to be the case since a neuropsychiatrist has been established in the depot, with all his advantages in familiarity with conditions and demands and power to recommend disposal.

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NITROUS OXIDE ANAESTHESIA: A CRITICAL EVALUATION

BY

R. BLAIR GOULD, M.B., Ch.B., D.A.

Anaesthetic Specialist in the E.M.S.

Nitrous oxide-oxygen is usually considered the safest and best anaesthetic agent. At the present time, when non-experts in increasing numbers are being called on to act as anaesthetists in both military and civil practice, a critical examination of this statement is necessary.

While quite suitable for many operations on susceptible patients, nitrous oxide, being the weakest of all anaesthetic drugs, is rather an agent for the production of unconsciousness than one which can provide any degree of muscular relaxation. The attempt to produce the former in many anaesthetic-resistant patients and the production of the latter in nearly all cases are usually accompanied by such a degree of anoxia as may often be dangerous. Thus Macintosh (1938) states that "its use by inexperienced anaesthetists for major surgery is fraught with disappointment if not carried out boldly, and with danger if it is"; while Clement (1939) in the standard work on the subject acknowledges that "deep, prolonged anaesthesia with nitrous oxide implies a drastic and continued curtailment of the oxygen supply which greatly augments any degree of anoxaemia that may be present" (p. 97); and, again, "The abnormalities" (of respiration) "occurring in the deeper planes are all evidences of oxygen want. . . . The symptoms produced in the nervous system by nitrous oxide-oxygen administration are in reality those of a gradually progressing state of anoxaemia" (p. 40).

Arguments against Nitrous Oxide

In these circumstances, why is nitrous oxide anaesthesia continually recommended when its use must often imply considerable oxygen want? The three main arguments are all propounded by Clement: (1) that anaesthetic agents in general produce their effects by reduced oxygen utilization, and nitrous oxide in particular "by the exclusion of the oxygen in the inspired air" (p. 98); (2) that nitrous oxide is an indifferent inert gas without any direct action or effect upon the body tissues (p. 23), and it is assumed, therefore, that any additional effect of anoxia on the tissues will be minimal, if not harmless; (3) that "the body shows a remarkable tolerance to moderate, and even temporary severe, degrees of oxygen want" (p. 97). In my opinion the weight of evidence is against each of these statements.

1. The theory that the narcotic action of anaesthetic drugs in general, or of nitrous oxide in particular, is due to depressed oxygen utilization is not supported by recent research. Henderson (1930), after reviewing considerable evidence, concludes that "oxidative processes and narcosis are separate phenomena. . . . No theory of anaesthesia will prove acceptable which is based on a proof of a depression of the resting oxidation of the cell." Pask (1941) reviews the recent work on this subject, and also concludes that under clinical and experimental conditions anaesthesia had no effect on the oxygen uptake of the intact organism or of isolated tissues.

2. Nor can it be assumed with certainty that the effect of nitrous oxide on the tissues is negligible. Clinical experience does not support this assumption, for short anaesthetics for minor surgery, even in the absence of anoxia, are often followed by headache, vomiting, and a feeling of distress and giddiness. Macintosh and Bannister (1941) state that they attempted to produce anaesthesia sufficient for dental extractions in 50 cases by nasal administration of nitrogen, and "although in all cases unconsciousness was reached, in the robust or anaesthetic-resistant type the full anaesthetic state

was not achieved. . . . If nitrous oxide has no anaesthetic effects, but acts only as an oxygen replacer, any inert gas would furnish as satisfactory an anaesthesia; actually, the anaesthetic properties of nitrogen are not as effective." Even were this assumption to be true, it is difficult to understand how it would render less harmful the effects of frank anoxia on tissue cells. Experience shows that the adoption of this assumption as a working basis often results in an anaesthetic technique which cannot be considered good practice.

3. The statement of Haldane (1922) that "anoxaemia not only stops the machinery but wrecks the machine" would appear to me to be as applicable to anaesthesia with nitrous oxide as to any other clinical condition. Indeed, recent research and clinical experience have not only confirmed Haldane's work but have demonstrated that the effects of anoxaemia may be insidious or delayed (Armstrong, 1939). Thus Samson Wright (1940) concludes: "A slight degree of oxygen lack may therefore act insidiously and only reveal its effects after a long latent period. . . . Following prolonged severe exposure to oxygen lack, very formidable after-effects occur." Courville (1936, 1939) has produced convincing evidence of the damaging effect which oxygen deficiency during anaesthesia, especially with nitrous oxide, may produce on the central nervous system, particularly on the cortex. He has shown how minor degrees of anoxaemia may cause permanent damage, which may not become apparent until after a considerable latent interval, while even a few minutes of severe anoxaemia may produce permanent damage. As Pask (1941) has emphasized, "immediate apparent recovery from a period of anoxia does not necessarily mean that a patient, particularly a shocked patient, has not suffered harm."

