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THE RETURN OF THE PULMOTOR AS A "RESUSCITATOR": A BACK-STEP TOWARD THE DEATH OF THOUSANDS[1]

By Professor YANDELL HENDERSON

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IN no field of scientific activity during the past half century have the advances been greater than in that concerned with the saving of human lives. Yet along with some of these advances there have been very considerable amounts of charlatanism; quackery and their inevitable consequence—increase of mortality. Fortunately what was false and harmful has generally been, after a time, exposed and rejected; but not always or soon. And now a particularly evil affair has developed: that of a device that thirty years ago was introduced as a life-saver, but that was shown to be rather a life-loser, and was therefore rejected; yet that now is again being exploited under another name with all the force of high-powered salesmanship and pseudo-science to the inevitable loss of many lives that could be, and should be, saved.

The device to which I refer is a breathing machine that at first was called a "pulmotor" and that now, slightly changed in form but identical in essentials, is being reintroduced under another name as a "resuscitator." By alternately sucking and blowing, these "pulmotor-resuscitators" were designed, and have been claimed, to remove poisonous gases from the lungs and

[1] For the evidence, experimental and clinical, and full references to the literature upon which this article is based, see: Henderson and Haggard, "Noxious Gases and the Principles of Respiration Influencing Their Action," 2d edition, New York, 1943; Henderson and Turner, "Artificial Respiration and Inhalation," *Jour. Am. Med. Asn.*, 116: 1508, 1941; Henderson, "Adventures in Respiration; Modes of Asphyxiation and Methods of Resuscitation," Baltimore, 1938; and same author, "Tonus and the Venopressor Mechanism: The Clinical Physiology of a Major Mode of Death," *Medicine*, 22: 223, September, 1943.

blood and to induce a return of breathing in cases of partial drowning, electric shock and gas asphyxiation. For this claim, no valid scientific evidence has ever been offered. The sole supporting argument for such suck and blow devices is a demonstration that, when one of them is attached to a rubber bag, the bag can be alternately inflated and deflated; and—more dramatically—that when an inflated rubber doll is substituted for the bag, the doll can be made to "breathe" realistically. On this basis, the claim is that, if the human lungs were similarly subjected to alternating positive and negative pressures, they would be similarly ventilated. Yet in reality they are not, unless the positive and negative pressures employed are so large as to induce mechanical injury, dangerous degrees of acapnia and failure of the circulation.

It is true that a healthy conscious man can voluntarily adjust his breathing to the rhythm of such apparatus, so that he appears to behave like the rubber doll. But if the patient is unconscious and the pressures applied, both positive and negative, are low enough to be harmless, there is generally either complete discordance between the patient's breathing and the rhythm of the apparatus; or else the well-known vagal reflexes from the lungs—which are lacking in a rubber doll—cause the diaphragm to resist the artificial respiration by contrary respiratory movements.

The inventors of the pulmotor assumed, and the promotors of "resuscitators" still claim, that by artificially forcing the lungs and chest through movements like those of breathing, a return of natural respiration should be induced. But, on the contrary, the far-reaching advances made during the past four decades in our knowledge of the physiological control and regulation of respiration have established the facts that the restoration and maintenance of respiration are principally dependent, not on the reciprocating reflexes of inspiration and expiration, but on the chemical stimulation of the respiratory center in the brain by the blood gases—particularly carbon dioxide, along with an adequate amount of oxygen. The argument for pulmotors and "resuscitators" implied by the rubber doll is that, just as a stalled gasoline motor in an automobile or motor boat can be restarted by cranking, so by analogous means a drowned or asphyxiated man, or an apneic newborn baby, should be resuscitated: which is in direct conflict with all that is known scientifically about resuscitation.

My own experience with carbon monoxide asphyxia began in 1910 when I was called to see a man who had been overcome in his bedroom by city gas and was under treatment with a pulmotor. He was not very deeply asphyxiated; but he was entirely unconscious and was breathing stertorously. What was most noticeable was that the rhythm of the apparatus was entirely out of step with the patient's own respiration, which it was rather opposing and impeding than aiding. However, in that case, consciousness returned after a time, as occurs in mild cases without any treatment; and recovery followed. Now, after the experience of thirty-two years and hundreds of cases far more efficiently treated, I can report a recent similar victim, not treated by me, who also was still breathing while a "resuscitator" clicked rapidly and ineffectively from blowing to sucking and sucking to blowing, wholly out of time and in conflict with the patient's own respiration. In that case, consciousness did not return, and the man died in coma a couple of days after the asphyxiation.

