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OXYGEN POISONING IN MAN

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PART II

Signs and Symptoms of Oxygen Poisoning

The available knowledge of the signs and symptoms of oxygen poisoning in man at the beginning of these experiments was extremely scanty. Only about 12 separate exposures where acute toxic symptoms had occurred had been described. It is not certain that Bornstein suffered from oxygen poisoning (see below). All these experiments were in compressed air, and with the exception of Bornstein all subjects were seated and at comparative physiological rest. The British Naval instructions at this time (1941) read as follows: "Symptoms: Tingling of the fingers and toes and twitching of the muscles, especially round the mouth (warning symptoms). Convulsions followed by unconsciousness and death if a remedy is not taken." The U.S. Naval instructions stated: "The first signs of oxygen toxicity are the flushing of the face, nausea, dizziness, and muscle-twitching. A feeling of being irritable and a sense of excitement may follow. As the pressure is increased nausea, vertigo, and, finally, unconsciousness and convulsions ensue."

It was inevitable, with the limited data available, that these instructions were brief and not altogether accurate. Tingling of the fingers and toes had not been reported in any experiment, but was inferred from its occurrence in the aura of idiopathic epilepsy. In the first large series of human experiments, described in this article, a more complete picture of the syndrome of oxygen poisoning in the human has resulted. Most of the signs and symptoms described in the pre-convulsive stage, in the auras, or in the non-convulsant equivalents of epilepsy have been encountered. As in that disease, the total of signs and symptoms is now known. Yet—again as in epilepsy—the individual pattern of signs and symptoms varies enormously within this framework. Signs and symptoms as experienced when the subjects were breathing pure oxygen in compressed air are first described, as the subjects' environment was more normal and careful direct observation was possible.

Facial pallor usually occurs a few minutes after the beginning of the exposure. It varies from person to person in degree and time of onset. The degree of facial pallor is in no way indicative of the subject's sensitivity or of an impending end-point. Fasciculation of the lips or face is often seen early in the experiment and intermittently throughout the exposure. This has been partially attributed to fatigue caused by the mouthpiece and a not unnatural nervous tension. It is a common occurrence when patients

are breathing from a spirometer for B.M.R. estimations. Fasciculation frequently appears in muscles which later show severe and sustained twitches, and it is undoubtedly increased by breathing oxygen at increased tensions. A number of subjects show facial perspiration varying in degree from fine beads to literal pouring. Generalized perspiration is infrequent, and is usually associated with the occurrence of more acute symptoms. Salivation seems to be increased (as in animals), but some is undoubtedly reflex from the irritation of the mouthpiece, and is therefore difficult to assess. Almost all the subjects appear to be under stress even though they have no specific symptoms. These are all early findings, and the subject will continue without further event for varying times according to his tolerance.

The next group of symptoms to be described may be classified as minor crises in so far as they are usually transient and the subject is able to continue breathing oxygen. The subject may complain of nausea, vertigo, malaise, apprehension, or choking sensations. Intermittent lip-twitching of a slight or moderate degree or an increase in the frequency of respiration may be noted by the observer. Palpitations, involving an awareness not only of the action of the heart but of arterial pulsation throughout the body, may cause the subject considerable discomfort. These disturbances may last for only a few seconds to a few minutes, and the subject finally resumes his former symptomless state and may continue the exposure for a considerable time before an acute end-point. The course of these minor crises is unpredictable, and the observer has to be constantly on the alert for a sudden exacerbation with danger of convulsion. Other subjects have no such transient episodes, but first experience pronounced symptoms shortly before or at the end-point.

