pasteurized milk as an antiscorbutic food is open to question because of the possibility that such milk may cause other infections.

We may therefore conclude that the maintenance of an adequate vitamin C intake is the responsibility of all those interested in the growth and development of children, and that the question of a reliable intake in all age groups and economic brackets is one of practical concern.

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RÉSUMÉ

L'auteur présente 37 cas de scorbut constatés depuis 1945. Malgré les progrès dans l'alimentation des enfants le scorbut n'est pas encore une maladie entièrement disparue. Tous les cas ont été diagnostiqués cliniquement et radiologiquement, sans dosage de la vitamine C. Les signes les plus fréquents furent, des douleurs dans les jambes, de l'irritabilité et de l'œdème. Très peu souvent on trouva des gencives hémorragipares. L'anémie fut constatée dans la plupart des cas. L'auteur explique ces déficiences en vitamine C par les faits suivants. Ou bien les enfants reçoivent une quantité suffisante de jus d'orange mais ce dernier est chauffé avant l'administration, ou bien il s'agit de négligence de la part du médecin ou des parents. L'auteur suggère qu'un questionnaire de routine soit toujours fait par le médecin traitant pour s'assurer que l'enfant recoit une quantité suffisante de vitamine C synthétique ou sous forme de jus d'orange.

YVES PRÉVOST

CLINICAL USE OF THE OXIMETER*

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THE degree of oxygen saturation of the peripheral arterial blood is a matter of fundamental importance in health and disease. Clinically, the only definite means of determining that there is oxygen unsaturation of the arterial blood has been the sign of cyanosis. This, unfortunately, is a very crude indication of anoxæmia, for it is well established that there must be a considerable degree of unsaturation before the amount of reduced hæmoglobin is sufficient to result in a blue colour.[1, 2] In a subject with a normal hæmoglobin, the oxygen saturation of the arterial blood must be reduced from the average normal of approximately 98% to between 65 and 70%. At this level approximately 10 grams of hæmoglobin in each 100 c.c. of blood will bear oxygen and 5 grams will be reduced hæmoglobin. These calculations serve to indicate the marked reduction in oxygen saturation which must occur before the classical clinical sign of anoxæmia, cyanosis, becomes evident.

The desirability of having a more subtle means of determining the lesser degrees of oxygen unsaturation is apparent. This may be done by arterial puncture with subsequent analysis of the blood by the technique of Van Slyke and Neill.[3] This procedure involves discomfort, it is time-consuming, and it is not applicable to routine clinical practice. The efforts of the past few years in devising a clinically applicable method to determine oxygen saturation have resulted in extensive studies in oximetry, a term which is applied to the study of oxygen saturation of circulating blood by photoelectric techniques.

The manner in which an oximeter is employed is as follows. An earpiece is attached to the pinna of the ear. It has been established that when the ear is flushed with heat, the blood contained within it has an oxygen content practically equivalent to that in the peripheral arteries. On one side of the ear is an electric bulb from which light of known intensity is emitted. The heat of this lamp causes the necessary vasodilatation. This illumination passes through the substance of the pinna to fall upon two filters—an infra-red filter and a red filter. Light which has been transmitted through the ear and through these filters then falls upon two light-sensitive photoelectric selenium cells. The potential developed by these cells is impressed upon a sensitive galvanometer and recorded as a spot of light illuminating a scale, from which calculations may be determined to ascertain the percentage saturation.

It is apparent that the pinna varies in its characteristics from one individual to another. Ears differ as to thickness, pigmentation and concentration of the hæmoglobin contained within their blood vessels. Various means are employed to account for these differences, the necessary deductions being obtained partly from changes in the incident light which has passed through the infra-red filter. Wood[4] employs marked pressure to compress the ear, rendering it bloodless, and taking measure-

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ments in the bloodless state and when it is flushed. With the use of the present instrument[5] it is unnecessary to compress the ear.

The red filter transmits light of wavelengths above about 600 millimicrons. Light rays in the band of about 620 to 680 millimicrons are more freely transmitted by oxygenated hæmoglobin than by reduced hæmoglobin. The transmission of light by hæmoglobin bears a logarithmic relationship to the percentage of its oxygenation. More light in this wavelength is transmitted by oxygenated hæmoglobin and less by reduced hæmoglobin.

