Cuffed Tracheotomy Tube vs. Tank Respirator for Prolonged Artificial Ventilation

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• During the 1960 epidemic of poliomyelitis in Maryland, 24 apneic patients were given respiratory aid with volume-cycled intermittent positive pressure respirators. A routine was established which provided adequate ventilation and prevented major pulmonary complications. The routine included the use of large bore cuffed tracheotomy tubes, humidification, artificial coughing and sighing, changing of position, sterile tracheobronchial aspiration and monitoring of ventilation. Five of the 24 patients died within three months. Two of the 5 deaths could possibly have been prevented. Six of the survivors will require artificial respiration for an indefinite period. In addition, circulatory and respiratory parameters of 4 patients were studied during positive pressure ventilation via tracheotomy and with the tank respirator. Clinical results of tank respiration during previous epidemics are compared with results of positive pressure ventilation via tracheotomy.

In spite of the anticipated disappearance of paralytic poliomyelitis, prolonged artificial ventilation will remain of practical importance. New indications for prolonged artificial ventilation are receiving increasing attention. They include: (1) respiratory paralysis from intoxication or from deliberate curarization in status epilepticus, tetanus or prolonged hypothermia; (2) severe disease of the lungs; (3) severe trauma of the chest wall; (4) restrictions of breathing movements, for instance, after an abdominal operation for abdominal distention or obesity, and (5) metabolic acidosis, for instance, after an open heart operation or prolonged hypoxia or during severe shock. Desperately ill patients suffering from reversible conditions may benefit from controlled ventilation (i.e., passive hyperventilation), which abolishes the work of breathing and thus reduces their oxygen consumption and acidosis.

In the United States of America, prolonged artificial ventilation of patients with poliomyelitis has been performed most commonly with the tank respirator (iron lung). In contrast, in Europe intermittent positive pressure ventilation via cuffed tracheotomy tube was preferred. In most American centers prolonged artificial ventilation has been under the direction of internists, while in most European centers it has been under the direction of anesthesiologists. Are these differences in practice merely differences in "habit," or is one method actually superior to the other?

Physiologically, both methods are positive pressure technics, since in each the intrapulmonary pressure during inflation is higher than the pressure surrounding the patient. Therefore, the effects on lungs and circulation are comparable.

During the 1952 epidemic of poliomyelitis in Scandinavia, Lassen,[1] Ibsen and others treated more than 300 patients by prolonged artificial ventilation. Of the first 31 patients, who were

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treated with tank respirators, 27 (87 per cent) died in the acute phase of the disease, primarily because of inadequate ventilation. Of the others, who were treated with intratracheal intermittent positive pressure ventilation (either manually by compression of a breathing bag or mechanically with a respirator), only approximately 40 per cent died; most deaths were late and due to pulmonary infection.

Material and Methods

At the Baltimore City Hospital, which receives almost all patients with paralytic poliomyelitis in Maryland, the tank respirator was used exclusively prior to 1956. Since 1957, intermittent positive pressure ventilation has been used exclusively in the intensive care unit.[2] More than 100 patients were treated with various types of positive pressure respirators, primarily for problems other than poliomyelitis, since paralytic poliomyelitis has almost disappeared. It was natural, therefore, that intratracheal intermittent positive pressure ventilation was used exclusively also during the 1960 epidemic of poliomyelitis in Maryland, when 88 patients with acute poliomyelitis were admitted unexpectedly to the hospital, and 24 of them required prolonged artificial ventilation.

Tracheotomy—Although the Scandinavians showed that intermittent positive pressure ventilation via cuffed tracheotomy tube can be carried out continuously and effectively for years, their results with this method should not be compared with their results with the tank respirator, for the following reasons: 1. Their patients treated with the tank respirator were not tracheotomized, while the other patients were. 2. Their patients treated with the tank respirator were the first ones treated during the epidemic, at a time when undoubtedly the staff had little experience and was overwhelmed by the great number of patients.

In contrast, almost all patients treated with the tank respirator at the Baltimore City Hospital were tracheotomized, and the experience and skill of persons taking care of the patients in the two groups seemed comparable. Most of the patients who were placed in the tank respirator without tracheotomy had to be tracheotomized later because of accumulation of secretions in the tracheobronchial tree and because of obstruction of the upper airway by soft tissue obstruction.