Finally, a group of symptoms occur which, although not demanding immediate cessation of the exposure, signify that intoxication is becoming more intense and that acute symptoms will not be greatly delayed. There may be pronounced mood changes with depression or euphoria. Severe irrational apprehension, sometimes amounting to acute terror, may be experienced. Alternatively, the subject may feel "far away" or experience complete indifference to his surroundings. Others are somnolent, and in one case the subject fell into a deep sleep from which he was aroused with difficulty. At this time the attendant may notice various abnormalities of behaviour, the subject showing clumsiness with his apparatus, loss of balanced judgment, fidgeting, or the unnatural disinterest already mentioned. A sensation of depression or constriction, frequently indescribable, in the epigastrium or in the praecordium may be experienced. Visual or auditory hallucinations are late phenomena and mean that the end-point is not far off. They have only occasionally been reported in the earlier crises. Visual disturbances include flashes of light, usually in the centre of the visual fields, haloes round objects, lateral movements of images, micropsia, and apparent changes in illumination. Auditory hallucinations such as bell-ringing and knocking are far less common. Both deafness and hyperacuity are encountered. Elaborate auditory or visual hallucinations, which are classified clinically under psychical seizures, are not experienced. (Unpleasant tastes and odours have not been encountered in the "dry" but were reported by two subjects in the "wet.") Constriction of the visual fields occurs only after prolonged exposures, is gradual in onset, and can be marked, without the more acute manifestations of oxygen poisoning. In a few cases nausea and vertigo, together or separately, become so severe that the subject reverts to air-breathing before convulsive symptoms appear.

Definite twitching of the lips usually means that the end-point is near. This is the most common termination. The twitches are powerful and sustained. They are usually first seen on one side of the upper lip, but if the exposure continues they increase in power and frequency and spread to the whole mouth and face and sometimes to other parts of the body. On occasion a marked twitch is followed by a long period of quiescence before recurrence. This is exceptional, and in most cases, if oxygen-breathing continues, convulsive movements of the lips pass into generalized jactitations or convulsions. Twitching of the cheek and nose are often seen with or without lip-twitching. Occasionally there is isolated twitching of the arm, leg, spinal, or abdominal muscles.

In some cases a few seconds or minutes before the end the respirations, which are normal and serene throughout, show a number of abnormalities. The commonest occurrence is rapid panting. In other instances there is marked inspiratory predominance, reminiscent of asthma, but without wheezing. Respirations sometimes become grunting in character, and in severe cases this may develop into an acute state of apnoea in the inspiratory position. Subjects with severe respiratory symptoms usually convulse, although a few escape on being turned on to air.

It will be seen that an accurate description of such a varying picture is not easy. The clinical impression gained was of two distinct processes occurring in many different patterns. One is an insidious intoxication which may affect the function of practically any part of the central nervous system, and added to this is an increasing convulsant tendency that is usually, but not always, first manifested in the facial muscles and finally becomes generalized. There are great variations in the resistance to the general background of intoxication and in the resistance to the convulsant factor. Certain individuals may show powerful twitching movements, either localized or generalized, but retain consciousness, while others pass into what is indistinguishable from an epileptic fit immediately after such convulsive movements and sometimes in their complete absence.

The syncopal type of attack was seen on only a few occasions. There were usually associated muscular twitchings. One of these subjects appeared like a case of so-called "shock," being pale, flaccid, and in a cold sweat, with a poor pulse. He did not convulse. The blood pressure was not ascertained. Another subject collapsed but did not appear to be "shocked." He was unable to move or speak, although he appreciated his surroundings. Such states are described in epilepsy under the name of cataplexy. Space does not allow the description of individual exposures.

Convulsive Attacks

The convulsive attacks of oxygen poisoning were on the average of two minutes' duration, the subject being unconscious. If the subject was turned on to air immediately the convulsion started only one attack resulted. In one case where oxygen breathing was inadvertently continued a second convulsion began after a pause of about thirty seconds. Incontinence occurred in a number of instances. Detailed description of these attacks is unnecessary as they in no way differed from a major convulsive attack of idiopathic epilepsy.

