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THE PREVENTION AND TREATMENT OF ASPHYXIA IN THE NEW-BORN *

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The first quarter of an hour after birth is the most dangerous period of life. Its mortality is as great as that of any subsequent month. No single discovery in medical science or improvement in practice could do more to save lives than would measures to avoid the losses that now occur within a few minutes after birth.

There are probably no procedures in medical practice which are so nearly the same as those of the dark ages, or which have as yet been influenced so little by modern scientific knowledge, as those of the midwife or obstetrician in dealing with a nonbreathing new-born child. Perhaps an excuse may be found in the statements still contained in textbooks of physiology and obstetrics regarding the questions why the fetus does not breathe in the uterus, and why it does start to breathe after birth. This topic is generally discussed rather philosophically, and so might be left to the merely philosophical if it were not that some of the statements in these discussions afford a basis for most unfortunate results. Thus, in such accounts stress is laid on the effects of exposure to cold air and the stimulation of the skin by contact with objects in the outside world. Such a notion having been implanted in the mind of the obstetrician, it then becomes the basis for plunging the child into cold water or applying a vigorous spanking. The new-born baby may be swung vigorously by the feet, squeezed and pulled and manhandled. The results are frequently serious, and probably in rare cases may even involve fatal organic injury. Such practices arise from the same mistaken idea as those of the so-called countershock treatment sometimes applied in the resuscitation of men partially drowned, electrically shocked, or asphyxiated by gas.

In the application of countershock, the victim of the accident is dropped on the ground, sometimes from a height of several feet, beaten on the soles of the feet, and in other ways handled with extreme roughness in the belief that such irritation of afferent nerves may stimulate a renewal of breathing. In fact, all that is really accomplished is that the patient has an added injury, sometimes severe, from which to recover. Similarly, in rural districts the belief still obtains that a drowned person can be resuscitated by the use of a corn cob, the larger and rougher, the better. It is fairly certain, however, that any person who breathes again after the application of such resuscitation apparatus would have breathed without it; he retains only an injured anus. Essentially the same brutal procedure is sometimes even now resorted to by anesthetists as a means of stimulating a patient who has stopped breathing under anesthesia.

Equally crude, ineffective and reprehensible is the treatment which ignorance and immemorial custom tolerate and even recommend for the nonbreathing new-born child. Such practices in all fields of resuscitation, alike for adults and for infants, are based on essentially the same erroneous conception of the physiologic conditions producing breathing. It is extraordinary how long such errors persist. For more than ten years now every young medical student has heard an explanation of the chemical control of respiration by a professor of physiology and has then gone on to clinical work to forget it. He adopts and applies the hoary errors of the clinic in regard to respiration.

In answer to the theoretical question why the fetus in the uterus does not breathe, it is sufficient to say that the reason is that the conditions of the circulation and the exchange of the respiratory gases in the blood are such as do not stimulate the respiratory center. Respiration does not occur because no chemical stimulus of sufficient strength develops in the blood and is brought to bear on the center.[1]

After birth the infant breathes in response to the same stimulus and by the same mechanism as those which the modern physiology of respiration has shown obtain in adults, in children, and in all mammalian animals. In all these, and in the infant no less, the maintenance and regulation of breathing depend on the carbon dioxide brought to the respiratory center in the blood. Oxygen is requisite if the center itself is to be maintained in normal condition, and if the tissues are to produce carbon dioxide, for deprivation of oxygen necessarily decreases the production of carbon dioxide. But the center may be quite normal and also quite inactive in the presence of ample oxygen if the blood is deficient in carbon dioxide. If the center has become inactive, or if its activity is subnormal, there is one, and only one, stimulus that will both restore and maintain normal activity: an increase of carbon dioxide in the blood.

This is true physiologically, and it is equally true therapeutically. It is now many years since physiologists have given up the idea that respiration is essentially due to afferent stimulation,[2] and have adopted the conception of Haldane [3] and his co-workers. From

* From the Laboratory of Applied Physiology, Sheffield Scientific School, Yale University.

