhalation of nitrogen. In the former case an early respiratory acidosis was reinforced by a severe metabolic acidosis, such that, by the time the circulation failed, the arterial pCO_2 was 65 mm. Hg (control value in this series, 36 mm. Hg). In fatal nitrogen asphyxia the early respiratory alkalosis, due to hyperventilation before

respiratory failure, was overcome by a later respiratory and metabolic acidosis, so that both the arterial blood acidity and carbon dioxide tensions were above normal when circulation failed. Another important finding was that, if artificial respiration with air at the animal's control ventilatory volumes was then begun, the arterial pCO_2 and hydrogen-ion concentration continued to *rise* until spontaneous respiration was resumed. This effect was attributed by these workers to the oxygenation of the haemoglobin releasing carbon dioxide, to the sweeping of metabolic acid products formed during asphyxia in the now restored circulation, and to the resumption of normal aerobic carbon dioxide production. They also showed that, on resumption of spontaneous breathing, hyperventilation occurred in an attempt to lower the pCO_2 and compensate the metabolic acidosis.

Summarizing, the theoretical possibility of such severe and immediate depression of metabolism by anoxia that low carbon dioxide levels could occur with anoxic respiratory failure was not substantiated. Low carbon dioxide levels were found only during hyperventilation due to anoxia before respiratory failure had occurred. After anoxic respiratory failure there was an increase of body pCO_2 and metabolic acidosis even in those animals which had previously hyperventilated considerably. When the respiratory centre recovered, as a result of oxygenation following artificial respiration, it was then able to respond to the increased concentrations of carbon dioxide and hydrogen ions which were already present in the body.

It is not definitely stated by those who advise the use of carbon dioxide in resuscitation whether they wish to induce a rise of the body pCO_2 or not, but one must presume this to be their aim. If this is so, then, if oxygen is available, one could ensure adequate oxygenation and a rise of body pCO_2 by deliberately maintaining low ventilatory volumes; the administration of exogenous carbon dioxide would thus be unnecessary. It is well known that artificial respiration under various circumstances may fail to achieve adequate pulmonary ventilation (Gordon, Affeldt, *et al.*, 1951; Nims *et al.*, 1951), and it is certain that further carbon dioxide retention occurs in many subjects receiving artificial ventilation and breathing only air or pure oxygen.

When a subject receiving artificial ventilation is given added carbon dioxide to the oxygen being administered the following events occur. The addition of 5–7% carbon dioxide to the inspired gas without any simultaneous increase in ventilatory volumes will cause an almost immediate rise of the pCO_2 in the alveoli of the same order—that is, with 5–7% carbon dioxide=36–50 mm. Hg) (Fenn *et al.*, 1946). In those subjects who are receiving adequate ventilation to begin with, the initial alveolar pCO_2 would be about 40 mm. Hg (5.5%). Thus the alveolar pCO_2 will rise to 76–90 mm. Hg (10.6–12.6%). If the subject is not being adequately ventilated or is still suffering from gaseous acidosis, then the alveolar pCO_2 will rise to far higher figures (15–25%). The arterial pCO_2 and that in the well-circulated organs, including the central nervous system, will also rise to these levels. Evidence is presented that such tensions in the body, particularly in subjects who have suffered nearly fatal anoxaemia, so far from being beneficial, are in fact harmful.

The advocates of carbon dioxide administration may argue that the artificial ventilation should be appropriately increased to avoid an undesirable rise of carbon dioxide tension in the body. The simultaneous administration and vigorous removal of a therapeutic agent is treatment reduced to absurdity. It has been suggested that enough carbon dioxide should be given with the oxygen so that with carefully judged artificial ventilation there is a "slight" rise of pCO_2 which will act as a "respiratory tonic." Granting this was desirable, it would be most difficult to achieve even by a team of respiratory experts with all the aids of modern science, and certainly impossible in first-aid conditions.