Confusion, dissociation, headache, nausea, and vomiting as experienced after an epileptic fit occurred in many cases. Some individuals showed marked emotional instability, which is not a feature of leptazol or electrically induced post-convulsive states. The majority, however,

were subdued and ataxic for about 15 minutes after, and if left alone fell asleep. Occasionally subjects complained of pronounced photophobia. In a number of cases there was post-convulsive automatism, the subject suffering from complete amnesia for a period from one-half to seven hours. There were some stiff backs and subcutaneous extravasation due to muscular violence.

Off-effect

A number of subjects suffered marked exacerbation of symptoms after returning to air-breathing. Severe nausea, increasing pallor, sweating, and vertigo have all occurred in subjects who were previously symptomless. Other subjects showed a sudden dissociation and panting. In a few cases it appeared that convulsions were precipitated by reverting to air-breathing. A possible explanation of this off-effect may be the sudden fall in oxygen tension, causing temporary cessation of respiration in already damaged nerve cells. In some cases, no doubt, the toxaemia was already of such a degree that convulsions were inevitable. Decompression appears to precipitate convulsions in such subjects and also in animals. The "startle" phenomenon, where sudden and unusual sensory stimuli precipitate convulsions—that is, decompression—may account for some of these cases.* It has therefore become a rule in this work that if a subject has severe symptoms and reverts to air-breathing he is not decompressed until his symptoms have gone and relative normality has been attained.

The recovery from a non-convulsant end-point is remarkably rapid and the subject appears normal in five minutes or less. All twitching usually disappears in about a minute. The subject may appear dazed for a few minutes longer and his respirations are inclined to be irregular, with intermittent deep excursions. Euphoria is frequent, but this may well be due to relief at having survived a toxic exposure without convulsing. In some cases pallor persists for as long as an hour, and sometimes the subject behaves as if he were slightly drunk for the same period. This latter syndrome is known in experimental diving circles as "oxygen jag."

Oxygen Poisoning under Water

So far only signs and symptoms as seen in the "dry" have been described. In a series of 388 dives to end-point, under water, the following symptoms were recorded: convulsions in 46 (9.2%) cases; twitching of lips, 303 (60.6%); vertigo, 44 (8.8%); nausea, 43 (8.3%); respiratory disturbances, 19 (3.8%); twitching of parts other than lips, 16 (3.2%); sensations of abnormality (drowsiness, numbness, confusion, etc.), 16 (3.2%); visual disturbances, 5 (1%); acoustic hallucinations, 3 (0.6%); paraesthesiae, 2 (0.4%). The most striking observation is the remarkable predominance of lip-twitching. It is probable that many of the more subtle symptoms occurred but that they were difficult to appreciate under water. A number of divers who reported severe lip-twitching, and were hauled up jactitating and confused but did not convulse, remembered only severe lip-twitching as their end-point. Further observations by the attendant at such a critical time were difficult, particularly with the subject in a diving-suit.

Since Bornstein's single experiment in the "dry" (1912) it has often been stated that exercise at toxic tensions caused twitching of the muscles employed. In a series of "wet" dives to toxic depths with hard work symptoms were analysed in 120 end-points. The findings were as follows: Convulsed, 6.8%; lip-twitching, 50%; vertigo, 20.8%; nausea (vomiting two cases), 17.5%; choking sensations, 2.5%; dyspnoea, 2.5%; body tremors, 1.7%.

It appears that nausea and vertigo increase in frequency if the subject is exercising. Twitching of the muscles being exercised was not encountered in the whole series. Carbon dioxide absorption has to be extremely efficient with hard work, especially in air, where the canister becomes very hot, and a large series of such experiments in the "dry" were marred by inadequate carbon dioxide absorption and are not reported here. In these "spoiled" experiments the subjects experienced twitching of muscles and severe tremors, and this was shown to be due to high tensions of carbon dioxide in the circuit.