1. Mieschcr-Rusch: Arch. f. Physiol., 1885, p. 355.
2. Heymans, J. F., and Heymans, C.: Sur les modifications directes et sur la régulation réflexe de l'activité du centre respiratoire de la tête du chien, Arch. internat. de pharmacod. **33**: 273, 1927.
3. Haldane, J. S.: Respiration, New Haven, Yale University Press, 1922.

their work and that of others who have confirmed and extended it, it is as certain as anything in the whole range of modern science that respiration is under a chemical control by the more or less direct action of the arterial blood, chiefly through its content of carbon dioxide, on the respiratory center in the brain. It has been proved also that oxygen is not a stimulant, a fact which clinicians seem to find extremely hard to appreciate, for they are continually trying to stimulate respiration with oxygen. The combustion in the human body is not like a fire which burns more or less vigorously according to the supply of oxygen. Slight deficiency of oxygen is to some extent a stimulant, but only for a short time. The stimulation passes readily into a depressant effect if the deprivation is acute or prolonged.[4] Oxygen is an essential foodstuff. Without oxygen the tissues cannot produce carbon dioxide. Asphyxia is usually thought of as a condition of oxygen deficiency and excess of carbon dioxide. This is a misconception; asphyxia usually, as in the typical condition of carbon monoxide poisoning, involves both low oxygen and low carbon dioxide content in the blood and tissues.

Thus the practical problem of the initiation and stimulation of respiration in a nonbreathing new-born child is very nearly the same as that of the resuscitation of an adult who has been partially asphyxiated. On the subject of resuscitation, knowledge and experience have now reached a very satisfactory degree of completeness.[5] The theory is well established, and has been confirmed by numerous laboratory tests. Apparatus has been developed for practical use and has proved its effectiveness by a wide distribution and application. There are now also records of large numbers—numbers rising into many hundreds—of successful resuscitations.[6]

In addition, there is direct evidence that the asphyxia of the new-born and of an adult overcome by an asphyxiant gas are effectively relieved by essentially the same treatment. This evidence has developed in a somewhat peculiar manner as follows: During the last twenty years, my associates and I[7] have kept up a nearly continuous campaign of propaganda for the practical application of the modern theory of respiration. What we have urged is, in a word, the immense possibilities for the saving of life available in the therapeutic use of inhalations of carbon dioxide diluted in air or in oxygen. Criticism from some of the older school of physiologists—those who still believed in the afferent control of respiration—was not wanting ten or fifteen years ago, but such opposition has now long since completely ceased. More recently some biochemists have objected to inhalations of carbon dioxide diluted in air or oxygen on the score of "intensifying an already existing acidosis"; but that objection also seems to have died away.[8]

Meanwhile, anesthetists generally have become acquainted with the modern conception of respiration, and as a result they are making extensive use of carbon dioxide,[9] mixed either with oxygen or with the anesthetic gases, as a means of controlling respiration during the initiation and maintenance, and for the rapid termination of anesthesia. In the hospitals with which such progressive anesthetists are associated there are now large and rapidly increasing numbers of cases recorded in which the obstetric department has called on the anesthetist for assistance, and he has started the new-born baby breathing in the only really effective and scientific manner, by an inhalation of oxygen and carbon dioxide. But the total number of children born in hospitals that have reached this degree of scientific advancement is extremely small compared to the number of lives lost, because in most places no such up-to-date assistance is available. It is certainly a very unfavorable comment on the art of midwifery that obstetricians do not as yet seem to have availed themselves of an acquaintance with the modern physiology of respiration, or to have provided themselves with the simple means necessary for putting it into effect. And yet there is probably more frequent need for resuscitation apparatus in this field than in any other. From such estimates as I can obtain, this apparatus would make a difference of one life in a hundred and it must be kept in mind that birth is a hazard through which all must pass. Thus, if this estimate is correct, the total number of lives to be saved by the introduction of such simple and easily practicable means would be greater than would result from the complete elimination of some of the diseases of infancy and childhood, such as poliomyelitis and epidemic encephalitis.

