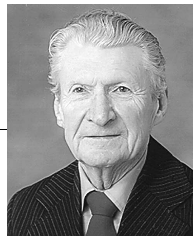
the history of artificial respiration



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Ever since man has been on this planet, there has been the need to inflate the lungs. Apart from biblical references to the breath of life, there is an unbroken line of progress in creating artificial respiration methods. Fisher [11] reported that midwives were the first to apply positive pressure to inflate the lungs using the mouth-to-mouth technique to start breathing in newborn infants as early as the 16th century. Good [12] states that "the lungs (of a subject) should be inflated with the warm breath of a healthy man, or which is better, oxygen gas."

The need for a practical manual method of artificial respiration became evident in the industrial revolution (late 1700s) when coal mining asphyxiations and drowning were frequent. The need increased when anesthesia entered medicine in the mid 1800s. In the late 1800s, when electrical energy was transmitted by high-voltage alternating current, the need became even more urgent because high-voltage shocks produce respiratory arrest. The post–World War II (1945) polio epidemic increased the need for artificial respiration applied continuously because the polio virus attacks the respiratory neurons. In modern times, the occurrence of frequent sedative drug overdose and cardiac arrest adds to the need for artificial respiration on an emergency basis.

Although a large number of manual artificial respiration methods were developed, few survived. The two that gained popularity were the Sylvester's [18] supine method, followed by the Schafer's [17] prone, back-pressure method. Both will be described briefly.

In the Sylvester method [18], the victim is placed on his back with a small pillow under the shoulders. The rescuer kneels astride the victim's head, facing him, and grasps both arms, pulling them out and upward until they are above the victim's head, as shown in Figure 1(a). Sylvester stated, "In my method we lift the ribs and sternum by the pectoral and other muscles, which pass from the shoulders to the parietes of the thorax, by steadily extending the arms up by the side of the patient's head; by elevating the ribs the cavity of the chest is enlarged, a tendency to a vacuum is produced, and a rush of air immediately takes place into the lungs. Expiration is brought about by simple compression of the sides of the chest by the patient's arms."

To illustrate the efficacy of his method, Sylvester connected a U-tube manometer to the nostrils of a dead body to measure intrapulmonic pressure. When the arms were raised above the head, the manometer indicated a negative pressure, thereby proving that his headward arm-lift method produced inspiration (or at least the potential for inspiration in the presence of an open airway). Expiration was aided by folding the arms on the chest and applying force.

There were several versions of this method; Figure 1(a) shows one version. Arm traction increased the size of the thorax and caused air to enter the lungs. The arms were then lowered and folded on the chest. Chest force was used to aid expiration.

With the Schafer method, the victim was placed face down with the head turned to one side. The rescuer kneeled astride the hips with the arms stretched, as shown in Figure 1(b). The rescuer places his hands over the lower ribs. Keeping his arms outstretched, the weight of the rescuer's body was rhythmically brought to bear upon the victim's posterior thorax by leaning forward. In this way, the thoracic cage and the abdominal viscera are compressed. Recoil of these compressed elastic regions drew air into the lungs.

The value of the foregoing manual techniques is that the rescuer could apply them at any time and place and that no equipment was needed. It appears that these early workers knew that abdominal compression moves air.

The death knell sounded for the manual methods (Sylvester, Schafer, and others) when Safar et al. [16] reported a study on 29 anesthetized and curarized adult volunteers. Tidal volumes ranging from 260 to 840 mL were measured. They also found that opening the airway by tilting the head backward was desirable. They concluded that "borderline tidal volumes, which were obtained with the manual methods with patent airways and healthy lungs, make it doubtful

