A British Medical Association Lecture

ON

THE CAUSE AND TREATMENT OF DYSPNOEA
IN CARDIO-VASCULAR DISEASE.*

(Abridged.)

BY

JONATHAN MEAKINS, M.D., F.R.C.P.E.,

CHRISTISON PROFESSOR OF THERAPEUTICS, UNIVERSITY OF EDINBURGH;
PHYSICIAN, ROYAL INFIRMARY, EDINBURGH.

DYSPNOEA is an extremely common symptom in cardio-vascular disease; it is, in fact, so common that it is almost held to be pathognomonic of some cardiac disturbance.

NATURE AND CAUSES OF DYSPNOEA.

What is dyspnoea? The following short definition may be given: Dyspnoea is the consciousness of the necessity for increased respiratory effort.

How is dyspnoea produced? If we confine this question to the diseases under consideration we may say that it is usually produced by two causes: (1) want of oxygen; (2) carbon dioxide retention, relative or absolute. Either of these or both must occur in the cells, which represent the functioning units of the body. The types of dyspnoea produced by these two factors are somewhat different, and in order to explain the differences it is best to take them up separately. If either condition be produced suddenly the symptoms will be much more violent than if the process were an insidious one.

In oxygen want there is always the question of the quantity or partial pressure of carbon dioxide present in the blood and also in the cells. If the oxygen want is acute, there remains a certain amount of carbon dioxide which has to be got rid of, as oxygen want makes the respiratory centre more irritable than normally to a given partial pressure of carbon dioxide. This has an important practical application. In mines where there is a rapidly increasing amount of black-damp, the presence of a sufficient amount of carbon dioxide gives the miner warning, as it produces panting and respiratory distress. In slowly increasing black-damp without carbon dioxide he gets rid of the carbon dioxide in his body by moderate over-ventilation and may lose consciousness without any appreciable distress.

The uncomplicated effect on respiration of increased carbon dioxide is best shown in acidosis, such as may occur in advanced cases of diabetes mellitus. In such cases, although the carbon dioxide be not increased, the hydrogen-ion concentration of the blood is increased, and it is by acting in a similar manner that carbon dioxide influences respiration. If the oxygen saturation of the blood be decreased and the carbon dioxide increased respiratory failure is apt to occur very quickly. This is really asphyxia, as is found in acute obstruction of the larynx. In such circumstances there is the typical deep purple cyanosis of suffocation.

Dyspnoea in Cardio-vascular Disease.

Dyspnoea in cardio-vascular disease may be produced in two ways. One may be called the pulmonary method, and the other the circulatory method. In the pulmonary method anything that interferes with the proper aeration of the blood as it passes through the lungs may produce it. If the lungs remain normal, there being no oedema, congestion, nor gross exudate into the pleural cavity, the arterial blood will contain a normal quantity of oxygen. There is no decline of oxygen saturation of the blood as it passes to the systemic arterioles. We have been able to show this quite conclusively by examining the arterial blood of many cases of auricular fibrillation, valvular disease, and myocardial degeneration with and without pulmonary complications. If oedema of the lungs should develop there will occur a decrease in the oxygen saturation of the arterial blood. This may usually be inferred from the physical signs

in the lungs and the degree of cyanosis. If oxygen be given under these conditions the saturation of the arterial blood will as a rule rapidly return to normal. Even at rest certain of these patients have violent dyspnoea, orthopnoea, and Cheyne-Stokes breathing. As soon as oxygen is given the symptoms disappear and the patients become quite comfortable. At the same time there is no immediate change in the character of the physical signs in the lungs. This would indicate that by increasing the partial pressure of oxygen in the alveolar air from 100 to 280 mm. the diffusion of oxygen through the swollen alveolar cells and the alveolar exudate is greatly increased. Such an increase would naturally be expected. For this reason the blood has less difficulty in becoming adequately saturated with oxygen. In auricular fibrillation we found no accompanying reduction in the pulse rate to account for this improvement. Certain cases had very pronounced cyanosis with delirium, but on inspiring air with a high partial pressure of oxygen the cyanosis and delirium disappeared and the oxygen saturation of the arterial blood returned to normal.