Although obstetricians have not as yet made more than the faintest beginning along this line, nevertheless through nonmedical channels in a roundabout and surprising manner the application is being made and is saving a great number of lives. What obstetricians have neglected to do for themselves they are enabled to bring about in many American cities today by calling in the city fire department. The rescue squads of the fire departments bring in their inhalators and start the baby breathing. Thus the fire department of one city now reports a large number of such resuscitations in a little more than a year.

In the course of the propaganda which my associates and I have carried on for the therapeutic use of carbon dioxide, it became clear, after about ten years of rather ineffective effort on my part, that little could be accomplished for the resuscitation of the victims of gas asphyxiation if our educational efforts were confined to the medical profession. Often the physician reaches the patient too late. Hospital boards are slow to buy and equip ambulances with inhalators, although all emergency ambulances should be so equipped. Accordingly, Dr. H. W. Haggard and I,[10] acting for a committee of which Dr. C. K. Drinker was chairman, devised, tested and introduced a suitable inhalator. As the result of a prolonged campaign of education, some thousands of inhalators are now in the hands of coal mining companies, city gas companies, chemical manufacturers and city fire departments, and are on a few hospital ambulances.

4. Henderson, Yandell; and Haggard, H. W.: Noxious Gases and the Principles of Respiration Influencing Their Action, New York, American Chemical Society Monograph Series, 1927, chapters 2 and 7.

5. Henderson, Yandell: Resuscitation, J. A. M. A. **82**: 758 (Sept. 6) 1924.

6. Drinker, C. K.: The Efficiency of the Oxygen-Carbon Dioxide Treatment of Carbon Monoxide Poisoning, J. Indust. Hyg. **7**: 539 (Dec.) 1925.

7. Henderson, Yandell: Fatal Apnea and the Shock Problem, Bull. Johns Hopkins Hosp. **21**: 235, 1910. Henderson, Yandell; and Haggard, H. W.: The Elimination of Carbon Monoxide from the Blood After a Dangerous Degree of Asphyxiation, and a Therapy for Accelerating the Elimination, J. Pharmacol. & Exper. Therap. **16**: 11, 1910; The Treatment of Carbon Monoxide Poisoning, J. A. M. A. **77**: 1065 (Oct. 1) 1921. Henderson, Yandell: Respiration in Anesthesia, and the Absorption and Elimination of Volatile Substances Through the Lungs, Brit. M. J. **2**: 1170 (Dec. 19) 1925; **1**: 41 (Jan. 9) 1926.

8. Henderson, Yandell: Physiological Regulation of the Acid-Base Balance of the Blood and Some Related Functions, Physiol. Rev. **5**: 131 (April) 1925.

9. Lundy, J. S.: Carbon Dioxide as an Aid in General Anesthesia, J. A. M. A. **85**: 1953 (Dec. 19) 1925. See also on this subject numerous communications by various anesthetists in Current Researches in Anesthesia and Analgesia.

10. Henderson, Yandell; and Haggard, H. W.: Report I of the Commission on Resuscitation from Carbon Monoxide Asphyxia: The Treatment of Carbon Monoxide Asphyxia by Means of Oxygen and Carbon Dioxide Inhalation, J. A. M. A. **79**: 1137 (Sept. 30) 1922.