From all these considerations it is evident that the administration of carbon dioxide under first-aid conditions to a subject in respiratory failure who is receiving artificial respiration is an uncertain and uncontrolled form of therapy with grave risk of high and dangerous tensions of carbon dioxide being induced in the subject.

Possible Dangers of Overventilation

It has been argued that efficient artificial ventilation may wash out such large quantities of carbon dioxide that it causes a depression of the body pCO_2 to below normal levels (acarbia), and that carbon dioxide should be administered to counteract this. Overventilation can certainly occur with mechanical respirators of the Drinker type. It has also been reported in patients with severe poliomyelitis under treatment, but there are always several important factors contributing to these sustained high ventilatory volumes—muscular paralysis, tracheotomy with intubation, and air or oxygen given at positive pressure (Astrup *et al.*, 1954). Indeed, the assisted respiration in such cases is very similar to the "controlled" respiration used in modern anaesthesia.

However, overventilation is most unlikely to occur for any period when manual methods of artificial respiration are used under first-aid conditions on unconscious persons who have been rescued from nearly fatal asphyxia and who not only have severe carbon dioxide retention but may also have some degree of respiratory obstruction and other lung damage. Nims *et al.* (1951), who studied the very effective "push-pull" methods, strongly support this view, and emphasize that the high ventilatory volumes obtained cannot be maintained for very long periods under first-aid conditions. Further, even if overventilation occurred occasionally, there can be no doubt that such efficient washing out of carbon dioxide would be too unusual to warrant the administration of carbon dioxide to raise the body pCO_2 in *all* cases. Even if such instances could be diagnosed, and carbon dioxide given, then a gaseous acidosis would be rapidly induced unless the volumes being ventilated were even further increased—an improbable event under first-aid conditions.

Finally, it may be pointed out that if a patient is "acarbic" while receiving artificial ventilation the resulting lack of respiratory stimulus will have no significant effect on the volumes being artificially ventilated or on the oxygenation of the blood, and the cessation of artificial respiration for a short time will cause the alveolar and arterial pCO_2 to rise to stimulating levels. There is no evidence that a period of low body pCO_2 will cause any damage to the centre, or any other part of the body, provided that oxygenation is adequate, and, in the presence of continued metabolism, such a state of affairs can only be short-lived under first-aid conditions. It is underventilation that is the main danger in resuscitation.

Carbon Dioxide as a Respiratory Stimulant

Although it has been shown that the administration of carbon dioxide during artificial respiration is an uncontrolled and uncertain form of therapy, it is still important to consider whether an induced rise in body carbon dioxide will increase the likelihood and degree of spontaneous activity of the respiratory centre. The effect of increased levels of carbon dioxide on humans or animals in respiratory failure not being artificially ventilated must therefore be reviewed.

If a normal subject is given 5% carbon dioxide then his respiratory centre will increase its activity, with a resultant increase in ventilation that will maintain nearly normal tensions of carbon dioxide in the lungs and body. Thus, although there is an increase of activity of the centre, it is a defensive increase and there is no evidence that it improves the condition of the centre or organism. It merely avoids an undesirable gaseous acidosis. This increase of normal respiratory activity due to carbon dioxide is loosely termed "stimulation." Stimulation is a vague term which has erroneously implied, to many people, that the exhibition of carbon dioxide will cause an increase of viability or efficiency of a failed or failing respiratory centre under all

circumstances. Yet it has long been known that the depressed respiratory centre becomes less and less able to respond, or actually incapable of response, to increased tensions of carbon dioxide. Many physiologists assess the degree of depression of the centre by drugs (such as ether, chloroform, morphine, pentobarbitone, chloralose, urethane, cyclopropane, polamidone, and pethidine) by the diminution of this response (Trevan and Boock, 1921; Schmidt, 1924; Dripps, 1947; Wang and Nims, 1948; Remy, 1950). The administration of carbon dioxide to a person with respiratory depression who is not being artificially ventilated will therefore inevitably result in further carbon dioxide retention.