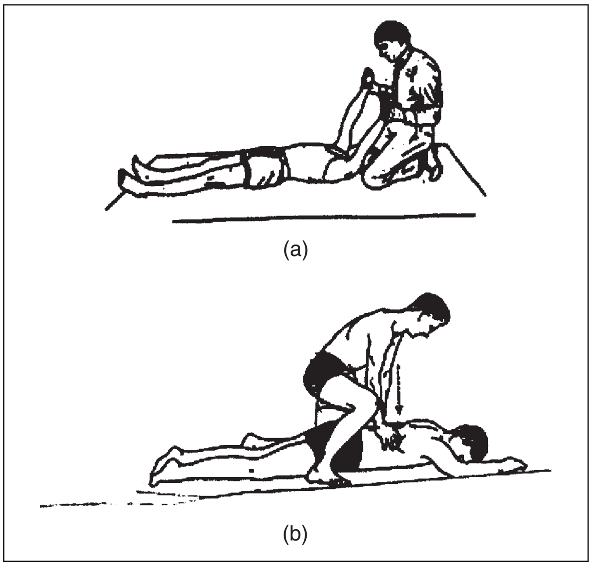

Fig. 1. The manual artificial respiration methods: (a) Sylvester and (b) Schafer.

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whether these methods should be taught at all in the future."

Mechanical Devices

Five types of mechanical devices were developed to provide artificial respiration. The first was a fireside bellows, used to apply positive pressure to the airway. The second used a facemask to deliver oxygen; it was called the Pulmotor. The third type applied negative pressure to the surface of the body to create negative pressure within the thorax, as exemplified by the iron lung (tank respirator) and the cuirass. The fourth type applied force to the body as exemplified by abdominal compression (the pneumobelt). The fifth type used the force of gravity to push the abdominal organs against the diaphragm by means of a rocking bed. All five types will be described.

Bellows

Undoubtedly, the first mechanical ventilator was the fireside bellows. According to Keith [13], it was used in the 17th century to inflate the lungs. He also reported that a double bellows was used; one inflated the lungs and the other deflated them. Use of the bellows was controversial, some saying that its place was at the fireside, but some used it effectively.

The Pulmotor

Largely as the result of asphyxia in association with mining, the Pulmotor was developed in Germany by Heinrich Dräger [4] around 1900. It took several different forms, the simplest of which is shown in Figure 2. It consisted of an oxygen cylinder, a pressure regulator, a pressure gauge, a clockwork-driven valve, and a facemask. The valve cycled every five seconds (12 breaths/min). When the valve opened, the rescuer applied the facemask; when the valve closed, the rescuer removed the facemask from the victim to allow expiration to occur.

The Pulmotor was a dependable, easy-to-use, and excellent first-aid device that was employed extensively in mines and by public-utility companies. It was soon used in hospitals. In modern terminology, the Pulmotor is a positive-pressure, time-cycled ventilator.

The Iron Lung

The tank, cabinet, or iron-lung respirator, as shown in Figure 3(a), consists of a chamber in which the patient is placed with the head excluded. Intermittent negative pressure is created within the chamber, causing the thorax and abdomen to expand, thereby drawing air into the lungs. A soft, snug seal surrounds the neck. Air is drawn into the lungs via the nose and mouth, and lung inflation is accomplished. The chamber is then returned to atmospheric pressure (or slightly above); the chest and abdomen recoil and air passes out of the lungs via the nose and mouth. The pressure fluctuations within the tank are created in most models by the movement of a large, flexible leather diaphragm at the end of the chamber. In another model, pulses of negative pressure are created by a valved suction pump. Figure 3(a) is a sketch of an iron lung.

The negative pressure developed within the iron lung need not be high to accomplish inspiration. Figure 4 shows the inspired volume versus the negative pressure applied to the chamber surrounding the patient. Several tens of centimeters of water is adequate to move a typical tidal volume.

The iron lung provided life support for thousands of polio patients. The gasketed port holes on both sides of the tank allow for some degree of nursing care while the device was in operation. By the early 1950s, many hospitals had rooms full of iron lungs, and power failure was a real hazard. Each hospital staff member was assigned to two iron lungs in case of a power failure. Each iron lung had a handle that permitted manual operation of the leather diaphragm. One person could operate two iron lungs easily. In those days, few hospitals had backup power supplies for the wards, although operating rooms had automatic emergency power.

