Landmark Article
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The Use of a New Apparatus for the Prolonged Administration of Artificial Respiration

I. A Fatal Case of Poliomyelitis*

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A number of patients have come under our observation who have shown intercostal paralysis and considerable weakness of the diaphragm early in the paralytic stage of anterior poliomyelitis; yet the accessory muscles and the diaphragm have been able to support sufficient respiratory movement to keep the patient alive until, in the course of a few days, the paralyzed intercostal muscles began to improve and the patient went on to almost complete recovery. Although this is not the usual termination of these cases, it occurs often enough to stimulate the desire to give all patients with respiratory paralysis this opportunity to recover normal breathing by maintaining artificial respiration over a period of hours, or even days.

LIMITATIONS OF PRESENT METHODS OF PROLONGING LIFE

The means of prolonging life in these patients are limited to the available methods of applying artificial respiration. Of these, the manual methods are not adapted to prolonged use. In cases of poliomyelitis, the respiratory excursion obtainable by manual efforts is most disappointing. In our experience, it is almost impossible to produce and maintain adequate oxygen interchange by manual methods of artificial respiration alone, in cases requiring long-time administration.

The pulmotor likewise has been disappointing. The patients are usually mentally alert until the end; they fight any mask over the face and oppose the efforts of the machine. In one patient, in whom life was maintained for two days by the pulmotor, the stomach and esophagus were ruptured and gastric contents were present in large amount in the mediastinum. The terminal efforts of this child had opened the esophagus rather than the trachea to the forceful inrush of air.

The failure of the present methods of administering artificial respiration has led to the demand for a mechanical device which would obviate these difficulties. In order to prove satisfactory, such an apparatus must be capable of working steadily over a long period of time; it must be adaptable to individuals of various ages and sizes; it must be so constructed that the rate and depth of respiration can be controlled; lastly, and most important, it must be capable of producing adequate artificial respiration without discomfort or harm to the patient. The machine devised by one of us and described briefly here seems to fulfill these requirements.[1]

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1. A detailed description of this apparatus with physiologic studies, by Philip Drinker and L. A. Shaw, will shortly be published. Its development through the experimental stage was made possible by the generosity of the gas and electric companies affiliated with the Consolidated Gas Company of New York through its Committee on Resuscitation and Related Activities.

THE MECHANICAL RESPIRATOR

The artificial respiration tank (fig. 1) consists of a cylinder 1.68 meters (66 inches) long and 0.56 meter (22 inches) in diameter. It is large enough to accommodate a man of 1.94 meters (6 feet 4 inches) weighing about 102 Kg. (225 pounds), but in an emergency it can be used for a small child.

The patient lies on a mattress placed on a truck which is attached to the lid of the tank. The head and neck of the patient extend beyond the lid through a rubber collar, the head resting on a stand of adjustable height outside the tank. The patient is rolled into the tank as soon as the collar has been adjusted and the position of the head determined. The lid and truck of the tank can be pulled in and out with ease to permit occasional examination of the patient. All of these motions can be accomplished very rapidly.

By means of electrically driven blowers, alternate positive and negative pressures are applied to the air within the tank. Inspiration is caused by negative pressures and expiration by positive pressures in a manner that seems to be physiologically normal. The pumps (fig. 1) which supply the pressures are capable of producing any pressure combination up to about ± 60 cm. of water.[2] These pressures greatly exceed those required to induce deep breathing in normal adults, in curarized animals or, as in the present case, in a child suffering from intercostal paralysis as a result of acute anterior poliomyelitis. In a normal individual, pressures greater than about ± 15 cm. of water produce marked overventilation. In curarized animals[3] we have found that alternate pressures of about 8 to 10 cm. are adequate.

The rate at which the pressure alternations take place is controlled by a rheostat and variable speed motor. Respiratory rates varying from 10 to 40 a minute can be obtained. The amount of the pressure is controlled by a valve which throttles down the air flowing to and from the pumps.

Since the respiration tank is equipped with a valve at the foot-end, this valve can be shut off and the body of the patient will then be enclosed in an air-tight cylinder. The apparatus thus becomes a true plethysmograph and, if it is connected to a suitable spirometer, records of breathing (fig. 2) can be made without the use of any sort of mask, nose piece or mouth piece. It is therefore a simple matter to close off the tank and, using it as a plethysmograph, to determine to what extent the patient is able to resume normal breathing. In cases like that reported here, this procedure is clinically very useful.