Carbon Monoxide Asphyxia

Unlike many other poisonous gases, carbon monoxide is not an irritant: even in amounts that are deadly, it does not directly injure the lungs, and may not appreciably diminish the percentage of oxygen in the air of the lungs. Instead, this gas combines with the hemoglobin, the red coloring matter and oxygen-carrying substance in the blood. Until it is largely displaced from the blood and the oxygen-carrying capacity of the blood thus restored, the tissues of the body, and particularly the brain, continue in a state of asphyxiation, that is, oxygen starvation. Accordingly, it was early realized that the only way that carbon monoxide can be displaced from hemoglobin is by the mass action of oxygen. But in practice, mere inhalation of oxygen alone often failed to resuscitate; and if the victims did not die in asphyxia, they sometimes survived as idiots or neurological cripples.

If then asphyxial damage to the brain is to be reduced to a minimum, it is essential that as large an amount of oxygen as possible shall be drawn into the lungs, and blown out again several times a minute for a half hour or more with continually fresh oxygen. This—as above stated—pulmotors and "resuscitators" were designed to do; but, owing to the fact that natural respiration will not cooperate with sucking and blowing machines, but rather opposes their action, they have proved incapable of accomplishing. Accordingly, the mortality induced by carbon monoxide poisoning in such cities as New York and Chicago—during what may be called the "pulmotor period" (1910–1922)—was not appreciably decreased from the "prepulmotor or oxygen inhalation period" (prior to 1910). A typical case of the deaths that were common in the "pulmotor period" was described in the *Journal* of the American Medical Association of March 8, 1912, page 738, by a competent witness, Dr. Morris Fishbein, now the editor of that journal, as follows: The patient "who had been poisoned with CO was subjected to the action of a pulmotor for

several hours. After nearly 5 days of unconsciousness, the patient died. At autopsy, hemorrhage into the lungs and visceral pleural emphysema (dilated areas) of the right lung were found, together with subpleural emphysema." In this and many similar cases it is particularly noteworthy that, as carbon monoxide is not an irritant gas, the condition of the lungs found at autopsy was clearly due mainly to the mechanical damage done by the sucking and blowing of the apparatus.

In the directions for the use of "resuscitators," which are supplied with the apparatus, it is stated that, if the patient is still breathing, or begins to breathe, the suck and blow action should be switched off and the inhalational action switched on. And this, little as the writers of those directions seem to realize it, virtually signs the death warrant of every deeply asphyxiated patient so treated. For this inhalation is given with a type of mask and valves such that much of the carbon monoxide that comes out of the lungs is re-inhaled and its elimination thus retarded. Neither in respect to artificial respiration by sucking and blowing nor by means of their inadequate inhalational attachment are the "resuscitators," now so actively promoted, capable of restoring natural breathing or eliminating carbon monoxide from the lungs and blood sufficiently rapidly, if the case is severe, to prevent serious and even fatal postasphyxial effects.

Resuscitation by Inhalation of Carbon Dioxide and Oxygen

Fortunately for the saving of life, that volume of lung ventilation which can not be produced by suck and blow machinery, without risk of serious harm, can be induced safely and with high efficiency by natural breathing when stimulated by inhalation of carbon dioxide. For when the requisite concentration (7 to 9 per cent.) of carbon dioxide is administered mixed with otherwise pure oxygen, so large a volume of breathing is induced and such a mass action of oxygen is brought to bear on the blood as it flows through the lungs that virtually all the carbon monoxide that has been absorbed is rapidly eliminated; and the asphxiation is thereby terminated.

Accordingly, in 1921, Henderson and Haggard introduced the method of resuscitation by inhalation of oxygen with enough carbon dioxide to induce a maximum minute-volume of respiration. After long and careful laboratory and clinical tests, they determined the conditions requisite for the most effective use of this mixture. These are (1) that it shall contain 7 to 9 per cent. of the stimulant carbon dioxide; (2) that the inhalator employed shall be capable of administering the maximum volume per minute that the patient can thus be stimulated to inhale; (3) that the inhalator shall not permit any rebreathing whatever; and (4) that the valves and bag shall be so arranged that the resuscitant gas flows to the mask only during inspiration; otherwise the supply may be exhausted before resuscitation is effected.

It should be emphasized also that the inhalator devised along these lines by Henderson and Haggard has never been patented, or its manufacture, sale and use limited in any way; it is free to any and all.

Manual Versus Mechanical Artificial Respiration

At nearly the same time (about 1912) that the pulmotor first appeared, the prone pressure method of manual artificial respiration was introduced by Professor E. A. Schafer, of Edinburgh. In order that there might be sound and authoritative evaluation of all methods, new and old, for artificial respiration, a Committee on Resuscitation from Mine Gases was appointed jointly by the U. S. Bureau of Mines, the American Medical Association, the American Red Cross and the National Electric Light Association; the predecessor of the Edison Institute. The members of this committee were W. B. Cannon, G. W. Crile, J. Erlanger, S. J. Meltzer and Y. Henderson; and as authorities on the conditions inducing death by electric shock, Elihu Thomson and A. E. Kennelly were added. All methods of artificial respiration known or proposed at that time (1912) were subjected to careful and prolonged experimental and clinical investigation by the members of the committee themselves.