These are cases of what one might call the pulmonary type of dyspnoea and cyanosis in cardiac disease. It is the dyspnoea which occurs when there are numerous crepitations and perhaps sonorous râles in the lungs. These signs are due to swelling of the epithelium of the bronchioles and alveoli and exudate into the alveolar spaces—conditions which interfere with the respiratory function. On the other hand, there may be a moderate hydrothorax compressing part of one lung through which the blood is still circulating. If that be the case the compressed lung will not aerate, the blood returning would merely pollute the fully aerated blood from the rest of the lungs. It is only in cardiac cases with indications of such pulmonary lesions that the administration of oxygen will relieve the dyspnoea, cyanosis, and other pulmonary symptoms.

On the other hand, there is another factor which must not be overlooked. This is the influence of vascular engorgement on the respiratory movement and pulmonary ventilation. This point I will defer until I take up the question of the circulation as a whole.

Effect on Cells.

We now come to consider how interference with the general circulation affects the cells of the various organs, because it is the cell, as it occurs in its aggregate to form the organic units or functioning organs, that gives rise to pathological symptoms or signals of distress. As is well known, interference in the local circulation, such as results from occlusion of an artery, may produce death of the distal portion. This is really local asphyxia. Such vascular interference may be partial or complete, and thus the consequences may vary in degree—as, for instance, hemiplegia or mental degeneration, gangrene of the toes or "intermittent claudication," rupture of the heart or angina pectoris. On the one hand the myocardium and the brain may continue to function normally until renal degeneration due to arteriosclerosis leads to a general breakdown. You may, on the other hand, have stenosis or obliteration of a coronary artery. If a sufficient quantity of the myocardium is asphyxiated then the myocardial symptoms may predominate. In other circumstances symptoms due to cerebral degeneration may play the principal part. If, however, the arteries are fairly healthy, but some valvular or myocardial lesion interferes with the general circulatory efficiency, then widespread symptoms may develop. In so far as such lesions reduce or limit the amount of blood circulated per minute in relation to the amount of work attempted, so symptoms occur. In the average individual at rest the blood flow per minute through the heart varies between 5 and 8 litres according to sex and development. An increased circulation is usually accomplished by an increase of the cardiac rate, but in some instances this is also brought about by an increased output per beat. The systole is more complete. Therefore not only is the rate to be taken into consideration but also the completeness of the systolic contraction. Barcroft and others have reported a case of acute paroxysmal tachycardia where the cardiac rate increased to 185. The minute blood flow was one-half what it was under normal conditions, and the output per beat decreased from 76 c.cm. to between 16 and 13 c.cm.

* Delivered before the Dundee Branch of the British Medical Association, March 14th, 1923.

In cases of auricular fibrillation and flutter a similar sequence of events occurs, although the decrease in the blood flow per minute is not as a rule so pronounced. Usually when the ventricular rate is increased above 100 there is a distinct decrease in the output per beat. This, of course, becomes much more apparent as the rate increases.

In mitral stenosis without evidence of myocardial disease, such as great cardiac enlargement, there is a very pronounced decrease in the output per minute and also on each systolic contraction. This decrease is particularly obvious when the individual attempts to do work. Tachycardia very rapidly supervenes and the blood flow may increase from 2 litres to as much as 5 litres per minute. This as a rule makes it necessary that the pulse rate shall increase two and a half times—that is from 70 to 180. The output per beat has never yet been found to be increased in this condition. Such a limitation of cardiac output necessarily limits the amount of exertion possible; in fact, in certain cases merely walking slowly about the room produces severe symptoms.