REPORT OF CASE

B. R., a girl, aged 8 years, was admitted to the Children's Hospital of Boston, Oct. 12, 1928, because of an illness of three days' duration. She had been taken sick with fever, headache, and stiffness of the neck and back. On the day of admission she was noted to have a weakness of the left arm and some difficulty in respiration. Examination showed part of the intercostal muscles to be paralyzed. The spinal fluid observations confirmed the diagnosis of poliomyelitis. Because of the persistence of fever, spread of the involvement was anticipated and the apparatus was made ready for the application of artificial respiration.

On the afternoon of October 13, it was apparent that respiration would fail in a few hours. The diaphragm was functioning, but the intercostal and pectoral muscles were completely paralyzed. In order that she might become accustomed to the procedure, the patient was placed in the respirator at 4 p. m. on that day and the pumps were run at low pressures. Records of the respirations at this time were fairly good and she was really in no need of assistance (fig. 2).

On the morning of the 14th at 6 a. m., the patient became dangerously cyanotic, apparently from weakness or fatigue of the diaphragm. She was quickly put into the respiration tank with the pumps running at approximately 30 cm. negative and

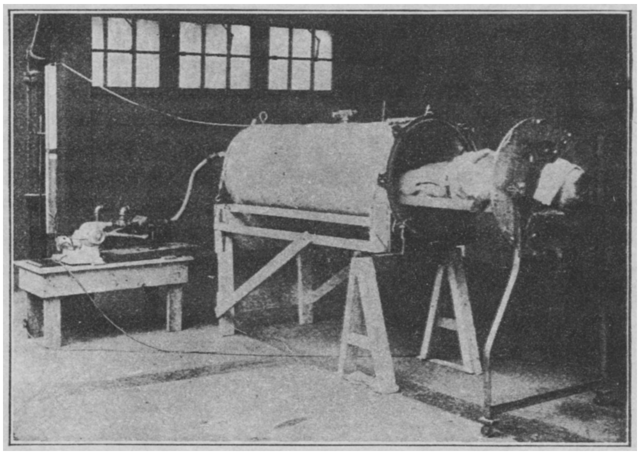

Fig. 1.—The mechanical respirator, showing patient ready to be pushed into the tank. The pumps and manometer for controlling the pressure are shown in the background, to the left.

15 cm. positive pressure. In a few minutes, her normal color had returned and she tried to talk. At that time, she had not learned to accommodate her efforts at speech to the pressure alternations. She soon was able to do so and learned also to clear her throat and cough with the help of the machine, acts most difficult for her outside the tank.

After three and one-half hours the patient was much improved and asked to be put back to bed. The pumps were stopped and the rubber collar was partly released. A little later the patient was removed to her bed and it was not necessary to put her into the respirator again until 4 p. m. of the same day. From that time until her death at 8 a. m., October 19, she was never completely removed from the respirator, nor was the rubber collar released. The maximum time that she was able to breathe by herself without becoming cyanotic diminished rapidly from one or two hours to periods varying from three to fifteen minutes. The administration of artificial respiration did not prohibit her from sleeping or taking nourishment.

The diaphragm functioned weakly throughout the entire time; apparently the machine relieved her efforts and rested this muscle sufficiently for it to maintain her during the short periods she was out of the tank, when she usually breathed at a rate of about 35 respirations a minute.

Physical signs of pneumonia appeared on the right side and became progressively more marked. After the onset of the pneumonic process, it was found best, before sliding the patient out of the tank for washing and changing, to run the pumps at approximately 30 cm. negative and 8 cm. positive pressure, at the same time allowing her to breathe about 50 per cent oxygen.

2. On normal adults, we have produced experimentally pressures of ± 75 cm. of water. Clinically such pressures probably have no application, as they quickly produce deep apnea and are very unpleasant.

3. Shaw, L. A.: Unpublished data.

After two minutes of this regimen, she was taken out of the respirator, the oxygen treatment being continued. Even so, she became cyanotic in a few minutes and had to be put back. The pumps were then run at from 22 to 28 cm. negative and from 6 to 8 cm. positive pressure. When the color improved, the pressures could usually be reduced to 16 cm. negative and 8 cm. positive pressure.

As the pneumonia became more marked, it was evident that the patient required greater pressure variations and, when taken out of the tank, she often asked to be put back again. In her own words, she could "breathe bigger" in the tank than outside it. If the negative pressure fell below about 16 cm., she generally asked us to "run it more."

Her color remained good and she was conscious and alert until a few moments before her death, which appeared to be due to cardiac failure.