The members of that first committee acted on a sense of responsibility for the preservation of human life: a moral sense not so evident in a more recent committee—the Council on Physical Therapy of the American Medical Association—which "accepts"—that is, approves—"resuscitators" on the basis of no personal investigation by any of its members—as admitted in their letters to me—other than the secretary, who is a mechanical engineer of no physiological training or medical experience.

The main point developed by the committee of 1912 in regard to manual methods of artificial respiration was, not that any one of them—whether Schafer, Silvester or others—induces a much larger ventilation of the lungs than any other—in fact, without inhalation of carbon dioxide too large a ventilation would be harmful; but that the prone pressure method has the great advantage that it can be applied immediately: a delay of even a few seconds, while apparatus is being brought and applied, may lose a life. Prone pressure is easier to teach and learn than any of the other methods; it can be continued longer without exhausting the operator; and

it aids the circulation by pushing blood toward the heart. Accordingly the Schafer prone pressure method was adopted, particularly by the American Red Cross, and the pulmotor and similar breathing machines (not then claiming the title of "resuscitators") which rely on alternately sucking and blowing were condemned. The resuscitation committee held that "inflation and deflation of a bag are deceptive because the bag, unlike the air passages of the body, offers no resistance till full. As soon as the inspiratory blast meets an obstacle in the air passages, it is automatically cut off and turned into expiration; and thus frequently no effective inspirations are performed." Thus the time within which the victim may be saved is lost while the apparatus merely clicks back and forth ineffectively. This has continued to be, and is now, the position of the American Red Cross (see its booklet on "Life Saving and Water Safety," page 189). It advocates (1) immediate manual prone pressure artificial respiration, and (2) simple inhalators as auxiliary aids; but it disapproves of suck and blow mechanical devices.

Between 1912 and the present time, four other committees have published the results of their investigations on methods of resuscitation: two in this country, one in 1918 and one in 1921, and one under the British Medical Research Council. Three of these committees have unanimously condemned suck and blow apparatus under whatever name; while only one —the above-mentioned Council on Physical Therapy —has accepted such devices. And thereby hangs the grotesque story which it is one of the objects of this article now to tell.

Why Doctors Promote "Resuscitators"

The story is that of how and why it has come about that at the present time a large proportion of American physicians believe that the American Medical Association, through its Council on Physical Therapy, recommends "resuscitators"—a belief which is the principal basis for the extensive introduction of this apparatus. As a result, the sales agents of the E & J —as the most promoted of these devices is commonly called—find in every city and town of the United States one or several physicians of good standing in the community who are "members of the A.M.A." and read its journal and who on this basis confidently and conscientiously assure their fellow citizens that the purchase of a "resuscitator" for the hospital or the fire department is a public-spirited act.

Commercially, the sales campaign of the E & J is thus far ethical. But it does not stop at measures that are scientifically and commercially ethical. Three times at least that campaign has involved attempts to prevent the publication of scientific opinion or evidence adverse to the E & J "resuscitator." It happens that the first report adopted by the Council on Physical Therapy was never published. It was adverse to the E & J "resuscitator." I know, because I wrote it. I was at that time a member of the council and, as I had already tested the "resuscitator" on animals in my laboratory and had found it to be essentially a pulmotor, I was asked by my colleagues to draft the council's report. It was approved and adopted by the council. It was, in fact, on the point of publication in the *Journal* of the American Medical Association. But at that point unfortunately the E & J Company learned—or were informed—that the report was adverse. Thereupon they sent their lawyers to the then president (1934–35) of the American Medical Association and the report was suppressed by action of the trustees; and I resigned from the council. On my part this was a conscientious, but unwise act; for the agents of the E & J thereupon set themselves to winning the secretary of the Council on Physical Therapy to the support of their device. In contravention of that influence, I then invited the council to delegate a subcommittee of its members to join with me in testing the "resuscitator" on animals. Whether that invitation ever reached the full council, I do not know. But I do know that it reached the secretary, and that he made no reply. I know also that soon thereafter the agents of the E & J achieved their object: instead of their "resuscitator" being disapproved, it was added to the "list of devices accepted by the Council" (see *Jour. Am. Med. Asn.*, 112: 1945, May 13, 1939). Ever since that it has been supported in frequent published statements by the council as being at least as efficient a means of artificial respiration as the Schafer prone pressure method.

In this respect, the American Medical Association is in direct antagonism to the American Red Cross.