Subjects breathing oxygen at increased tensions before toxic signs or symptoms occur are remarkably normal. The mental torpidity described by some observers has not been noted, even at considerable depths, except after long exposures in the "dry." Judgment and the capacity for hard physical work appear to be in no way impaired. Under-water divers are more free of symptoms than those in the "dry" right up to the moment of lip-twitching or convulsing. No doubt the abnormal environment and accoutrement obscure the minor premonitory symptoms. This apparent normality and the frequent suddenness of convulsive symptoms make oxygen-breathing under water at toxic depths highly dangerous, particularly as the subject often gains a very false sense of security.

Special Investigations

These experiments were carried out under war conditions, and owing to the urgency of the work and the many other immediate operational problems being investigated it was unfortunately not possible to extract the maximum data from this unique series by elaborate special investigations. However, a number of important observations were made, and these will now be considered under appropriate headings.

"Lorrain Smith Effect" (Pulmonary Damage) in the Human

Lorrain Smith (1899) reported fatal pneumonia in a rat after four days' exposure to 73% oxygen. Many animal experiments have been carried out since, and the general conclusion has been that 60% oxygen causes no pulmonary damage in animals or man (Barach, 1926) even after indefinitely prolonged exposures. Becker-Freyseng and Clamann (1939) produced bronchopneumonia in a healthy man by breathing 90% oxygen for 60 hours.

In over 1,000 experiments where subjects were breathing oxygen at toxic pressure (4.68–1.9 ats. abs.) the exposure was always terminated owing to signs or symptoms involving the central nervous system. Frequent chest examinations were completely negative. At more shallow depths, however, nervous symptoms are encountered only after very long exposures or not at all. It was thought possible that there might be a greater risk of lung damage at such depths. Dives up to three hours at 2.1 ats. abs. in the "wet" caused no pulmonary irritation. A series of prolonged dives to 12 ft. (3.7 m.; 1.36 ats. abs.) with periods at 50 ft. (15.2 m.; 2.5 ats. abs.) gave equally negative results. An example was a dive for 6 hours 9 minutes, continuously in oxygen at 12 ft. (5 hours 39 minutes) and at 50 ft. (30 minutes), where no pulmonary irritation was encountered.

It can be stated with reasonable certainty that no real underwater dive will be made where lung damage will result from high tensions of oxygen, and that at depths greater than 30 ft. (9.2 m.) nervous symptoms will terminate the dive long before any pulmonary irritation occurs. Lorrain Smith (1899) reported that a rat died of pulmonary damage after 20 minutes at 4.5 ats. abs. of oxygen, yet a subject completed 61 minutes at 4.6 ats. abs., breathing oxygen, with no demonstrable pulmonary damage. Total evidence suggests that man has more resistance to lung damage than small experimental animals.

* Since writing this article it has been noted that a similar suggestion was made by J. W. Bean (1945).

A number of these subjects breathed oxygen at increased tensions several times a week for two years. It was considered possible that although the pulmonary damage suffered in a single exposure was inappreciable there might be a cumulative effect. Frequent routine examinations of the subjects' chests were therefore carried out. Radiographs were taken regularly and the vital capacities noted. In not a single case has there been any positive finding suggestive of lung damage. The subject who dived to 70 ft. (21.3 m.) to end-point two or three times a week for three months won the Portsmouth middle-weight boxing championship during this period. It would appear that there is no cumulative effect on the lungs in oxygen-diving.

Cardiovascular Findings

Benedict and Higgins (1911) reported bradycardia in man breathing increased percentages of oxygen at atmospheric pressure. This finding has often been confirmed, both in man and in animals. Bean and Rottschafer (1938) showed with animals that, although the bradycardia was mediated by the vagus, blocking of this nerve had no effect on oxygen poisoning. In the experiments described here it was found that, although the pulse changes were little more than could be accounted for by prolonged basal conditions, there was in some cases a marked slowing of the pulse (35–50), particularly after long exposures at 60 ft. (18.3 m.). The pulse was regular and there was no suggestion of dropped beat or any type of heart-block. Some of these subjects who did not convulse did not recover their normal rate till several hours after the exposure. The degree and rate of onset of the bradycardia had no fixed relation to tolerance or other symptoms, nor did the pulse changes give any warning of acute symptoms or convulsions.