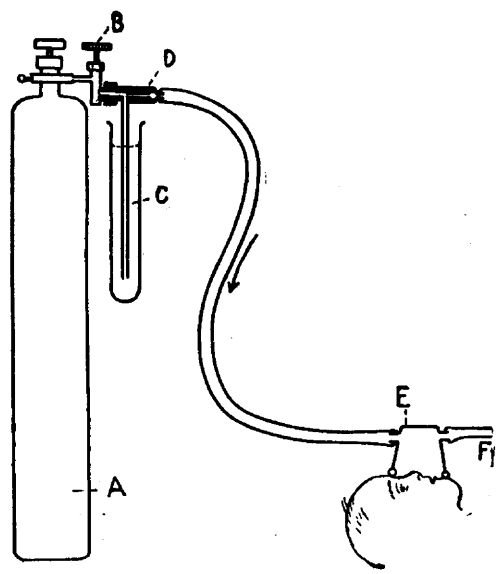
The success of such apparatus for its primary purpose of resuscitation of the victims of gas asphyxiation has been extensive. In addition, and quite unforeseen, has been the application of the same treatment to saving the lives of the new-born. This happens in the following manner, and not once only but repeatedly in every city where these inhalators are introduced: Cases of gas asphyxiation occur; the rescue crew of the fire department is called and resuscitates the patient. A physician sees the resuscitation, and is impressed by the effectiveness of the treatment. Some time thereafter he finds himself confronted with a child which he has delivered, and which has come through a prolonged labor. It refuses to breathe effectively, in spite of the application of all the ancient practices. The respiratory center has been depressed by the diminished blood supply to the brain resulting from compression of the head, and needs more than the normal amount of carbon dioxide to stimulate breathing. So the physician calls in the fire department. If, as is often the case, the fire department succeeds where his medical skill and knowledge have failed, he calls for it again the next time. Now the hospitals in some cities are adopting the practice of calling for the inhalator of the fire department whenever they have a baby who breathes poorly. In effect, they add the rescue crew of the fire department to their board of consultants, and these new consultants thus contribute another service to the community over and above that for which the fire department is primarily organized. Obviously, it is the hospitals that should be equipped to treat asphyxia—asphyxia of every form—and thus to help firemen overcome by smoke and gas, instead of relying on the fire department to help the hospital in such a matter as asphyxia of the new-born.

Turning now to specific points in the treatment of the nonbreathing baby, the negative factors, the things that should not be done, may first be specified. The baby should not be handled or treated with even the slightest degree of roughness, but on the contrary as gently, and with as little irritation and injury as possible. It should certainly not be allowed to get cold, much less "stimulated" by being plunged in cold water. Nor should it be subjected to certain other ancient and unphysiologic procedures, such as the still common practice of allowing an appreciable amount of blood to flow from the cord before it is tied. No blood that can be saved to the child should be lost, for it will be many months before its food contains an appreciable amount of iron.

As to the positive factors, the things that should be done: The child should be carefully kept warm, for it has not yet developed its own heat regulating functions. If the child has not itself spontaneously expanded its lungs by the first cry and does not then continue to breathe normally under the stimulus of its own blood gases, there are two and only two things that the obstetrician should do; there are in reality only two things that it is possible for him to do in order to help. The first form of assistance is to inflate the lungs a few times slowly and gently. For this purpose, air from the obstetrician's own lungs may be used, as has been the practice ever since the days of Elisha.[11] But it is better to use oxygen containing 5 or 6 per cent of carbon dioxide, or perhaps even with a higher percentage of the stimulating carbon dioxide. The second measure of assistance is then to continue to administer an inhalation of the mixture of oxygen and carbon dioxide as long as respiration is subnormal without it. If the respiratory center is incapable of normal activity under these conditions, no amount of irritation of the afferent nerve endings in the skin will induce continuing respiration. As a stimulant to respiration, nature offers carbon dioxide, but no alternative drug or treatment. Practically, it is the only effective stimulant for maintaining breathing.