All patients receiving prolonged intermittent positive pressure ventilation at the Baltimore City Hospital in 1960 were tracheotomized. The effectiveness of intermittent positive pressure ventilation is always increased by the use of a tracheal tube or tracheotomy tube, since the tube prevents gastric insufflation and air leaks, facilitates tracheobronchial suction and provides a patent airway at all times. Sometimes intermittent positive pressure ventilation was started via an orotracheal tube, and tracheotomy was performed later, when the need for prolonged artificial ventilation became apparent. When intubation is necessary for more than one or two days, tracheotomy is advisable, because the orotracheal tube may produce laryngeal edema and may become plugged with crusts, since it lacks an inner cannula. In addition, the conscious person tolerates a tracheotomy tube better than an orotracheal tube.

With adults, intermittent positive pressure ventilation was performed via cuffed tracheotomy tubes, to prevent inhalation of gastric contents or saliva around the cannula and to permit constant volume ventilation without leakage of air. Tracheal ulceration did not occur when the cuff was inflated only sufficiently to prevent leakage of air. The cuff was deflated briefly every two hours. In conscious patients with intact reflexes of the upper airway, a minimal leak between cuff and tracheal wall was maintained to allow the patient to talk during inflations.[3] Inspite of this minimal leak, constant volume ventilation could be maintained.

The indications for tracheotomy of patients with poliomyelitis were approximately the same for those treated with the tank respirator and those treated by intratracheal intermittent positive pressure ventilation: (1) decreased vital capacity; (2) difficulty in swallowing; (3) the presence of secretions in the airways; weak cough; (5) ascending paralysis, and (6) signs of encephalitis.

Tracheotomy care, however, was not comparable, since before 1956 suction was not performed by a sterile atraumatic routine. In 1960, shortly after the beginning of the epidemic, a routine of sterile atraumatic tracheotomy care was introduced[3] (fig. 1).

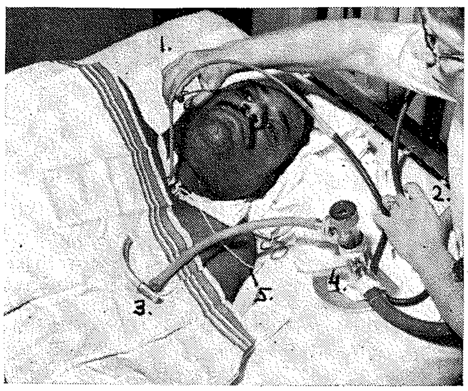

Fig. 1—Sterile tracheotomy care: (1) Catheter with curved tip inserted with forceps; (2) intermittent occlusion of T-tube for suction; (3) inner cannula with swivel connector; (4) nonrebreathing valve; (5) tube for inflation of cuff.

Respirators—Drinker tank respirators providing negative and positive tank pressures were used. The intermittent positive pressure respirators usually were modified Mörch piston respirators,[4] which proved reliable and simple. Other respirators are equally or even more satisfactory, provided they fulfil the following requirements: 1. Ventilation must be adequate for oxygenation and removal of carbon dioxide, even for patients with reduced lung-thorax compliance and increased airway resistance; volume-set respirators are more reliable in this respect than pressure-set respirators. 2. There must be means of monitoring tidal volumes and airway pressures (fig. 2). 3. Peak airway pressures must be high enough to overcome increased pulmonary resistance, but mean airway pressures should be as low as possible; this does not require a negative phase during exhalation if the expiratory pause at atmospheric pressure is at least as long as the inspiratory phase. 4. The respirator must function with room air and without carbon dioxide absorbents. 5. It must be simple and reliable in long term use, i.e., it must be "nurse proof." 6. It must deliver humidified air or a mixture of air and oxygen, with a relative humidity above 90 per cent at the tracheotomy tube; this is possible only with the use of specially heated humidifiers. (The Mörch piston respirator, which normally does not come with a heated humidifier, had to be modified.)

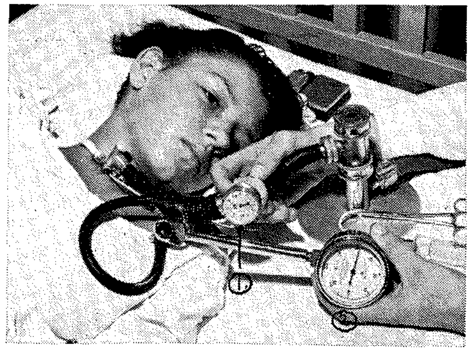

Fig. 2—Monitoring of tidal volumes and airway pressures. Ventilation meter (1) and pressure gage (2) are placed temporarily between nonrebreathing valve and tracheotomy tube during adjustment of Mörch piston respirator.