It might be supposed that in patients with greatly enlarged heart, but without any evidence of valvular disease, as well as hypertrophy of the wall, the capacity of the ventricular cavity would be greatly enlarged. If such a heart were completely emptying itself at each systole the amount of blood circulated per minute would be much above normal. It is found, however, that this is not the case, the output per minute being approximately normal if there are no symptoms at rest. On exercise, however, the symptoms may become extreme, while the cardiac output per minute is but slightly increased, although the cardiac rate may be greatly increased. When cardiac failure occurs there is a sharp decline in the output per minute as well as in the output per beat. The obvious conclusion is that the ventricular systole in these circumstances is not complete. Instead of the ventricle expelling 100 c.cm. per systolic contraction, as is found to occur frequently in these cases of enlarged heart, the output per beat may be only 15 to 25 c.cm. This occurs in spite of the fact that physical examination may give evidence of the cardiac dullness being increased. This is probably what occurs in acute and chronic cardiac failure. In such circumstances the ventricle on each contraction does not completely empty itself, and there is consequently a residue of blood left in the ventricle at the beginning of the diastole. This corresponds to the difference in the capacity of the ventricular cavity and the amount expelled at each systole. As the amount of this residue increases, so the symptoms of cardiac failure become more pronounced.

This decrease of circulation rate, whether due to pathological tachycardia, mitral stenosis, or myocardial inefficiency, is probably one of the most important factors in the production of symptoms in cardiac disease, but the question naturally arises as to how a decrease of blood flow would produce symptoms. There are many other symptoms besides dyspnoea—fatigue, exhaustion, vertigo, cyanosis, vomiting, loss of consciousness, etc. All these symptoms may be produced by a deficiency of oxygen and an increase of carbon dioxide in the cells. It is well known that the rapid circulation of blood through a part keeps up the partial pressure of oxygen and diminishes that of carbon dioxide. If, on the contrary, the blood flow becomes slow, the partial pressure of oxygen diminishes and that of carbon dioxide increases. This brings about in the cell a condition of cellular asphyxia and acidosis. In such circumstances there occurs a swelling of the cell, and fluid, chlorides, bicarbonates, and other salts, pass from the blood into the surrounding tissues and tissue spaces. The blood coming from the part becomes more concentrated and acid. This, we believe, is a most important contributing factor in the production of oedema and other symptoms in cardiac cases.

Such a condition occurring in the cells would affect the respiratory centre as well as other portions of the body. The severity of the symptoms will be influenced not only by the degree of slowing of the circulation but, as has already been pointed out, by the suddenness of the disturbance. If the organism be given time to accommodate itself to the new conditions, or if the new conditions develop slowly, it will be found that the skeletal blood flow is very much reduced. This is brought about in order that the blood supply to the nervous system, suprarenals, heart, liver, and other vital

organs, may be sufficient. If the general blood flow is still further reduced symptoms will then develop even when the body is at physical rest. If exertion be undertaken the muscles as functioning organs will require an increased blood supply which can only be provided at the cost of the blood supply to the viscera. Therefore symptoms will appear even though they were not present during the resting state. Consequently it can be seen that the symptoms in cardio-vascular disease are merely an index of the ratio between the blood flow and the amount of work done at the moment. The severity of the symptoms in relation to the work done bears a direct ratio to the inadequacy of the general circulation. From the severity of the symptoms and the appearance of the patient one can obtain a much better working index of the severity of the lesion than from the physical signs.

Late Symptoms of Cardiac Failure.

As cardiac failure progresses symptoms appear even at rest. There may be constant cyanosis, orthopnoea, and varying degrees of Cheyne-Stokes breathing. It has been demonstrated by Haldane, Meakins, and Priestley that the recumbent position is more apt to lead to irregular respiration than is the upright one. Further, that any interference with the pulmonary expansion or ventilation aggravates this respiratory irregularity. This may be caused by anything which interferes with the action of the diaphragm, such as hydrothorax and ascites. In addition there is the important factor of pulmonary engorgement. The lung has somewhat the character of an erectile tissue, and with engorgement or exudate into its spaces its elasticity is very much diminished. That such limitation of expansion, and therefore of ventilation, occurs in cardiac cases is very well known and can be demonstrated by the great decrease in the vital capacity of the lungs. There is no disease where this is diminished to such an extent as in cardiac failure.

Therefore when the cells of the body, and with them those of the respiratory centre, are suffering from a more or less severe asphyxia due to diminished circulation, one of the natural responses is by an increased pulmonary ventilation. This can best be accomplished by the patient assuming the upright position. With this increased capacity for breathing, over-ventilation occurs and the amount of carbon dioxide removed is greater than the oxygen taken in. A period of apnoea, therefore, will ensue, which in its turn is followed by a period of hyperpnoea, and thus more or less pronounced periodic or Cheyne-Stokes breathing is produced.