A brief résumé of the history of the oximeter will indicate the impetus provided by the war in the practical development of this type of instrument. The German scientists Kramer[6] and Matthes[7] independently in 1934 published methods for the determination of the oxygen saturation of arterial blood by means of photoelectric cells. The greatest advance in bringing about the ready clinical use of this concept was made by Millikan[8] in 1942 when he was faced with the problem of determining oxygen saturation of peripheral arterial blood of U.S. Air Force flyers at various altitudes. After the war, Wood[4] was the first to develop an oximeter for the recording of absolute measurements of the percentage saturation of peripheral arterial blood.

Clinical studies in oximetry have included reports concerning congenital heart disease, acquired cardiac and pulmonary disease, poliomyelitis and anæsthesia. Gullickson *et al.*,[9] Montgomery and co-workers[10] and Bing[11] have observed the fall in oxygen saturation in patients with cyanotic types of congenital heart disease with exercise, and the delayed rise in oxygen saturation in these patients when breathing oxygen as compared with the rapid response in normal individuals. Godfrey and his associates[12] employed the Millikan oximeter in the study of cases with cardiac and pulmonary disease. Their results are in terms of the "oximeter response" when the subject changes from breathing room air to 90 to 97% oxygen. They noted that oximeter studies enabled a better assessment of the need and efficacy of oxygen therapy, and that anoxæmia was recognized which would otherwise have been overlooked. Elam and co-workers,[13] using the Millikan-Smaller oximeter, have reported on the usefulness of oximetry in studies of pulmonary function in poliomyelitis. They stress the high incidence of hypoxia in patients with acute poliomyelitis of spinal, bulbar, and bulbospinal types, and in convalescent patients, and noted that alveolar and ventilatory function could be assessed by oximetric studies.

With reference to the control of anoxæmia during surgical anæsthesia, McClure *et al.*,[14] using their oxyhæmograph, have graphically recorded relative changes in oxygen saturation, and have made observations on the effects of various anæsthetic agents on oxygen saturation of the peripheral arterial blood. In studies on anoxia tests for cardiac function, Pennys and Thomas[15] have demonstrated that the oximeter may be used to control the level of anoxæmia, and concluded that this was a more reliable procedure than having the patient breathe a gas with fixed oxygen concentration. The majority of the studies noted above were carried out with instruments which provided relative oxygen saturation percentages.

The oximeter,[5] Fig. 1, which has been employed in the determinations to be noted presently, has been developed as a joint project

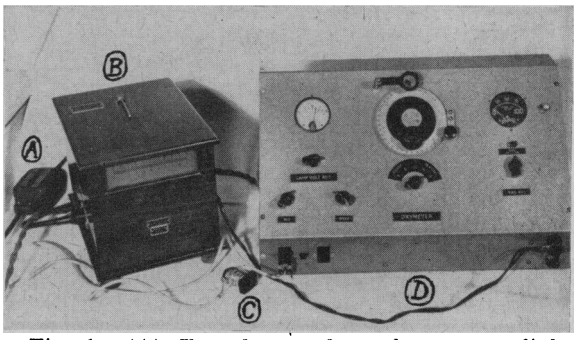

Fig. 1.—(A) Transformer for galvanometer light. (B) Galvanometer. (C) Millikan earpiece. (D) Oximeter. Power source is 115 volt A.C.

of the Department of Physiology, McGill University, and the Children's Memorial Hospital. It is based upon the same spectral properties as is the Millikan oximeter. It differs from the latter, however, with respect to its conception, electrical circuits and operation. The Millikan earpiece has been used. There are disadvantages to this earpiece, and if it is left on the ear for more than 25 to 30 minutes, it is possible to cause a 2nd degree burn. A new earpiece has been developed which will permit longer use without the hazards of a burn, is smaller, and may be fitted to the smallest ear.

This oximeter permits calculation of absolute values of percentage oxygen saturation. It is *not* necessary to preset the instrument with the patient breathing oxygen. The oxygen saturation percentage may be quickly obtained by the use of a nomogram, without the necessity of mathematical calculations. Changes in oxygen saturation are indicated immediately by the movement of the light beam on the galvano-

meter scale. If a normal subject is breathing room air when the earpiece is applied, an absolute value of oxygen saturation percentage can be determined. If a patient is suspected of having some degree of hypoxia or anæmia when the earpiece is first applied, the oxygen saturation may be known if the hæmoglobin level is determined. In a cyanotic patient with a right-to-left shunt, an absolute value can also be calculated if the hæmoglobin content of the blood is known. In subjects with a normal circulation the average accuracy of the instrument is ± 2½% as compared with the values obtained by Van Slyke analysis in a percentage saturation range between 40 to 100%. In patients with a right-to-left shunt the accuracy is approximately within ± 5%. The instrument can be used for coloured individuals.