For most adult patients tidal volumes between 500 and 1,000 ml. of air at a rate of 15 inflations per minute were required to prevent cyanosis and to make the patient feel adequately ventilated. This amount of ventilation is about twice that recommended by the Radford Nomogram. This hyperventilation usually caused arterial carbon dioxide tensions between 20 and 35 mm. of mercury. Normal ventilation according to the Radford Nomogram often provided normal carbon dioxide tensions, but hypoxia was common. This suggests abnormality of the lungs with venous admixture, common in patients treated by respirator. Therefore, in addition to hyperventilation it is always advisable to increase the concentration of inhaled oxygen of the respirator air to approximately 50 per cent during prolonged artificial ventilation.

Apneic patients with poliomyelitis crave hyperventilation, even when carbon dioxide and oxygen values are normal. Therefore, complicated technics for monitoring of blood gases are rarely essential when deliberate mild hyperventilation with 50 per cent oxygen is used. Hyperventilation was maintained for months with the patient remaining conscious and showing no signs of tetany.

Ventilation for Emergency Reoxygenation, Interval Ventilation and Transportation[5]—Under emergency conditions the use of complicated equipment is not only cumbersome but dangerous. The simplest and most versatile methods of reoxygenating the lungs of asphyxiated persons and for short term intermittent positive pressure ventilation are manual compression of a breathing bag or bellows or insufflation of exhaled air (mouth to mouth or mouth to tracheotomy tube).

The self-inflating foam rubber bag designed by Ruben or hand bellows do not depend on a supply of compressed oxygen. Ventilation with the self-inflating bag, which was connected via a nonrebreathing valve to the tracheotomy tube, proved extremely simple and effective whenever there was need for discontinuing the respirator, e.g., during nursing care, service to the machine or transportation of the patient to another hospital. Long tubing between the bag and the nonrebreathing valve provided maximal flexibility during transportation. Suction during transportation was performed with a foot pump, which does not depend on power supply or oxygen.

Whenever possible, transportation of patients who require respiratory assistance should be performed under the supervision of an anesthesiologist, assisted by a nurse. A regular ambulance car is sufficient. Transportation in tank respirators requires a large team of experts, usually does not provide uninterrupted adequate ventilation and is unnecessarily cumbersome.

Results

The results are summarized in tables 1 and 2. In 1952, 1953 and 1955, 48 patients were treated with the tank respirator; most of them were tracheotomized, and more than half of them died during artificial ventilation. In 1960, 24 patients were treated by intratracheal intermittent positive pressure ventilation; all of them had been tracheotomized, and 17 per cent of them died during artificial ventilation. Deaths which occurred after the return of adequate spontaneous respiration are not included in table 1.

Table 2 indicates that in 1955 death occurred during the acute phase of disease of all 5 adults who died. The other 5 adults were discharged to a respirator center after one or two months, when they still required artificial ventilation Most patients treated in the iron lung suffered from pulmonary complications which eventually were lethal. Until 1956, almost all patients who survived in the tank had to remain in it until discharge to a respirator center between one and three months later.

In contrast, in the 1960 series (table 2) 14 patients regained adequate spontaneous respiration after intratracheal intermittent positive pressure ventilation for periods ranging from two days to three months. Twelve of these 14 patients were discharged with adequate spontaneous respiration. One patient, a 22-year-old man, was breathing adequately and ready to be discharged, but died suddenly during defecation (Valsalva maneuver) on the fifty-first day after admission. Another patient, a 5-year-old mongoloid boy, had regained adequate spontaneous respiration after three months of intermittent positive pressure ventilation, but died of fulminating bilateral pneumonia during the fifth month after admission.

Six patients were discharged to respirator centers while they were still essentially apneic between 1 and 4½ months after admission. One of these patients died in a tank respirator at the respirator center. Four of these 6 patients regained some minimal breath-

Table 1: Poliomyelitis at Baltimore City Hospital
Number of Patients

	Total	Bulbar and Bulbospinal Paralysis	Tracheotomy	Prolonged Artificial Ventilation	Deaths During Artificial Ventilation	Mortality (% of Respirator Patients)
1952*	137	25	5	5*	4	80
1953*	255	59	23	28*	13	46
1955*	129	?	12	15*(5 children; 10 adults)	8 (3 children; 5 adults)	53
1960†	88	43	25	24†(10 children; 14 adults)	4 (3 children; 1 adult)	17

*Tank respiration.
†Intermittent positive pressure ventilation with cuffed tracheotomy tube.