Cyanosis

Clinical experience does not support the view put forward by Clement: "The difference between the cyanosis associated with nitrous oxide-oxygen and that with other anaesthetic agents has been frequently overlooked" (p. 38); "cyanosis during nitrous oxide-oxygen anaesthesia has been given the same significance as with all other anaesthetics, thus the mode of action of nitrous oxide in producing anaesthesia by the exclusion of oxygen is ignored" (p. 103). The implication in these statements is that cyanosis is of a different nature when associated with nitrous oxide, and they have often been taken to justify its use in circumstances which must imply a considerable degree of anoxaemia.

Cyanosis depends on the absolute amount of reduced haemoglobin in the blood, the amount of oxygenated haemoglobin present being of little importance (Lundsgaard and van Slyke, 1923). Thus in plethoric individuals cyanosis may occur without anoxaemia, but such patients form a very small proportion of those coming to operation. Unless the haemoglobin concentration of any surgical patient is known to be above normal the possibility of cyanosis occurring without anoxaemia may be ignored.

Far different is the case with anaemic patients, who, in surgery, comprise the great majority. Here, the oxygen-carrying capacity of the blood being below normal, even when fully oxygenated there may be some anoxaemia, although the amounts of reduced haemoglobin present in the capillaries may not be sufficient to produce clinical cyanosis. But when the latter is present, the amount of haemoglobin available for carrying oxygen is further reduced and oxygen want intensified. Cyanosis therefore *must* be prevented in anaemic patients if anoxia is to be avoided.

McCarthy (1941) has described signs, affecting the respiratory and circulatory systems, by which he considers anoxia may be recognized, irrespective of the presence or not of cyanosis. Unfortunately, however, in my experience these signs do not occur in minor degrees of anoxaemia, where their value would be greatest; they are almost invariably late signs, indicating that circulatory and respiratory depression is already profound.

Prevention of Anoxaemia

It would appear, therefore, that the only method of avoiding anoxaemia is by maintaining scarlet blood in all cases. Where, however, anaemia is known to be present before operation, or is produced during operation by blood loss or other means, then not only must cyanosis be prevented but an increased concentration of oxygen must be given, over and above that necessary to produce scarlet blood, to compensate for the reduced haemoglobin, for by this means an increased blood-oxygen concentration may be produced (Boothby *et al.*, 1939, 1940; Wood, Mason, and Blalock, 1940).

Clement, however, states that "it is impossible to produce narcosis (with this agent) in the majority of patients and still maintain a pink skin and scarlet blood" (p. 103). This conclusion has a profound bearing on the evaluation of nitrous oxide as an anaesthetic agent, for I would regard the maintenance of a pink skin and scarlet blood as essential in all cases. The prevention of anoxaemia is one of the primary duties of the anaesthetist, and I would submit that to avoid anoxaemia nitrous oxide must be used with great discretion, particularly in shocked or anaemic cases. "Agents are potent or impotent as their toxicity is great or small" (Gillespie, 1942). To increase the potency of a weak agent such as nitrous oxide by associating with it any degree of tissue anoxia, however mild, is in my opinion to employ a method whose toxicity to those tissues may well be lethal; for there is much evidence that, whereas the effects of anaesthetic agents on tissue cells (in the absence of anoxia) are recoverable, the effects produced by anoxia are irreversible. (While I consider abundant oxygen essential with any anaesthetic technique or drug, I doubt whether the advantages of nitrous oxide are great enough to justify the additional transport of the necessary nitrous oxide cylinders to all the various isolated theatres of war.)

Other methods of increasing the potency of nitrous oxide are available, and are to be preferred. I do not agree with Clement that by the addition of ether, for example, to the mixture "the benefits of gas-oxygen alone are largely sacrificed" (p. 103). I would rather submit the principle advanced by Lundy (1932)—of the use of a combination of agents or methods to decrease the toxicity of a single agent—as being a more rational principle on which to base anaesthetic practice. In my opinion, the addition of some supplementary agent to nitrous oxide anaesthesia confers a benefit to the patient in that it enables the anaesthetist to maintain anaesthesia in an atmosphere of abundant oxygen.

Summary of Conclusions

Nitrous oxide is a weak anaesthetic agent whose effects are often produced only in the presence of anoxia.