In experiments on the effect of these increased tensions of carbon dioxide in respiratory failure, Schmidt (1924) showed that the administration of carbon dioxide to dogs with respiratory depression due to morphine and heroin actually reduced their minute-volume in many instances. Frequently carbon dioxide inhalation was followed by permanent respiratory failure even in animals with previously adequate ventilation. Ivy *et al.* (1947) gave 5% carbon dioxide to animals with developing respiratory failure due to anoxia, and showed a progressive decrease of the response to this gas. In a number of instances, as in Schmidt's experiments, the volumes ventilated were decreased and the gas not only increased the degree of respiratory failure but also precipitated circulatory failure.

Not all these experiments are feasible or desirable in the human subject, but there is a great deal of evidence emphasizing the dangers of increased tensions of carbon dioxide in the body of humans.

Effects of High Levels of Carbon Dioxide

Anaesthetic and Narcotic Effects

Carbon dioxide was, in fact, the first gaseous anaesthetic used surgically, and Hickman performed surgical operations on animals under its influence as long ago as 1824 (see Duncum, 1947). Paul Bert (1878) subsequently confirmed that high concentrations of carbon dioxide (15% upwards) rendered normal animals unconscious, and again suggested its use as an anaesthetic during surgical procedures. Since that time many workers have described the depressant narcotic effect and the antagonism to analeptics produced by high concentrations of carbon dioxide in animals (Gellhorn and Heymans, 1948; Stein *et al.*, 1949; Pollock, 1949); and in man (Richardson, 1885; Brown, 1930; Seevers, 1944; Dripps and Comroe, 1947). Stein *et al.* (1949) reported that 30% carbon dioxide for 30 minutes would prevent electrically induced convulsions in man. This implies, incidentally, that the administration of carbon dioxide is likely to weaken the effectiveness of any analeptics given during resuscitation. These reports concern the inhalations of high percentages of carbon dioxide by normal subjects, in whom even a normal response to carbon dioxide was unable to prevent severe gaseous acidosis with its attendant dangers.

Over 40 years ago Krogh and Lindhard (1913) noted that the administration of oxygen with carbon dioxide appeared to reduce the ventilatory response to the latter gas. Work during the recent war (Barlow *et al.*, 1945; Donald, 1945) showed that in the absence of efficient carbon dioxide absorption in respiratory apparatus, exercising subjects breathing oxygen could readily become anaesthetized by carbon dioxide without appreciating any preliminary respiratory stimulation, and that, in resting subjects, concentrations of 10% or more carbon dioxide in oxygen readily induce unconsciousness.

In controlled respiration, with high oxygen tensions, as used in modern anaesthesia, it has been shown that a relatively small decrease of minute-volume will cause the body pCO_2 to rise to narcotic levels (Orton, 1952; Dripps, 1952), and levels of up to 20% carbon dioxide have been recorded (Dripps, 1947; Buckley *et al.*, 1953); this may cause considerable delay in return of consciousness (cf. Scurr, 1954; Gray and Fenton, 1954). All anaesthetics and narcotics will, if given in larger doses, finally cause medullary failure, and there is no reason to believe that carbon dioxide is an exception.

It has only recently been appreciated that carbon dioxide narcosis, far from being an academic curiosity, is not uncommon in routine clinical practice (Barach, 1948; Donald, 1949; Comroe *et al.*, 1950). If patients with very severely damaged lungs (emphysema, extensive tuberculosis, bronchiectasis) develop bronchopneumonia, severe bronchitis, or status asthmaticus, they frequently suffer extreme and fairly sudden anoxaemia—that is, arterial blood saturation of 20 to 40%. The body pCO_2 of these very ill patients rises considerably as anoxaemia develops, and this would suggest the development of some degree of anoxic central respiratory failure (Donald, 1953) with resultant depression of ventilation. In this state the respiratory centre appears to be insensitive to carbon dioxide, but still responds to some extent to anoxaemic stimuli from the sino-aortic zones. The administration of oxygen to such patients, although life-saving, does not cause an immediate return to normal respiratory behaviour, and, as the main effective stimulus to the damaged centre under these conditions is now removed, the patient ventilates even less, with the retention of increasing amounts of carbon dioxide and, frequently, resulting loss of consciousness. Removal of the oxygen under these conditions will often cause marked increase in ventilation and reduction of carbon dioxide levels with return of consciousness even though the extreme anoxaemia returns. It is to be emphasized that these very ill patients are not receiving artificial ventilation. Recently a Drinker respirator has been employed to allow improvement of oxygenation in such cases without dangerous carbon dioxide narcosis (Boutourline-Young and Whittenberger, 1951; Stone, 1953; Lovejoy, 1954).

