daily, using half a pint at each douching, as recommended by F. H. Thomson, E. J. Mann, and H. Marriner.

Should these measures fail after three or four weeks' conscientious trial, the nasopharynx should be thoroughly examined by a throat specialist with a view to operative treatment. In throat carriers tonsillectomy can be relied on to terminate the carrier state in practically every case. Nasal carriers should be examined with a view to clearing out such defects as hypertrophied adenoids, enlarged turbinates, or deflected septa. Ear cases, in which the diphtheria bacillus is usually associated with a chronic otitis media, may require a mastoid operation. Proof of the termination of the carrier state should only be accepted when the patient has given three consecutive negative cultures at weekly intervals.

TESTS FOR RESPIRATORY EFFICIENCY

A CRITICAL REVIEW

BY

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Ever since the researches of Hutchinson on vital capacity in the middle of the last century many workers have considered methods which might be of help in assessing respiratory efficiency. Dr. Alan Moncrieff, in a recent valuable monograph,¹ gives an admirable survey of the tests which have been recommended in the past. After careful consideration of them all he selects four of these as giving the most useful and reliable information, and describes the results of applying these tests in a group of eighty-six patients suffering from various pulmonary affections. The tests employed were the measurement of the vital capacity, the determination of the ventilation equivalent for oxygen, the measurement of the dead space, two tests with the mercury tube (the maximum height to which the mercury column can be raised by an expiratory effort and the time for which the mercury can be maintained at a level of 40 mm.), and the ratio of expiratory to inspiratory time as shown by graphic records. A careful and detailed account is given of the way in which the tests are best carried out, and it is explained how they can be completed in less than ten minutes. Dr. Moncrieff has classified his cases according to the clinical estimate of their respiratory state into "good," "fairly good," "fair," "poor," and "bad," and has attempted to correlate the clinical assessment with the results obtained from the use of the tests that have been enumerated.

VITAL CAPACITY

The vital capacity, as is well known, depends on the age, sex, height, weight, and the physical fitness and occupation of the subject. Normal standards have been worked out with which the figures obtained in patients can be compared. It may be reduced by 20 to 30 per cent. by physical weakness uncomplicated by organic disease. Moncrieff's studies show that on an average there is a fairly satisfactory relation between the clinical estimate of respiratory inefficiency and the degree of reduction of the vital capacity. The averages for the cases labelled "bad," "poor," and "fair" were 36, 54, and 69 respectively (with 100 taken as the normal standard), against 76 and 97 for the groups described as "fairly good" and "good." In the "poor" group all the cases had a vital capacity below 74, but in the "fairly good" nineteen out of thirty-one, and in the "fair" seven out of twenty-nine, had a capacity of 75 or over. It seems, then, that significance can only be attached to a low figure for the vital capacity. In none of the cases described as "good" did the vital capacity fall below 70. A case is, however, quoted

which serves as a warning of the limited value of an isolated test—that of a man whose clinical state was "fair" and who suffered from a pneumothorax. His vital capacity was well above the normal.

VENTILATION EQUIVALENTS

The term "ventilation equivalent for oxygen" was introduced by Anthony in 1930, and is defined as the volume of air inspired (in litres) per 100 c.cm. of oxygen consumed; in the normal subject its value is on an average 2.5 litres. By expressing the pulmonary ventilation in this fashion variations due to differences in metabolic rate and consequently in oxygen consumption are excluded. The ventilation equivalent and the respiratory exchanges can be readily determined by means of a modified Knipping apparatus, and convincing evidence is provided that this method is reliable; it has the advantage over the usual Benedict-Roth type of apparatus that the carbon dioxide output as well as the oxygen consumption can be measured.