Value in Anæsthesia

It will be quite apparent that the chief clinical use of the oximeter is in anæsthesia. By its means the anæsthetist may know from moment to moment the degree of oxygen saturation of his patient. This he knows only crudely without the oximeter, for the main indication he has of a reduced oxygen saturation is cyanosis.

A few examples may be cited to indicate the information provided to the anæsthetist. In

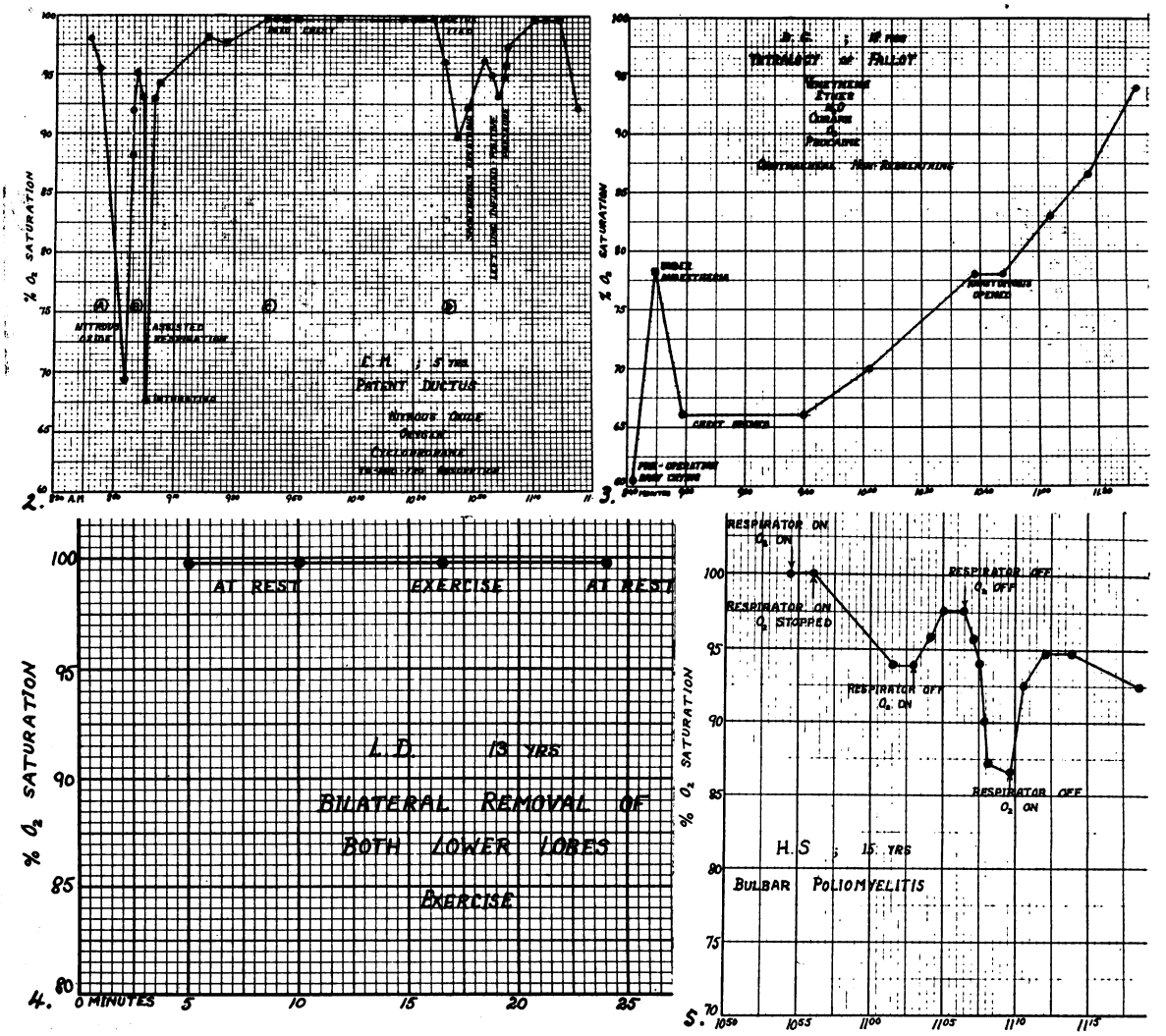

Fig. 2.—Between (C) and (D), when one lung was collapsed, arterial saturation remained at 100% when abundant oxygen was supplied and respirations were assisted. (A) During induction phase, note decrease in saturation when oxygen supplied is less than 20%. (B) Fall in saturation is due to spasm associated with endotracheal intubation. **Fig. 3.**—Note that under anæsthesia with added oxygen the oxygen saturation rises. After the Pott's anastomosis was opened the oxygen saturation rose rapidly. Oxygen was supplied continuously. **Fig. 4.**—Despite the absence of both lower lobes and the right middle lobe, full oxygen saturation was maintained during exercise. **Fig. 5.**—Note that adequate oxygenation could not be maintained without the aid of mechanical respirator.

thoracic operations the question has frequently arisen as to how well oxygenation can be maintained when one lung is collapsed. The data shown in Fig. 2 indicate that satisfactory oxygen saturation may be maintained in the peripheral arterial blood when high concentrations of oxygen are inspired and the patient's respiration is assisted. During operation for ligation of a patent ductus arteriosus, the left lung was collapsed, but normal oxygen saturation was maintained. It is of interest to note also that during induction with nitrous oxide, the oxygen level fell. This was due to there being less than 20% oxygen in the inspired mixture. There was a second fall in oxygen saturation associated with spasm during the endotracheal intubation.

The oximeter is of particular help to the anæsthetist during operations on patients with congenital heart disease of the cyanotic type. A patient aged 18 months with the tetralogy of Fallot, undergoing a Pott's type of anastomosis, showed changes in oxygen saturation illustrated in Fig. 3. It is observed that under anæsthesia with added oxygen the patient's arterial oxygen level is higher than that noted prior to anæsthesia. The level of oxygen saturation is fairly well maintained, despite the collapse of the left lung. Following the establishment of the Pott's anastomosis, the oxygen saturation rose in a very satisfactory manner. Oxygen was supplied continuously.