Even very grave respiratory infections rarely cause such a severe degree of anoxaemia in previously healthy persons with hitherto normal lungs. Further, they do not have the initial respiratory acidosis and increased body base which is usually found in the patients described above. However, Engström (1954) and Christie (1954), workers of great experience in the field of poliomyelitis, state that carbon dioxide intoxication does occur in the acute phases of the disease, particularly with oxygen therapy and inadequate ventilation. Although it is still uncertain whether a similar syndrome would occur in a healthy subject who has been exposed to acute and nearly fatal anoxaemia due to drowning or asphyxiation, it would seem very likely, and animal experiments strongly support this view. Marshall and Rosenfeld (1936) caused partial respiratory failure in healthy dogs by severe anoxia and showed that the administration of oxygen appeared to remove the only remaining effective drive of spontaneous respiration and resulted in a further reduction of respiratory volumes with retention of carbon dioxide.

These clinical observations, and the experiments of Schmidt (1924), Ivy *et al.* (1947), and Marshall and Rosenfeld (1936), all suggest that a respiratory centre which is depressed either by drugs or anoxaemia, although still capable of a considerable response to the anoxaemic stimulus, may no longer respond to increased carbon dioxide or hydrogen-ion concentration, and that any attempt to increase the body carbon dioxide tension further will not only be ineffective but also dangerous. They also emphasize that efficient artificial ventilation is the keystone of resuscitation even when oxygen is being administered.

Vascular Effects

Low concentrations of carbon dioxide have, initially, a stimulant effect on the vasomotor centre with peripheral vasoconstriction. However, concentrations of 15% or greater appear to cause vasomotor depression (Nowak and Samaan, 1935; Liljestrand, 1948). There is also a direct capillary-dilating action which may well contribute to peripheral failure. Rats and guinea-pigs exposed to a cold environment fail to maintain their body temperature

normally when exposed to 3% carbon dioxide. This may be due not only to the peripheral circulatory changes but also to depression of the thermo-regulatory centres (Gellhorn, 1937). Although it is not intended to discuss this in detail here, circulatory failure is often the critical cause of death even in persons with respiratory failure (Swann, 1953), and any contributory cause of peripheral vasodilatation and fall in blood pressure must be avoided.

MacDonald and Simonson (1953) have reported considerable abnormalities of cardiac rhythm in human subjects after very brief periods (23 to 63 seconds) of acute respiratory acidosis (30% carbon dioxide). Altschule and Sulzbach (1947) describe electrocardiographic signs of reversible myocardial injury in subjects receiving 5% carbon dioxide in 95% oxygen by intratracheal tube. Under anaesthesia vagal action is said to be potentiated by hypercapnia (Campbell, 1950), with the danger that usually harmless manipulations in the respiratory tract may stop the heart. These adverse effects on the heart are highly undesirable when life is, in any case, threatened by the possible onset of irreversible cardiac failure or acute ventricular fibrillation.