The administration of oxygen alone, either for the inflation of the lungs or for inhalation, is far less effective than oxygen plus carbon dioxide, for oxygen does not have a stimulating action on respiration. Artificial respiration is to be avoided aside from the few initial inflations. Even these inflations should be gentle; there are strong objections to such artificial respiration apparatus as the pulmotor or lungmotor, for they are inevitably applied neither gently nor moderately. The person applying them invariably undertakes to do the breathing for the patient, whereas the correct objective is to get the patient as soon as possible to breathe for himself. Even with a simple device for inflating a child's lungs, the operator must be warned not to overdo inflation either in volume or in pressure. The only safe rule is not to use an apparatus with which it is possible to overdo artificial respiration. If use is made of the pressure from a cylinder containing oxygen and carbon dioxide, it must be remembered that the pressure within the cylinder is many atmospheres whereas that which can safely be administered to the child is only one one-hundredth of an atmosphere.

In this matter I hesitate to suggest any precise form of apparatus, for it is best that the men who are actually working under clinical conditions should develop the



A simple and (properly used) safe form of infant inhalator. The cylinder (*A*) filled with oxygen and 5 per cent carbon dioxide, may be only an inch in diameter and 10 or 12 inches long. Attached to it is a reducing valve, or, as shown here, a special needle valve (*B*) fine enough for careful adjustment of the flow of the gas mixture. The large test tube (*C*) is 6 inches long, of heavy glass, and filled to a mark with water. The vertical tube downward from the T serves as a pressure gage and escape whenever the pressure exceeds a maximum of 3 inches of water column. The capillary tube (*D*) just beyond the T is about an inch long and of such small diameter that under the maximal pressure allowed by the manometer only about a liter of the gas mixture a minute can pass to the face mask (*E*) and on out through the escape tube (*F*) at the right. For inflating the lungs, the escape tube is closed between the fingers for two or three seconds. This is essentially the same type of apparatus as that previously described by Henderson, Haggard and Coburn (The Therapeutic Use of Carbon Dioxide After Anesthesia and Operation, J. A. M. A. **74**: 783 [March 20] 1920), a type embodied in some of the anesthesia apparatus now widely used (Foregger, R. V.: Percentages and True Flow of Gases for Gas-Oxygen Anesthesia, Current Researches in Anesthesia and Analgesia **6**: 225, 1927).

11. The Bible, II Kings, 4:32.

apparatus and be guided continually by their experience with it. Merely as a suggestion, and following closely a type of apparatus already in successful use, the accompanying diagram shows in principle one possible simple device. But any one of the common anesthetic inhalers having a rubber bag will also serve. For the mask, the nose piece used by dentists is a convenient size for the infant's face. The lungs are expanded by gently compressing the bag, as described by Sword.[12] Neither of these forms of apparatus includes anything new. Both could be made small and light enough to be carried in an overcoat pocket. Doubtless both can be much improved, especially for hospital use, where weight is unimportant; for instance, a convenient device developed by Joseph Kreiselman, H. F. Kane and R. B. Swope[13] is now in successful use in Washington, D. C. Every anesthesia machine for nitrous oxide, ethylene, and so on, should have an attachment for the inhalation of oxygen and carbon dioxide for the new-born, in order that the anesthetist who relieves the pains of the mother may also start the baby breathing.

But until hospitals and outside obstetricians are provided with such apparatus and with cylinders of oxygen and carbon dioxide, they will do well to remember, when the baby does not breathe, that the fire department in every progressive city now has such equipment.

SUMMARY

Failure of the new-born to breathe or a condition of insufficient natural respiration should not be treated by the old-fashioned methods of cutaneous "stimulation." Such methods are essentially unphysiologic and harmful. They are probably also ineffective in all cases except those in which inflation of the lungs alone would have been sufficient to initiate breathing without additional "stimulation."

Resuscitation of the new-born should be based on the modern conception of the regulation of respiration by the action of the blood gases on the respiratory center. Oxygen is not a stimulant but a foodstuff. Deficiency of oxygen, beyond a first slight stimulating effect, depresses the nerve centers. In the absence of oxygen the tissues of the body cannot produce carbon dioxide. It is the carbon dioxide carried by the blood from the tissues to the brain that is the physiologic stimulant to respiration. When the center is depressed, it requires more than the normal amount of this stimulant to induce activity.