Only a limited number of blood-pressure recordings were made at 90 ft. (27.4 m.). There was a gradual rise of both systolic and diastolic pressures, which stabilized after some 20 minutes at about 15 mm. above the normal levels. Just before the onset of acute symptoms a further brisk rise of about 15–20 mm. occurred. These findings are similar to those of Behnke *et al.* (1935–6). Microscopical study of the subjects' nail-bed capillaries while under toxic tensions and while suffering acute symptoms revealed no significant changes. *X*-ray and clinical examinations have shown no enlargement of the heart in subjects who were often exposed to toxic tensions over a long period. It is difficult to see why this should occur unless there is severe pulmonary damage, but it is a common belief among medical officers and divers, particularly in the Italian Navy, that oxygen-breathing increases the size of the heart. This was not confirmed.

Neurological Findings

In experiments continued over a period of three years no adverse after-effect has been noted in any subject's neurological integrity, intellectual ability, or personality. Neurological examination of subjects while breathing oxygen at 60 ft. (18.2 m.) and 90 ft. (27.4 m.) in the "dry" showed no significant change in reflex activity. Constriction of the visual field has already been mentioned. Some subjects showed marked dilatation of the pupils as they approached the end of the exposure. The only other important finding was the development of a positive Chvostek sign in a number of subjects during exposures. Although this usually developed in the latter half of the exposure, it was not a reliable sign of the approach of acute symptoms, although if present it became more marked as the exposure continued. Some subjects had an acute end-point without the occurrence of a positive Chvostek sign at any time. Controls in air at atmospheric pressure revealed that a few otherwise normal subjects had a positive Chvostek sign, which in some cases was present one day and absent on another. Such a finding in air, or even developing during the exposure, did not necessarily signify poor oxygen tolerance. In one quite unique subject acute symptoms always started with twitching of the muscles of the left hand (the only case of twitching of the hand recorded in the whole series), which then spread up the arm to the shoulder, and on two occasions this was followed by convulsions. This series of events was similar to a Jacksonian attack and quite unlike the usual muscular twitching.

Electro-encephalographical Findings*

Briefly, exposure to oxygen at 120 ft. (36.6 m.) had no immediate effect on the E.E.G. recordings. In general there was a slight increase of fast activity (25–32 p/s) and also increase in voltage of the 3–5 p/s waves. Coupled with this was a progressive decrease of the amount and voltage of the dominant frequencies (6–12 p/s). The tracings tended towards a sequence of 3–5 p/s waves with a superimposed ripple of fast activity. These abnormalities were episodic. Infrequently, spikes—that is, single high-voltage fast sine waves—appeared and increased in number. They were bilateral and symmetrical. Subjects who had non-convulsant end-points showed no other changes. Those who convulsed gave a picture of electrical activity during and after the fit which was indistinguishable from that seen in grand-mal epilepsy. It was apparent that there was nothing specific in the convulsions of oxygen-poisoning, as regards electrical activity, once they had started. In some cases there were signs of disturbance—that is, short bursts of 5 p/s activity with increasing voltage just before the attack. Others showed no change of cortical electrical activity before the major convulsive attack. In view of the similarity of the convulsions, both clinically and electrically, to those of epilepsy it was thought that a study of the E.E.G. of subjects in air, and with hyperventilation, might show inborn instabilities that could be correlated with oxygen tolerance. Fifteen subjects from the Admiralty Experimental Diving Unit were graded in order of average oxygen tolerance. This was based on many dives at various depths in the "wet" and in the "dry" over a long period. There was no statistically significant correlation, although the three most resistant subjects had normal E.E.G.s. However, the other two "normals" occurred in the last five in the endurance rating. No "normals" had convulsed at this time, but two did so in the later experiments.

Electromyographs of the lower facial muscles showed bursts of potential with lip-twitching without any associated abnormality of cortical electrical activity. Conversely, bursts of fast cortical activity occurred without increase in muscle action potential. Observations showed that clonic movements or twitching of peripheral muscles was not necessarily associated with changes in the E.E.G.