Cuirass

Although the iron lung is an excellent artificial respirator capable of providing a large tidal volume with a small negative pressure, nursing care was inconvenient and many patients did not need the full capability that it provided. It was soon recognized that the negative pressure need not be applied to the whole body surface, thus was born the cuirass respirator in which the negative pressure is applied to a shell covering the chest and abdomen or the chest only. Figure 3(b) shows both types. Figure 4 presents the ventilatory capabilities of the two types of cuirass.

The word cuirass is derived from the French and is translated as *breast plate*. It was held to the body by two straps that passed around the back. The shell was gasketed to the body by an air-filled bladder. If the patient was recumbent, expiration was due to the elastic recoil of the chest and abdomen: if the patient were sitting or standing, the effect of gravity on the abdominal organs aided in expiration. Nursing care

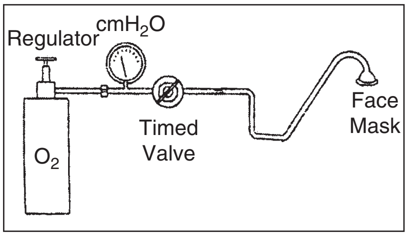

Fig. 2. The Dräger Pulmotor.

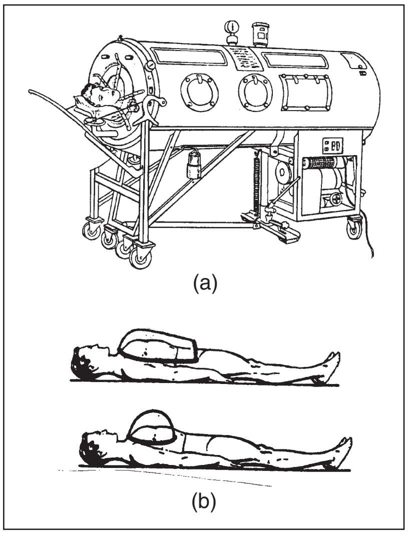

Fig. 3. The negative-pressure ventilators: (a) Iron lung (courtesy of Emerson) and (b) cuirass (courtesy of Monghan).

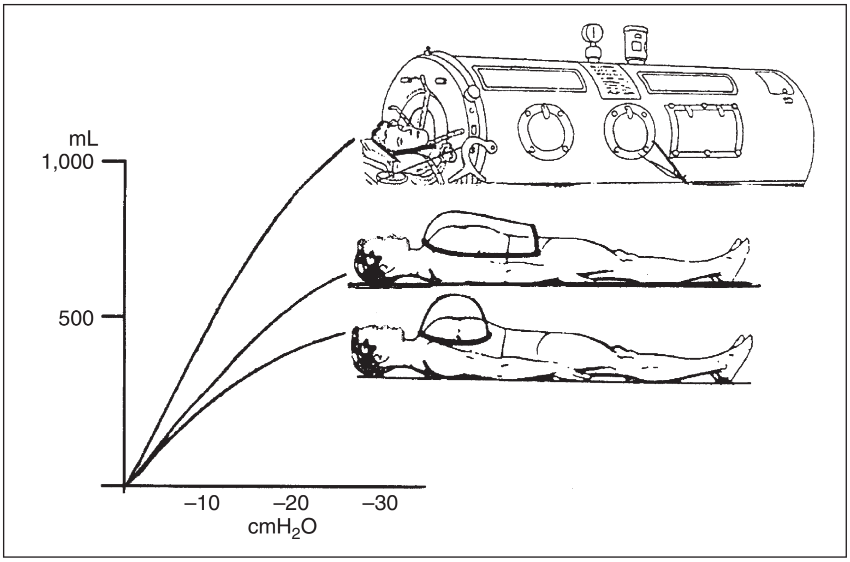

Fig. 4. Performance of the negative-pressure ventilators. Composed from data published by Collier and Affeld (20).