Twice in recent years the lawyers of the E & J Company have threatened suit against the publishers of the books in which I have reported my investigations in the field of resuscitation. One of these publishers ignored that threat with the scorn that it deserved. And nothing happened. The other publisher took the matter so seriously that he delayed the publication of the book ("Noxious Gases," by Henderson and Haggard), for six months and went to considerable expense for legal advice—as did I also—in defense of the right of an author to tell the truth.

In addition, it is of interest—to me at least—that in the latest advertisement of the E & J "resuscitator" one of those books is cited as supporting that device.

So matters have gone on until in their hunger for sales the agents of suck and blow apparatus have

nagged bureaus in the U. S. Army, Navy and Shipping Board to the point of asking the National Research Council for the appointment of a committee on the subject of "resuscitators." That committee met recently and made its report; and this report is about as adverse to "resuscitators" as is this article of mine.

So far so good. The various bureaus of the Federal Government will now be saved very considerable amounts of money, as well as the lives of many soldiers, sailors and marines. But that report is unfortunately "restricted" and will not decrease the mortality from asphyxia among the 130 million citizens of the United States, who will never hear of it.

THE CENTENARY OF THE CINCINNATI OBSERVATORY

By Dr. RAYMOND WALTERS

PRESIDENT OF THE UNIVERSITY OF CINCINNATI

THE commemoration in November, 1943, of the establishment in November, 1843, of the first astronomical observatory in America proved to be an occasion of national importance. Testimony to this importance was supplied in the felicitous letter of greeting received by the University of Cincinnati from the President of the United States:

> The founding of the Cincinnati Observatory a hundred years ago was an event of great significance in the march of science and culture in this country.
>
> The enormous advance in the science of astronomy since the venerable John Quincy Adams, former President, journeyed to Cincinnati to lay the cornerstone of the original building emphasizes the debt we owe to the Cincinnatians of a century ago whose vision and generosity made possible the establishment of the observatory.
>
> May I, in extending hearty greetings, express the hope that the work of the observatory will go steadily forward and that the sphere of its influence will ever widen in the decades ahead.

As reported in SCIENCE, the American Astronomical Society held its seventy-first annual meeting at Cincinnati from November 5 to 7, in conjunction with the university celebration; and digests of the papers then read have been published in this journal.

Scientific and human aspects of what Dr. Harlow Shapley, president of the society, termed "this romantically founded civic enterprise" were presented before a large audience of scientists and citizens in three centenary addresses delivered by Dr. Shapley; Mr. Robert L. Black, a member of the board of directors of the University of Cincinnati; and Dr. Raymond Walters, president of the university.

The historic background of Cincinnati a hundred years ago and the personality of Professor Ormsby MacKnight Mitchel, of Cincinnati College, founder of Cincinnati Observatory, were sketched by Mr. Black. In vivid, picturing words, he described the laying of the cornerstone of the Cincinnati Observatory on "that chilly November day when a national salute of 21 guns fired from Mount Ida, re-echoing from the low, heavy clouds, roused the 50,000 odd inhabitants of Cincinnati." The orator of the day was the illustrious John Quincy Adams, "small, neat, a quiet personage, still apple-cheeked in spite of his 76 years," who had endured rain, snow, cold and the rigors of a thousand-mile journey from Massachusetts to accept the invitation of Judge Jacob Burnet, one of the founders of Cincinnati College and president of the Cincinnati Astronomical Society.

Mr. Black depicted the scene: "Judge Burnet, tall, swarthy, austere," and Professor Mitchel, "a little terrier of a man, sharp-eyed, talkative, full of bounce," sat in the barouche with Mr. Adams as "the heavens opened, filling the streets with water." The long line of citizens paraded through the rain up to the top of Mount Ida, the location of the observatory-to-be. On a small stage there,

> Judge Burnet introduced the "old man eloquent" to the auditory of umbrellas. Mr. Adams read his address rapidly; before he was done the manuscript was so defaced by the rain as to be scarcely legible.
>
> Thereupon he laid the cornerstone, "invoking the blessing of Him, in whose presence we all stand, upon the building which is here to rise and upon all the uses to which it will be devoted.

Mr. Black then recounted the dramatic story of how it happened that a President of the United States, a judge and a professor thus met on a hilltop overlooking the Ohio River. The hero of the story was Ormsby MacKnight Mitchel, Kentucky-born son of Scotch-Irish folk, graduate of West Point, engineer, professor of mathematics and natural philosophy in Cincinnati College, and astronomer.

There was at that time no working telescope in America. Mitchel, lecturing on astronomy at Cincinnati, saw a vision. He "resolved to devote five years to the erection of a great astronomical observatory right here in the City of Cincinnati."

> He had not a penny in his pocket, no future prospect whatever except his $1,500 a year for teaching; he had little influence, political or social. "I will go to the people," he said . . . "I will plead the cause of science. . . . I am determined to show the autocrat of all the Rus-