Toxic Effects of Oxygen on Brain Metabolism

Prof. F. Dickens (1946), in associated M.R.C. (R.N.P.R.C.) research, investigated the action of high-pressure oxygen on rat-brain slices. This work is briefly referred to here for the sake of completeness. He showed that the respiration of isolated cerebral cortical tissue is progressively and irreversibly poisoned. Curves plotting the percentage fall of initial respiratory rate against time were remarkably similar in type to those showing the elimination of a group of individuals by toxic symptoms at a fixed depth (see Fig. 4 "dry"). The time/pressure relationship for a fixed degree of respiratory poisoning was also of a similar type to that obtained for the means of times causing acute symptoms in a group of men at various depths. The order of sensitivity to high pressures of oxygen of the various rat tissues was as follows: Brain cortex > spinal cord > liver > testes > kidney > lung > muscles. The actual tension of oxygen in the brain tissue *in vivo* and *in vitro* under these conditions is not yet accurately known, but from Dickens's experiments it is certain that convulsions occur in man and animals when the brain tissue respiration is but minutely impaired. A similar problem is presented by the effect of narcotics on brain slices and *in vivo* (Quastel, 1939). Dickens presents strong evidence that the primary effect may be in the inhibition of pyruvic oxidase, and that the secondary effects would be general poisoning of carbohydrate oxidation, since all known paths of carbohydrate oxidation converge at the stage of pyruvate. Magnesium, manganese, and cobalt ions strongly protect pyruvic oxidase from oxygen poisoning in tissue slices. Protection by metallic ions is not entirely similar *in vivo* in animal experiments (Marks, 1944). In view of the known –SH character of this enzyme and the known ability of these metals to protect this group, it is likely that

* These unpublished E.E.G. investigations were carried out in the later collateral M.R.C. (R.N.P.R.C.) research by Brown, Downman, MacIntosh, and Williams. The unit subjects were employed in a number of the experiments.

the –SH group of pyruvic oxidase is the seat of oxygen poisoning. The irreversibility of the poisoning in these experiments may be explained by the known difficulty of reconstituting the –SH group *in vitro*. If, as it appears, convulsions or acute symptoms occur in a very early stage of this process, then reactivation in the more physiological conditions of the intact organism is extremely feasible. This would account for the reversibility of acute oxygen poisoning in man and animals if the exposure is immediately discontinued.

Discussion

The most important aspect of oxygen poisoning is the intoxication of the central nervous system. It seems that the whole cerebrospinal axis is involved. The twitching of the muscles is definitely subcortical in origin, and the sensitivity of the facial nerve to tapping would indicate that even the most peripheral components are affected. Meanwhile the cortex is also being poisoned, and in a number of cases phenomena exactly similar to epileptic auras occur which are presumably due to cortical dysfunction. In some cases severe muscle-twitching, and even convulsions, may be precipitated without any such aura being reported. The more peripheral motor discharges may predominate throughout and even cause generalized jactitations without electrical or clinical evidence of cortical disturbance. In other cases non-convulsant cortical disturbances may cause symptoms of such severity that the exposure is discontinued. The remarkable individual variation in reaction to unphysiological tensions of oxygen is again emphasized.

It is not known why the lips should be so specifically affected. The possibility of the added irritation and fatigue caused by the mouthpiece was considered, but was excluded by the demonstration of lip-twitching in man in helmets without mouthpieces (Donald, 1942), and also in rabbits and other animals (Marks, 1944). These peripheral twitching movements are almost certainly related to the myoclonic seizures of epilepsy, in contrast to the Jacksonian type of attack. These myoclonic seizures commonly affect the face, but can occur elsewhere. Penfield and Erickson (1941) concluded from electro-encephalographic studies that these attacks originate from the grey matter in the brain stem and spinal cord. It is significant that a similar conclusion has been reached with regard to the origin of the muscular twitching in this work. Of equal interest is the comparative rarity of myoclonic seizures and frequency of Jacksonian seizures in epilepsy, and the reverse in oxygen poisoning. The rarity of somato-sensory disturbances (paraesthesiae) and elaborate hallucinations (perhaps associated with absence of petit mal) is worthy of note. At no time was any attack akin to petit mal observed either clinically or electrically. Thus even in oxygen poisoning, in which epileptic auras are closely imitated, petit mal is unknown. This emphasizes the uniqueness and importance of that phenomenon in idiopathic epilepsy.