The oximeter can be of help in assessing postlobectomy cases. In the instance of a 12-year old boy, (Fig. 4) who had undergone bilateral removal of the lower lobes and the right middle lobe, it was easily demonstrated a few months postoperatively that during exercise he was able to maintain a normal oxygen saturation.

In the assessment of cases with congenital heart disease, the oximeter has been of value. Exercise tolerance may be measured objectively in terms of a fall in oxygen saturation. A patient, aged 12 years, with congenital heart disease of the cyanotic type, had an oxygen saturation of 73% at rest. While breathing oxygen the saturation percentage rose to 90%. It required 3½ minutes to demonstrate this maximal response. With light exercise the oxygen saturation fell rapidly to 57%.

The removal of a patient with bulbar poliomyelitis from the mechanical respirator is frequently fraught with difficulty. Considerable aid may be given by recording the percentage oxygen saturation when in the respirator and for any desired time after the patient has been taken out of it. Inasmuch as a patient frequently experiences marked apprehension and emotional instability when removed from a mechanical lung, this perfectly objective evidence of the efficiency of the patient's respiratory exchange is of help, both to patient and physician. In the case illustrated in Fig. 5, it was noted that adequate oxygenation could not be maintained for any length of time without the aid of the mechanical lung.

In any problem concerned with oxygen therapy, the oximeter will provide information regarding the need for oxygen and the efficacy of therapy.

It will readily be appreciated that the oximeter has a wide clinical use. The cases cited are examples of how it may be employed, and many other instances come readily to mind. It has great value in teaching the principles of oxygen unsaturation and oxygen therapy. Many investigative problems become possible or are facilitated through its use. At the present time the drawback of the instrument described is that it is a delicate apparatus and must be operated by a trained technician. An instrument is now being completed which is similar in principle but rugged in construction, and with an electronic calculator incorporated which it is hoped will provide a direct reading of the percentage oxygen saturation.

We wish to express our appreciation to Miss Carol Horsborough, Mrs. Joan Oliver, Miss Lesley McBride and Miss Nancy McGill for technical and secretarial assistance which has facilitated these studies.

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