Carbon dioxide administration, even in small concentrations, causes dilatation of the cerebral vessels (Wolff and Lennox, 1930; Kety and Schmidt, 1948). Further, there is a considerable rise of cerebrospinal fluid pressure—that is, up to 350 mm. of water with 10% carbon dioxide (Cobb and Fremont-Smith, 1931). A similar rise of cerebrospinal fluid pressure was demonstrated in patients who become unconscious with oxygen therapy (Davies and MacKinnon, 1949), and later was attributed (Donald, 1949) to carbon dioxide narcosis and associated cerebral vasodilatation. It has been suggested that this cerebral vasodilatation will cause a beneficial increase of blood flow to the whole cerebrospinal axis; and yet the fact that many such patients are unconscious, are hypoventilating, probably because of respiratory failure, and have a great increase of intracranial pressure, often with papilloedema, would emphasize that such high tensions of carbon dioxide in the body are, if possible, best avoided.

"Off Effect"

Even in normal subjects the sudden cessation of 5% carbon dioxide inhalation, after exposure for periods of half an hour or more, causes "shock-like" symptoms such as pallor, shivering, vomiting, and severe malaise (Alexander *et al.*, 1939). Miller *et al.* (1952) reported serious or fatal cardiac irregularities in 18 out of 19 dogs on returning to air-breathing after several hours' carbon dioxide (30 to 40%) administration; 15 of these animals died, 12 from ventricular fibrillation. Cyclopropane anaesthesia has been found, if respiration is not assisted, to cause alveolar carbon dioxide tensions of up to 20%. Abrupt withdrawal of the anaesthetic mixture, and hence also of the high levels of carbon dioxide, produces the condition originally called "cyclopropane shock" but now recognized to be caused by the removal of a severe hypercapnia. It is accompanied by a dangerous fall in blood pressure, cold clammy skin, bradycardia, and sometimes delirium (Dripps, 1947; Buckley *et al.*, 1953).

Summary and Conclusions

The value of the administration of oxygen and carbon dioxide to subjects in respiratory failure and receiving artificial respiration is reviewed. It is emphasized that without immediate artificial respiration all other measures will be useless. However, the administration of oxygen to patients receiving artificial respiration is given unqualified support.

The value of the administration of carbon dioxide under these conditions is considered in greater detail. The possibility of low levels of body pCO_2 in the presence of respiratory failure prior to resuscitation is discussed, and reasons are given why it is thought that this syndrome does not occur. If carbon dioxide is administered during artificial respiration, then the partial pressure of carbon dioxide in the lungs and well-circulated organs will be raised to highly abnormal levels unless a considerable further increase of ventilation can be induced. Under first-aid conditions the rescue worker will never know the initial levels of carbon dioxide in the body of the subject, nor the ventilatory volumes he is producing. The administration of carbon dioxide under these conditions is therefore uncontrolled and uncontrollable, and in many cases is apt to cause a dangerous intensification of carbon dioxide accumulation and intoxication.

The question of possible overventilation and the lowering of the body pCO_2 by manual methods under first-aid conditions is considered. It is concluded that this is very unlikely to occur for any significant period, that it would not alter the prognosis, and that, even in the most improbable event of its being diagnosed by a first-aid worker, carbon dioxide therapy would be unnecessary and undesirable.

The ability of even slight-to-moderate rises of body pCO_2 to increase the viability and promote further spontaneous activity of a failed or failing respiratory centre is also questioned.

The dangers of high concentrations of carbon dioxide in the body are emphasized. These include depression of the central nervous system and respiratory centre, vasomotor depression with peripheral vasodilatation, dangerous cardiac arrhythmias, and fall in body temperature. The sudden removal of the gaseous acidosis also causes severe symptoms. Barcroft and Margaria (1931) said of even normal subjects that "the breathing of 7.5% carbon dioxide for 20 minutes produces a shock from which the system does not wholly escape for some hours or perhaps even a longer time."

For these reasons it is recommended that in first-aid practice carbon dioxide should not be administered with oxygen in the resuscitation of subjects requiring and receiving artificial respiration.

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CAN WARD ROUNDS BE A DANGER TO PATIENTS WITH MYOCARDIAL INFARCTION?