The ventilation equivalents in Moncrieff's series were quite irregular in their distribution both in respect of the average in the different groups and the range within each group. This is not altogether surprising when one bears in mind that the ventilation equivalent is, as explained, simply a measure of the amount of respiratory effort involved in obtaining a standard volume of oxygen. It must be remembered that breathing serves other purposes than the provision of oxygen. It is affected, for example, by alterations in blood reaction; thus in states of acidæmia (such as occur in diabetes or nephritis) the pulmonary ventilation is increased not to provide oxygen but to eliminate excessive amounts of CO₂ in order to preserve the normal alkalinity of the blood. Though the ventilation equivalent would be high in such conditions it does not indicate respiratory insufficiency, but merely means that breathing is being used for a purpose other than the provision of oxygen. The hyperpnoea produced by emotional causes would result in a similar raising of the ventilation equivalent, but would throw no light, of course, on the state of the respiratory apparatus. It is likely that such emotional hyperpnoea occurs very commonly in patients who are being examined with novel apparatus. On the other hand, in states of central respiratory depression such as that produced by morphine poisoning the ventilation equivalent would be low. That merely means that breathing is becoming inadequate for its purpose rather than indicating a high level of respiratory efficiency.

SIZE OF DEAD SPACE

The size of the dead space is calculated from a knowledge of the composition of the expired and the alveolar air and the measurement of the tidal air, the formula employed being:

$$\text{Dead space} = \frac{\text{Tidal air (CO}_2\% \text{ in alveolar air} - \text{CO}_2\% \text{ in expired air)}}{\text{CO}_2\% \text{ in alveolar air.}}$$

It must be acknowledged that alveolar air determinations are difficult to carry out accurately in untrained subjects. In all probability the anatomical dead space—or in other words the actual capacity of the respiratory passages—alters comparatively little in different conditions, and is only affected by constriction or dilatation of the bronchioles. Calculated in the manner described above, the dead space usually amounts to about 150 c.cm. and constitutes 25 to 30 per cent. of the tidal air. In some conditions the apparent or calculated dead space rises to 500 or 600 c.cm., and may constitute 60 or 70 per cent. of the tidal air. These figures cannot represent a true anatomical change, but indicate that a larger proportion of the tidal air is functioning as dead space in the sense that it is not helping to remove carbon dioxide from the alveoli of the lungs. Moncrieff very properly suggests that the dead space should be expressed not as a volume but as a percentage of the tidal air, and put in this way it indicates what proportion of each respiratory effort is being turned to good use in eliminating CO₂. Dead space determinations carried out in this way are influenced very readily by emotional hyperpnoea, and this probably reduces the value of the test in untrained subjects. On the whole, Moncrieff's results show that there is little correlation between the size of the dead space and the clinical state of the patient. In all probability this is because the factors which have been

¹ *Tests for Respiratory Efficiency*. By A. A. Moncrieff. Medical Research Council Special Report Series, No. 198. H.M. Stationery Office. (1s.)

mentioned as modifying the ventilation equivalent similarly influence the determination of the dead space.

The average results with both types of mercury U tube tests in Moncrieff's series fall well below the standard minima required by the Air Force regulations; these latter are probably too high for the hospital population, but the results obtained are shown to fall below the average for hospital out-patients not suffering from cardio-respiratory disease. Unfortunately, there were a considerable number of individuals in each group who reached or attained the normal standards, and this limits the value of the test in practice.

The expiratory to inspiratory ratio obviously throws light on cases of asthma, and it is further claimed by some workers that what they call the respiratory style of the individual may bear some relation to the ease with which dyspnoea can be induced.

COMPLEXITY OF THE PROBLEM

Moncrieff's historical review and the results which he has obtained prove very clearly that tests for respiratory efficiency present a more complex and less readily solved problem than that which has to be faced when one attempts to assess cardiac or renal function. The heart and kidney are, after all, merely organs, while breathing is a function which depends for its effective execution on the nicely co-ordinated activity of the brain, spinal cord, and peripheral nerves, various groups of muscles, the respiratory passages, and the lung substance. It has to perform a number of tasks, such as the provision of oxygen, the elimination of carbon dioxide, the regulation of blood reaction, and the maintenance of normal temperature; and it is influenced by numerous nervous and humoral factors. The question is further complicated by the fact that a good deal of confusion appears to exist as to what exactly is meant by the term "efficiency" as applied to respiration.