Dyspnoea in Arterial Disease.

In cases of arterial disease without evidence of a primary cardiac lesion, dyspnoea, orthopnoea, and Cheyne-Stokes breathing may frequently occur. In these cases the interference with the blood flow results from arterio-sclerosis with diminution in the number of arterioles as well as a decrease in the lumen in the larger vessels. As a result increased blood pressure usually ensues. This in time may show a secondary decline due to myocardial failure, and consequently the local blood supply is decreased. There is cellular asphyxia, which in turn stimulates a temporary increase of the blood pressure and therefore of the local blood flow. This for the moment supplies the cells with the necessary quantity of oxygen, but the hyperpnoea resulting from the cellular asphyxia produces an increased elimination of carbon dioxide, and as a consequence a condition of acapnia is produced leading to a period of apnoea. In this manner periodic breathing is perpetuated. The acute attacks of dyspnoea and the violent periods of hyperpnoea in this type of periodic breathing are probably the symptoms which occur in so-called cardiac asthma.

TREATMENT OF CARDIO-VASCULAR DYSPNOEA.

In regard to treatment, it is necessary to have a clear understanding of the underlying conditions producing dyspnoea in order that the symptoms may be relieved. As they are fundamentally due to lack of oxygen in the cell it would be naturally assumed that they can be relieved by supplying oxygen. In cases where this lack is due to an exudate into the alveoli or swelling of the alveolar mucous epithelium, and in those cases where engorgement of the pulmonary tissues prevents adequate expansion, increase of the partial pressure of oxygen in the alveolar air by enriching

the inspired air with oxygen usually, if not always, gives relief. On the other hand, when the symptoms are due primarily to a slowing of the whole circulation or a circulatory deficiency due to a local vascular lesion, the administration of oxygen may have little or no effect. The reasons for this would seem to be self-evident. In certain cases, however, the administration of oxygen may give relief when not expected to do so; on the contrary, its failure to be efficacious is sometimes experienced when a good result would be most expected. A more thorough examination of these cases usually indicates that a combination of these causes is operative. To what extent either factor predominates may, however, be difficult to ascertain.

If the partial pressure of oxygen in the alveoli is to be increased the inspired air must be enriched with oxygen by the time it enters the nasopharynx. This necessitates the administration of a sufficient quantity of oxygen a minute by some apparatus which will ensure its being inhaled. The placing of a funnel one inch from the patient's face will not accomplish this. In our experience only two methods are efficacious—by the use of a fairly tight-fitting mask, or by introducing a rubber catheter through the nose into the nasopharynx. Through this catheter there is passed an adequate supply of oxygen. The supply is frequently regulated by, in lieu of some better method, bubbling the gas through a Wolff bottle or other similar contrivance. In order that a sufficient quantity shall be administered it must enter the bottle through a tube of at least 1 cm. bore, and the bubbles must be so rapid as not to be countable.

The use of oxygen, of course, does not remove the necessity for adopting all other means of treating cardiac failure, and by no means the least important of these is physical and mental rest. It is remarkable how patients do improve by good nursing and general comfort. It would appear that the reason for this is the conservation of circulatory energy for those vital organs which of necessity require a good blood supply.

The employment of drugs which increase the cardiac power is not to be ignored. Of these there is, to my mind, only one which is of value, and that is digitalis. The indications for its use and the method of its administration must be left for consideration at another time.

Many of the observations upon which these conclusions have been based were undertaken in the Department of Therapeutics, Edinburgh University, in collaboration with Drs. Davies, Dautrebande, and Fetter.

THE EFFECT OF HEAT UPON OPERATIONS FOR EXOPHTHALMIC GOITRE.