BY

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Like physical effort, emotional stress may bring on anginal pain in a patient suffering from a disease of the coronary arteries. The contributory effect of mental tension can often be shown even in cases of myocardial infarction. Besides physical rest, complete mental rest is a fundamental requirement in the treatment of myocardial infarction (Miller, 1942; Stroud, 1945; White, 1945; Scherf and Boyd, 1947; Friedberg, 1950; Levine, 1951). Physical rest is usually easy to organize: bed rest in itself guarantees it. A more difficult factor to control is mental rest. Internal mental stresses may affect the patient to such a degree that it is difficult to control them. This makes it all the more necessary that attention should be devoted to the external factors disturbing the patient's peace of mind.

Contacts in Hospital

For the in-patient, contact with others doubtless causes the strongest psychological stresses to which he is exposed. The persons with whom the patients come into contact are the patient's relations and friends, other patients, and hospital personnel.

Relations and Friends.—It is often found that the visit of a certain relative or friend to a patient with myocardial infarction does not have the desired effect of soothing him. On the contrary, one result of such a visit may be increased pain. This is an occurrence that can, of course, be avoided if the attending physician, in serious cases, decides which visitors may be allowed to see the patient, and how often.

Other Patients.—The patient with myocardial infarction reacts differently towards his fellow-patients than towards his relations. The influence of the patient in the next bed may be soothing, that of another irritating. By choosing the patient's bed the mental stress arising in this way may be eliminated. In serious cases of myocardial infarction the practice in our clinic is often to place the patient in a single-bed room to start with.

Hospital Personnel.—Of the hospital personnel, only nurses and physicians come into close contact with cases of myocardial infarction. In selection and training of the nurses emphasis is placed upon those qualities that have a reassuring effect on the patient. It may be taken as read that credit for preserving the patient's peace of mind must go to the nurses. What is more difficult to assess is whether the attending physician may not introduce emotional stresses deleterious to the patient. Calmness of the doctor and wisely worded pronouncements by him may have a beneficial influence on the patient's worried state of mind. On the other hand the patient with myocardial infarction, knowing that his condition is dangerous, is probably anxious about the doctor's verdict. This may induce a harmful state of excitement. My personal experience has been that on several occasions, just as the ward round has advanced to the patient suffering from coronary disease, or, more often still, to the patient preceding him, he gets an attack of angina pectoris, in some cases fatal.

The present paper is an attempt to ascertain, by analysing the fatalities from sudden myocardial infarctions, whether the ward round may be a danger to such patients. No analysis of the anginal pain felt by these patients and possibly associated with the doctor's round has been included, for the simple reason that it is generally impossible to show these pains objectively.

Material

The material investigated is taken from the 373 patients with myocardial infarction treated in 1950–3 at the Third Medical Clinic of Helsinki University, and comprises those who died of acute myocardial infarction while in hospital. Where the death occurred later than six weeks after the acute myocardial infarction the case is not included. The series consists of 84 cases in which death occurred—69 male and 15 female. The average age of the male patients at the time of death was 57.4 years, and of the female patients 66.5 years. In 47 cases the diagnosis was confirmed

TABLE I.—*Analysis of 84 Deaths from Acute Myocardial Infarction*

Age Group	Male	Female	Lapse of Time from Onset of Infarction to the Moment of Death		
			24 Hours	7 Days	8 Days–6 Weeks
30–39 ..	1	0	—	—	1
40–49 ..	12	0	7	2	3
50–59 ..	26	1	6	6	15
60–69 ..	24	9	7	8	18
70–79 ..	5	5	3	5	2
80–	1	0	1	—	—

at necropsy. Table I gives details of the age and sex distribution of the 84 cases and the lapse of time between the onset of infarction and death. It shows that the first 24 hours accounted for a considerable proportion of the total deaths. A probable contributing factor is that all the patients lived in the neighbourhood of the clinic; this means that serious cases were admitted to hospital more or less immediately after the attack of infarction. In hopeless cases, therefore, death occurred in the hospital more often than would have been the case had the distance of transportation been longer. In addition, Table I shows that 45 of the patients died within seven days of the attack. As the first week must be regarded as a very critical period for these patients, it was thought undesirable to draw conclusions