When we talk of the mechanical efficiency of a muscle we refer to the degree of economy of the process in the sense of how large a proportion of the total energy of the chemical reactions taking place during contraction is converted into mechanical work. This sort of idea seems to be behind the ventilation equivalent and the dead space tests. But it has already been pointed out in respect of the ventilation equivalent that it is only a measure of the economy of breathing in relation to one objective—namely, oxygen consumption. The breathing may be extravagantly large for this purpose, but still be well adapted for serving some equally urgent need such as the regulation of blood reaction.

The dead space determination measures two forms of efficiency: first, the proportion of the air inhaled which is used for alveolar ventilation; and, secondly, the efficiency with which CO_2 is being eliminated. Ventilation may in certain circumstances appear excessive and wasted from the point of view of CO_2 elimination and yet be just adequate for other purposes, as, for instance, in states of anoxia where the overruling aim is to supply sufficient oxygen. It has already been sufficiently stressed that both the ventilation equivalent and the dead space measurements are frequently vitiated by the presence of hyperpnoea resulting from the emotional excitement which accompanies the test, and the determinations may frequently not be indicative of the normal style of breathing. The other sense in which respiratory efficiency might be used is as a measure of the ability of the breathing apparatus to carry out its functions satisfactorily under conditions of increasing strain. When we test cardiac efficiency we see how much work an individual can do in a given time without the development of pain or undue respiratory distress. Similarly in the case of renal tests we study the power of eliminating large quantities of water or waste products and the degree to which the normal composition of the blood can be maintained.

Looking at breathing from this point of view a new series of possible tests present themselves which appear to have a sound physiological basis. One could determine, for instance, the degree of increase in the ventilation in response to excess of CO_2 in the inspired air; the degree to which the alveolar CO_2 level is kept constant in such circumstances; the response to varying grades of oxygen lack; the response to acidaemia or alkalaemia produced, for example, by the ingestion of ammonium chloride or of sodium bicarbonate. A great deal of information is already available about the normal reactions to such tests, and their study in respiratory disease might be of considerable value, and seems to present a promising field of investigation. It must be confessed, however, that such tests are very elaborate, and would involve the expenditure of considerable time and effort. For general clinical use much simpler tests would be desirable, but Moncrieff's review clearly shows that on the whole the tests that have been devised in the past give information of only limited value.

WHEN TESTS ARE ESSENTIAL

The whole question is still further complicated by the fact that breathing is nicely co-ordinated with the circulation so as to serve the purpose of effecting satisfactorily gaseous interchanges between the outside air and the tissues. In examining the response to exercise both the circulatory and the respiratory systems are being tested. It is probably fair to say that in the absence of disease of other organs or systems dyspnoea occurring too early, or limitation in the field of response, would be indicative of insufficiency of the respiratory apparatus. It is possible that the usual tests of cardiac efficiency could be modified to throw light on respiratory function. It must be recognized, however, that it is only in a limited number of cases that one would require objective tests of this character to aid one in assessing the present condition and future progress of an individual patient. A routine clinical and radiological investigation and a wide experience would, in the majority of instances, give all the information required. There is, however, a group of cases in which further help is urgently needed, and one has in mind especially patients who are to be subjected to surgical procedures such as thoracoplasty. In these one ought really to consider the various stresses to which they are going to be subjected during the course of the operation and to try to determine in advance, as far as possible, what effect they are likely to have on the state of the patient. It is more a case of assessing the patient's ability to withstand a series of shocks than of determining his respiratory efficiency in either of the ways in which it has been defined.

A. I. Goldschlager (*Arch. Int. Med.*, February, 1935, p. 939), who records eight cases, states that trichinosis occurs more commonly than is generally known, as is shown by the following figures: 263 cases from fifteen States were reported by the United States Public Health Service in 1932, and 208 cases from thirteen States in the first nine months of 1933, more being reported by New York and California than by any other State. All Goldschlager's cases, which occurred in patients aged from 16 to 60, were due to consumption of imperfectly cooked pork or sausages. Oedema of the eyelids, intense headache, and pain on flexing or extending the neck were the outstanding features of all the cases. The intradermal tests introduced by Bachmann in 1928 were positive in all cases in 1 in 100, 1 in 1,000, and 1 in 10,000 dilutions. The results of precipitation tests were less positive. It is stated that all the patients recovered. Mild trichinosis may very easily be overlooked or mistaken for influenza or other infectious diseases.