The recognition of anoxia being difficult or impossible in many cases, it is better to avoid it by increasing the oxygen content of the anaesthetic mixture.

Should this render anaesthesia with nitrous oxide difficult in any particular case, it is an advantage to the patient to add some supplementary agent, for reduction in the oxygen supply to "potentiate" nitrous oxide is never justifiable.

It follows that nitrous oxide anaesthesia is not as safe as is often supposed, and its application should be strictly limited.

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An important factor in the first phase of injury from cold, states Killian (*Zbl. Chir.*, 1943, No. 2), is the production of heat by contraction and tremors of the muscles. In the resynthesis of the lactic acid thereby formed, an important part is played by the phosphorylation which is controlled by the suprarenal hormones. If the suprarenal hormones are lacking, severe disturbances of muscular metabolism and cardiac metabolism must ensue. Exposure to cold for long periods results in the supplies of cortical hormones being used on account of muscular exhaustion. Since cortical insufficiency enters into the picture of shock and collapse, casualties showing these signs are specially liable to damage from cold. In the second phase of frostbite, where oxygen lack in the tissues is the dominant feature, there is not only an abnormal consumption of "cortin" but an actual lesion of the suprarenals. Cortin, Killian believes, seems to be justified in cases of extensive frostbite, especially those showing toxic symptoms.

MARCH FRACTURE OF THE METATARSAL BONES

BY

H. H. FOURACRE BARNES, M.B., B.S.,
F.R.C.S., M.R.C.O.G.

Flight Lieutenant, R.A.F.V.R.

March fracture, or spontaneous stress fracture, is most often seen in the metatarsal bones, but has been observed in others, including the femur (Peterson, 1942). This type of fracture was well recognized before and during the war of 1914-18. A number of articles have been published recording cases that have appeared during the present conflict.

A Series of Cases during Training

This communication records 20 cases of march fracture of the metatarsal bones that have occurred during the first five months of the training programme at a recruits' training station in the Royal Air Force. The training programme is in two parts. The first part, of three weeks' duration, is devoted mainly to disciplinary training; the second part, of five weeks, covers more advanced subjects, including those which are more strenuous, such as bayonet-fighting, unarmed combat, etc.

The number of recruits passing through the station during the period in which the fractures occurred was several thousand, so that the incidence is small. With three exceptions the patients were from 18 to 21 years of age. This cannot be taken as significant, however, as the age of the majority of the trainees falls within this age group. All the patients were of the highest medical grade (Grade 1) on entering the Service, and their physique was classed as normal in half the cases and medium in the remainder. No obvious foot deformity was observed in the patients. Their histories revealed that the majority, previous to entry into the Service, lacked regular exercise and were in occupations necessitating long hours of standing. Eight of the 20 had been in the A.T.C., in which they did drill from one to three times a week, for periods ranging from three months to two years. All the fractures occurred during the last five weeks of training.

The injuries were sustained during active exercise and were due to indirect trauma. One patient, however, sustained his fracture during a fall at football. His legs were tangled up with those of another player. This is the only case in which direct trauma may have been responsible. Of these 20 fractures, 10 developed during route marches, 2 while bayonet-charging, 2 at drill, and another at football as already mentioned; the remaining 5 could not be ascribed to any particular exercise.

It is usually stated that the onset of symptoms is insidious (Drummond, 1940; Krause, 1942). This was not the common finding in the present series. In 2 of the earlier cases the histories are incomplete, but of the remaining 18 the onset of symptoms was sudden in 12 and insidious in 6.

Pain, localized to the affected bone, is the chief symptom. This is felt on standing, and especially when on the toes. It causes the patient to limp and, when the second or third metatarsal bone is affected, to walk on the outer side of the foot. A sensation of stiffness of the toes is often experienced. This is presumably due to reflex spasm of the interosseous muscles. A few hours after the onset of pain some swelling, which pits on pressure, may be observed on the dorsum of the foot at the base of the toes. There is localized tenderness, but bruising has not been noticed in the present series. The right foot was affected in 10 patients and the left in 10 also. There were 15 fractures of the third metatarsal, 3 of the second, and 2 of the fourth. In the large series of cases analysed by Tobold (1903) and Jansen (1926) the fracture was found to occur more frequently in the second metatarsal bone.

Radiography in Diagnosis

In order to confirm the diagnosis of the early case first-class x-ray pictures are needed. In the present series two views of the foot were taken—an antero-posterior with the foot in the normal standing position, and another antero-posterior with the foot in the everted position, thus taking an oblique view of the foot. In a number of cases no fracture was to be seen in the antero-posterior view but could be seen in the oblique view. This is due to the fact that the earliest signs of fracture