A small group of naval epileptics (five) tested by the M.R.C. workers did not show any apparent increase of sensitivity to oxygen poisoning, but the experiments were too few for definite conclusions to be drawn. Penfield emphasizes the great variability in the physiological state of the epileptic cortex. "It may be quite normal in reaction, or it may be abnormally stimulable, completely refractory, or at other times unequally hyperactive." Such variability of behaviour combined with the enormous variability of human susceptibility to high pressures of oxygen makes a far larger series of experiments desirable. However, the pattern of toxic symptoms appeared similar to those in normals, and the general impression gained was that there was no essential difference of reaction, or any increased accessibility to the convulsant mechanism, by the channels or processes involved in oxygen poisoning. It is possible, and indeed highly probable, that there are distinct chemical or cellular systems the adequate and separate disturbance of which will allow or cause convulsions. On first principles it would appear likely that the depression of essential carbohydrate oxidation in nerve cells would cause depression in function and not increased activity. If this is the case, then the "auras," motor twitches, and convulsions are more likely to be release phenomena and not due to primary excitability of the parts of the central nervous system concerned. The sudden violent discharge to utter exhaustion (as shown in convulsions by the E.E.G.) is strange behaviour in cells in which the oxidative processes are damaged.

The relatively slow and deliberate evolution of auras akin to those experienced in epilepsy is, so far as I know, unique to oxygen poisoning and should be further exploited by experimental workers. Although the condition is artificially produced, it approximates far more closely to the natural epileptic phenomenon than other induced convulsant states. The electrical localization of epileptic discharges in idiopathic non-convulsant equivalents has already been carried out in a number of cases. It would be possible to select resistant subjects who experienced definite auras without marked "peripheral" motor discharges. The electrical study of these auras in such subjects would be a new approach to the problems of cortical localization and function. Further study of the various patterns of cortical dysrhythmias before convulsions may contribute to the knowledge of the mechanisms of epilepsy.

The therapeutic use of oxygen as a convulsant in the various psychoses has been suggested in the past, but the lack of knowledge of the syndrome, combined with the greater ease and safety of other methods, has so far prevented its use for this purpose. The complicated and rather frightening ritual (to strangers) of pressure work, and breathing from a closed circuit, render the value of this method very questionable. Changes in the central nervous system could be induced up to the point of convulsions. With experienced attendants these could be avoided in most cases if desired. Evidence may be obtained as to whether the improvement, if any, was caused by such changes alone or by the convulsions they can precipitate.

Conclusions

In the first large series of experiments on human beings, knowledge of the dangers and symptoms of oxygen poisoning has been expanded. It has been demonstrated that these dangers are far greater than was previously realized. The variation of tolerance between individuals, the variation of tolerance of each individual, the impairment of tolerance with work and under water, all make diving on pure oxygen below 25 ft. (7.6 m.) of sea-water a hazardous gamble. The impairment of tolerance under water is as mysterious as it is unfortunate. Despite the fact that a comprehensive picture of human symptoms of oxygen poisoning is now available, it is emphasized that no signs or symptoms can be given that would ensure a timely cessation of oxygen-breathing in all cases. The variation of symptoms even in the same individual, and at times their complete absence before convulsions, constitute a grave menace to the independent oxygen-diver. The only possible conclusion is that such tensions of oxygen should be scrupulously avoided.