BY

A. J. WALTON, M.S., F.R.C.S., M.B., B.Sc.,
LONDON HOSPITAL.

THAT the results of operative treatment in many cases of exophthalmic goitre are satisfactory is now generally admitted. Until some fifteen or twenty years ago the danger of such an operation was, however, so great that few physicians felt justified in advising it. To-day the results have been so enormously improved that the mortality is no higher than that of other major operations. At the discussion of the Royal Society of Medicine in 1921,⁶ and again at the meeting of the British Medical Association in Glasgow, it was generally agreed that the mortality was somewhere in the region of 5 per cent. In the hands of individual surgeons it has often been lessened considerably below this. Romanis⁵ was able to show a mortality of only 2.4 per cent. in a series of 250 cases, and the latest statistics from the Mayo Institute published by Pemberton⁴ record a series of 1,093 operations with 11 deaths—that is, a mortality of 1 per cent. All who have operated on large numbers of these cases feel, however, that in spite of their care and attention to detail there is an element of uncertainty in the result which is absent in other cases. My own experience has been that although these cases can be divided into definite groups, one of which has a higher death rate than the others, yet now and again a death will occur when least expected. This feeling of uncertainty and anxiety has been expressed also by Berry,² Dunhill,³ and

Romanis,⁵ and all are agreed that there is some factor which is at present not fully understood.

If the causes of danger in the operation be analysed, it is possible to appreciate not only what are the means by which so much improvement in the operative results has been obtained, but also which is the factor at present uncertain and to which attention must be given in future. Pemberton⁴ has well analysed these dangers. He classifies them into the three following groups:

1. Those directly resulting from the disease and the effects of the disease.
2. Those directly due to accidents such as haemorrhage, pulmonary embolism, etc.
3. Those the joint result of disease and accident.

Careful attention to the technique of operation, to the limitation of haemorrhage, to careful handling of the gland, etc., have done very much to lessen the dangers of groups 2 and 3; so that the risks arising therefrom are in no way specially applicable to operations of exophthalmic goitre. In the first group the dangers are twofold. If the hyperthyroidism has been present for a long period, secondary changes will have taken place in the heart and kidneys, and the patient will stand any operative measures badly. In the future it is probable that risks of this nature will be almost negligible, for the condition will not be allowed to progress too far before operation is undertaken. At present, however, but little can be done to reduce the mortality. The secondary conditions can be readily recognized, but the operation must be undertaken in spite of them, with a full knowledge of its danger, in order to give the patient her one chance. It is the inclusion of so many such cases that, in my own series of 140, has maintained the mortality at about 5 per cent. In fact, at the present time the reduction of the mortality much below this figure would, in my own hospital practice, made up as it is so largely of ignorant patients, lead to the suspicion that advanced cases were being unjustifiably refused the benefits of operation.

The second danger in this group is the presence of hyperthyroidism. If a patient dies unexpectedly after operation there are nearly always presented symptoms of profound post-operative hyperthyroidism, and hence it is to this danger that attention must in the main be directed. The importance of not operating in the first six months of the disease, when the symptoms can be most easily controlled and often, indeed, cured by medical treatment, I have previously laid stress upon. The fact that every case must be carefully watched in a nursing home or hospital until the hyperthyroidism is at its lowest ebb, the importance of the basal metabolic rate as an indication of the extent of the hyperthyroidism, and the value of medicinal measures in reducing the hyperthyroidism before operation, have been noted by many operators. In fact, more has been done by attention to such details to lower the mortality than by any other step. All surgeons have appreciated the fact that chloroform in such patients is a deadly poison and must be avoided. Some surgeons, indeed, advocate that all general anaesthetics should be abandoned, but here there is not so much unanimity of opinion, for many, and among them myself, have felt that the nervous upset of the patients which is produced when they are conscious at the time of the operation will more than balance the benefit gained by omitting a general anaesthetic. My own custom is to obtain unconsciousness by a minimal dose of rectal ether, and to continue the anaesthesia by means of ether administered on an open mask. Even with every care in the use of such methods, and in the administration of large doses of fluid before and after operation, it will be found that there is a post-operative reaction. In the more satisfactory cases this is slight, but in others the temperature may reach 103° for two or three days, and the pulse may rise to 160. The patient will sweat excessively, will suffer from dyspnoea, and will show a very considerable restlessness which is only controlled with difficulty by morphine. I have previously directed attention to the fact that two distinct groups of cases may be recognized, although there is every gradation between the two. The one occurs in young females who have a large soft, smooth thyroid, marked exophthalmos,