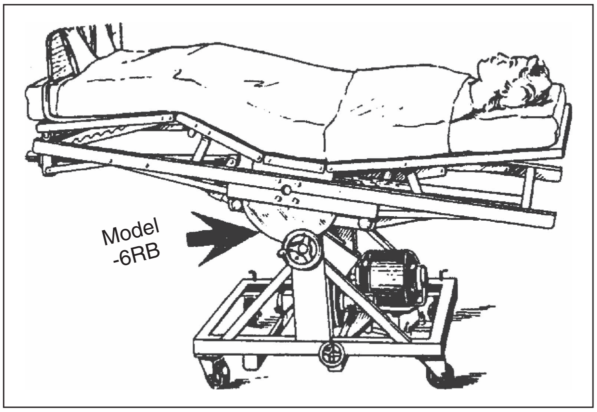

Fig. 5. The rocking bed.

was greatly facilitated for those who could be ventilated by the cuirass.

Pneumobelt

That rhythmic abdominal compression provides artificial respiration was known for some time. The device, first described by Adamson and Stern [1], consisted of a large, flat bladder built into a girdle. The cycling of pressure could be synchronized with a patient's breathing to provide respiratory assistance.

Adamson and Stern [1] stated, "A new mechanical respirator, operating on the principle of assisted expiration through intermittent abdominal pressure, has proved effective as a ventilatory aid in a group of 15 patients with respiratory paralysis." Adequate ventilation of all subjects was accomplished with less than 50-cm H_2O applied to the abdomen, with the subjects in a sitting position. Ventilation rose progressively as the subjects' trunks were raised from the recumbent to the sitting position and, similarly, as the abdominal pressure was increased. The respirator has been found to be a valuable adjunct to other respiratory aids in permitting rehabilitation activities without hypoxia. For some activities, it is the respirator of choice. Preliminary observations in patients with pulmonary emphysema suggest that this new respirator may have a definite place in the overall management of this disease.

A similar device was described by Miller et al. [14]. In a study of 15 patients, a bladder pressure of less than 50-cm H_2O produced a normal tidal volume, and they strongly recommended its wider acceptance for the high quadriplegic population.

With pneumobelt-like devices, bladder inflation produces expiration; inspiration is produced by the elastic recoil of the compressed abdominal tissues and organs. Force applied to the abdomen pushes the diaphragm headward to expel air from the lungs. Removal of the force causes the elastic recoil of the compressed tissues to draw air into the lungs. If the subject is standing or sitting, gravity assists inspiration. If the subject is recumbent, it is the elastic recoil of the compressed tissues and organs that provides inspiration.

Rocking Bed

The rocking bed (Figure 5) represents a different concept for providing artificial respiration because it uses the weight of the abdominal organs to move the diaphragm. The concept originated with Eve in 1932 [10], who postulated that the abdominal contents would raise the diaphragm as the head was tilted downward and that inspiration would occur as the head was tilted upward. Interestingly, patients learned to sleep in rocking beds.

Postscript

Although there are many elegant positive-pressure ventilators with sophisticated safety controls, they are rarely available in the field, thereby forcing a rescuer to resort to the very effective mouth-to-mouth breathing method [5]–[7] used by midwives since the 16th century. Mouth-to-mouth breathing is the cornerstone of cardiopulmonary resuscitation. However, there is the risk of transferring infection [2], [15]. To minimize this risk factor, a variety of airway assist devices such as facemasks or shields have been created. However, some rescuers still refuse to perform mouth-to-mouth breathing if there is suspicion of disease. Therefore, it would appear timely to rediscover rhythmic, abdominal compression to provide lung ventilation, either by manual means or by means such the pneumobelt, which can be seen to provide quite adequate ventilation.

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