Summary

Previous research into the effect of increased tensions of oxygen on man up to the commencement of this work is briefly described.

An account is given of experiments to determine the tolerance of groups of men to such tensions of oxygen under varying conditions.

The signs and symptoms of oxygen poisoning in man are described.

The possibility of pulmonary damage by increased tensions of oxygen is discussed.

Electrical and chemical changes in the central nervous system are briefly described.

The relation of oxygen poisoning to epilepsy and the possibilities of further useful investigations are discussed.

The danger of breathing oxygen at increased tensions is emphasized.

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The British Legion Unit of Rheumatology, set up experimentally by the British Legion a year ago, to specialize in the treatment of ex-Servicemen and women suffering from rheumatic diseases, has now been transferred, complete with staff, from the Three Counties Hospital, Arlesey, Beds., to the North-West Hospital, Haverstock Hill, London, N.W.1. The Minister of Health has agreed to take over the unit on May 31, and to encourage the provision of further units throughout the country.

ACUTE NON-SPECIFIC DIARRHOEA AND DYSENTERY

LOCAL CHILLING OF THE ABDOMEN AS A CAUSATIVE FACTOR

BY

G. R. KERSHAW, M.A., M.R.C.S., L.R.C.P.

Acute enteritis of unknown origin is common in Europeans visiting and living in hot climates. It is so common and so widespread that the lay public in every country use a colloquialism peculiar to their district to describe the local manifestation of a complaint which, though second only to sea-sickness in its power of temporary prostration, seldom lasts more than a few days, so that it is soon forgotten or is accepted as a perennial part of the white man's burden. Its social and economic consequences, though brief, are severe to the individual, but its military consequences can be disastrous to a community of fighting-men: apart from jeopardizing a single operation there is nothing so calculated to lower morale as recurrent attacks of diarrhoea.

In the intervals it is made light of by the public and is rarely considered seriously by the profession. Not all standard textbooks or monographs even refer to it, and in those that do so it is seldom discussed at a length which suggests that it is probably the illness encountered most commonly among the white population in hot climates. Even the most reputable authors, moreover, show little confidence, agreement, or justification in describing its cause, and still less in recommending prophylactic measures. It is ascribed variously to "exposure to chill, and irritation of the bowel by coarse and unsuitable food" (MacArthur, 1942), to potentially pathogenic bacteria (McDonagh, 1942), to "the recognized dysentery organisms, precipitated by sudden chilling" (Napier, 1946), and as "probably bacterial in origin" (Manson-Bahr, 1945). Macgregor (1946) gives good reasons for this dissatisfaction with the traditional causes and, after showing a close association in time with acute upper respiratory disease, favours a virus infection, on the principles believed by Burns and Gunn (1944) to cause diarrhoea in infants, as described in a *B.M.J.* editorial (1942).

Opinion is, therefore, overwhelmingly in favour of infection, and this belief is based on three main points: (1) Its symptomatology is similar to that due to known pathogens. (2) It occurs in outbreaks as well as sporadically. (3) In the many outbreaks of enteritis of unknown cause during the war it has been shown that the more thorough the investigation the more often is a known pathogen recovered (Hardy and Watt, 1945). Similar symptomatology, however, is known to occur with any form of irritation within the lumen of the gut, and its simultaneous appearance in different people is by no means necessarily indicative of infection; while to attribute the disease to an unknown organism which has never been demonstrated is to admit to a degree of professional complacency which is as astonishing as it is unscientific.

Chilling of the Abdomen

Perhaps equally unscientific, but of longer duration, is its traditional association with chill. In some (MacArthur, 1942; Napier, 1946) references to acute enteritis exposure to chill, in quite general terms, is mentioned as a probable factor in its cause, either predisposing or actual; this appears to have passed from one book to another without much consideration or justification. Now it is in fact a matter of common knowledge that *chilling of the abdomen* by the rapid ingestion of cold fluid in large quantities when the body is hot does often induce diarrhoea, and it is fairly