Compression of the head and the consequent decrease of the supply of blood to the brain during prolonged labor depress the respiratory center, so that after delivery the center does not receive a chemical stimulus sufficient to overcome this depression. Because of this condition of the center, the first cry does not occur, and the lungs remain atelectatic. In order to start respiration, a gentle inflation with oxygen and carbon dioxide for two or three seconds three or four times a minute should be applied. As soon as natural breathing develops, the inflations should be stopped, but inhalation of this gas mixture should be continued until full breathing is established. This is not only the physiologic and therefore best method; in its essential features it is really the only possible method that nature and science offer.

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12. Sword, B. C.: Clinical and Laboratory Advantages of Carbon Dioxide in Anesthesia, Current Researches in Anesthesia and Analgesia **6**: 177 (Aug.) 1927.
13. Kreiselman, Joseph; Kane, H. F., and Swope, R. B.: Personal communication to the author.

THE NONTUBERCULOUS CHILD*

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The pediatrician is a general practitioner to the young, a chronologic, and not a regional specialist. We have not, therefore, that incisive special knowledge concerning the diagnosis of pulmonary tuberculosis that the specialist in tuberculosis has. We sit in proper awe, possibly a little skeptical at times, but only wholesomely so, as you unravel the mysteries of a suspected chest with that peculiar precision that you have acquired and that we, and I might include not a few internists, frankly do not possess. If we sometimes feel that an immediate autopsy might be instructive it is only because of that reasonable skepticism that is imposed on every intelligent clinician by the still existing limitations to unfailing diagnosis in chest conditions, that makes it still rather an art than a science. I shall not therefore "bring coals to Newcastle" by dwelling on finer points of diagnosis but will attempt as a pediatrician, speaking before a body of men interested especially in tuberculosis, to tell you what a pediatrician has in mind and thinks he ought to say on an occasion like this, with especial emphasis on the child that might have, but does not have, tuberculosis.

It is one of the pediatrician's frequent experiences to have brought to him a child whom the mother has anxiously suspected of having tuberculosis of the lungs. In the great majority of cases her suspicions are unfounded clinically. Her fears are commonly based on one or more of the following points:

1. The child is underweight, whatever that may be; and is, or is not, run down, easily fatigued, and lacking in "pep."
2. He has a persistent cough.
3. He has a persistent low-grade temperature slightly above the accepted normal.
4. He has had a "pneumonia" and still has a fever and pathologic changes in the lungs.
5. He has been suspected of having tuberculosis of the lungs by his physician and this suspicion has been confirmed by a positive Pirquet test or a roentgen-ray diagnosis.
6. He has been exposed to tuberculosis.

It will perhaps not be amiss to take up these points seriatim. Before doing so, however, I should like to stress two points: the positive value of an examination of the sputum if it is positive, and the equally positive value of a Pirquet test if it is negative. Examination of the sputum is omitted more often than it should be because of the assumed difficulty or impossibility of getting a serviceable specimen from a young child who has not yet learned to spit. As a matter of fact, the procuring of a specimen is a very simple matter even in the baby. Immediately after a coughing spell, either spontaneous or induced by faucial irritation, the throat is swabbed low down and the specimen transferred to a slide. While the field of usefulness of this procedure is limited in childhood, it is sometimes of decisive value in the child with a persistent, productive cough without definite lung changes, and in the child with marked lung findings that may or may not be tuberculous in origin. In the present discussion of the nontuberculous child, examination of the sputum does not play a prominent part because it is of value only in establishing a diagnosis of tuberculosis and that too late, and of little or no value in excluding it.

* From the Children's Memorial Hospital.
* Read before the Mississippi Valley Conference on Tuberculosis, St. Louis, Sept. 20, 1927.