Necropsy was performed and showed a normal left lung, without emphysematous areas or ruptured alveoli. The right lung was the site of an extensive bronchopneumonia, largely in the stage of gray hepatization. The unilateral distribution opposed the idea that the pneumonia was hypostatic. Neither lung showed any evidence of trauma due to overinflation. Had trauma occurred, it would certainly have been apparent at least in the right lung. The spinal cord showed widespread lesions characteristic of poliomyelitis. However, the edema had subsided and there is reason to suppose that under these circumstances this child would not have regained the use of the chest muscles, had life been maintained longer.

A mechanical respiration device known as the "barospirator" has recently been described by Thunberg.[4] It was used by him and his associates in a fatal case of poliomyelitis[5] with results not unlike those we have recorded in this paper. With his apparatus, the patient is entirely enclosed in a metal tank. By means of a large electrically driven pump, the pressure within the tank is changed positively and negatively at the desired rate to the extent of about 55 mm. of mercury (75 cm. of water). Under these conditions, the lungs of the average person are aerated without any lung or chest movement whatever and the volume of gas exchange varies directly with the pressure changes.

We believe that these two instances of the administration of artificial respiration to patients suffering from respiratory failure due to anterior poliomyelitis are sufficient justification for future clinical treatment of similar cases in this manner and that they support the hope that in certain of these cases prolonged application of artificial respiration may bring the desired result.

The facts brought out in this paper should not be construed to mean that the mechanical respirator here described can in any way displace the Schäfer prone pressure method of artificial respiration for emergency resuscitation and rescue work in the field. As a relatively

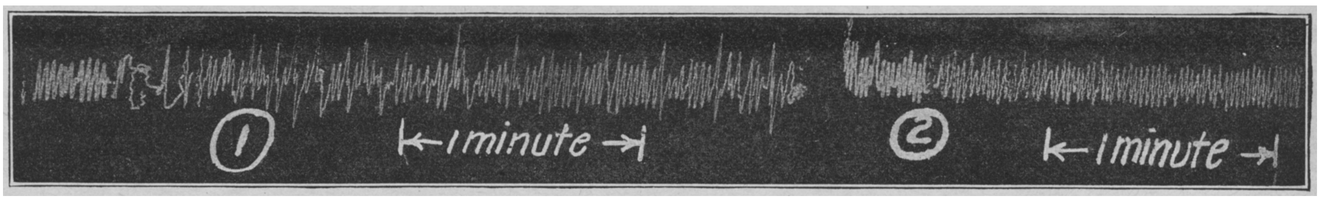

Fig. 2—Records of patient's respiratory movements: (1) on the evening of October 13, eleven hours before the administration of artificial respiration was required; (2) on the morning of October 15, when respiration was weak and wholly diaphragmatic. Attention is called to the absence of the occasional deep breaths seen in 1.

COMMENT

The normal respiration of a child of 8 years is about 18 a minute; we therefore ran the pumps to give from eighteen to twenty-four pressure changes, or breaths, a minute. Although this rate seemed to be satisfactory in this case, we believe that the optimum respiratory rate will vary somewhat with each patient and that it will always be higher for children than for adults.

The reason we used negative pressures (inducing inspiration) that were sometimes two or three times as great as the positive was to keep the rubber collar from rubbing against the child's chin. On positive pressure (expiration) the collar bulges out and, although this does not annoy an adult, a child's neck is relatively shorter and the chin, therefore, rubs against the collar. In the new tank now being constructed especially for children, this difficulty will be eliminated.

We experimented with different pressure combinations as much as could safely be done, but the child's condition was always critical and it seemed best, therefore, to run the pumps at the pressure combinations which we could see were satisfactory. The pressures were kept down to the lowest limits possible without producing discomfort or anoxemia.

complicated and nontransportable apparatus, it is at present a purely clinical tool, to be placed in hospitals in the hands of competent clinicians.

SUMMARY

A clinical test of a new apparatus for the administration of artificial respiration over prolonged periods indicates that it fulfills the desired clinical requirements. Artificial respiration was maintained almost continuously for 122 hours in a girl, aged 8 years, suffering from acute anterior poliomyelitis, without discomfort or apparent harm to the patient. Administration of artificial respiration did not prohibit sleeping or the taking of nourishment.

Death was believed to be due to cardiac failure. Examination of the lungs of the patient after death did not show any evidence of trauma due to overinflation.

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4. Thunberg, T.: Der Barospirator: Ein Apparat für künstliche Atmung nach einem neuen Prinzip, Abderhalden's Handbuch der biologischen Arbeitsmethoden, 1927, section 5, part 1, p. 561.

5. Petrén, K., and Sjövall, E.: Eine Studie über die tödliche akute Form der Poliomyelitis, Acta med. Scandinav. 64:260, 1926.