Table 2: Poliomyelitis at Baltimore City Hospital
Duration of Artificial Ventilation

1955 Tank Respiration		1960 Intratracheal Intermittent Positive Pressure Ventilation			
		Adults		Children	
Period	Result*	Period	Result*	Period	Result*
1 day	Died	2 days	S.R.	3 days	S.R.
2 days	Died	3 days	S.R.	3 days	S.R.
3 days	Died	4 days	Died	5 days	S.R.
9 days	Died	10 days	S.R.	7 days	Died
12 days	Died	14 days	S.R.	10 days	Died
1 mo.	R.C.	15 days	S.R.†	11 days	S.R.
1 mo.	R.C.	16 days	S.R.	11 days	Died
1 mo.	R.C.	24 days	S.R.	1 mo.	S.R.
2 mo.	R.C.	1 mo.	S.R.	3 mo.	S.R.†
2 mo.	R.C.	1 mo.	R.C.	4½ mo.	R.C.
		3 mo.	R.C.†		
(Adults only; data on children are not available)		3½ mo.	R.C.		
		3½ mo.	R.C.		
		4 mo.	R.C.		

*S.R. indicates recovery with adequate spontaneous respiration; R.C. indicates discharge to respirator center with artificial ventilation.
†Late death.

ing movements, but still required respiratory assistance one year later, 1 child was still apneic 1½ years later.

Four patients died during prolonged intratracheal intermittent positive pressure ventilation:

1. A 35-year-old woman (E.M.) died soon after admission from what seemed to be circulatory collapse, inadequately treated, in spite of adequate reoxygenation of the lungs.

2. A 9-year-old boy (R.H.) was admitted with bilateral pneumonitis, large amounts of tracheobronchial secretions and bulbospinal paralysis. He died on the seventh day from what seemed to be a combination of circulatory collapse and hypoxia due to pneumonitis.

3. A 3-year-old girl (V.T.) died from an unrecognized obstruction of the tracheotomy tube. This was an entirely preventable death.

4. An 11-year-old boy (N.D.), admitted with tracheobronchial secretions and severe hyperthermia, died with signs of encephalitis, hyperthermia and pneumonitis soon after admission. The hyperthermia was inadequately treated.

In some of these patients cardiac action was restored by external cardiac massage. However, all of them died subsequently.

The use of the tank respirator provided adequate ventilation only when the airways were clear, the lungs and thorax were compliant and there were no significant leaks of air at the collar. It often was difficult to provide a leak-free seal of the collar of the tracheotomized patient, particularly when the neck was short.

For patients with abnormal lungs and large amounts of tracheobronchial secretions and for patients who were heavy and obese, only intermittent positive pressure ventilation via tracheotomy provided adequate ventilation in the acute phase of the disease. For many patients whose pulmonary condition deteriorated while they were in the iron lung in spite of tracheotomy, initial resuscitation was possible by switching to positive pressure ventilation with a breathing bag.

The incidence of atelectasis was increased during the use of the tank respirator, apparently because of difficulty in changing the patient's position and in performing physical therapy, physical examination and roentgen examination. Patients treated in the tank respirator frequently required bronchoscopic aspiration. None of the adults treated by intratracheal intermittent positive pressure ventilation required this. This difference, we believe, was due to the routine of sterile and atraumatic tracheotomy care, the artificial coughing and sighing maneuvers[3] and the fact that the positive pressure technic provides increased tidal volume. Prolonged ventilation with small tidal volume leads to a reduction in lung compliance and atelectasis.

Other disadvantages of the tank respirator are: (1) poor psychologic effect on the patient, who feels as though encased in a box; (2) difficulty in nursing care, which leads to a higher incidence of pressure sores and phlebothrombosis; (3) difficulty in synchronizing the machine with spontaneous respiration; (4) the patient's inability to talk in the presence of a tracheotomy tube, and (5) the high price.

The advantages of the tank respirator over intratracheal intermittent positive pressure ventilation are: 1. The tank can be used by patients who do not require tracheotomy, but these are exceedingly rare. 2. In the absence of direct supervision, accidental interruption of ventilation is less likely to occur in the tank, since there is a possibility of accidental kinking or disconnection of tubing of positive pressure ventilators. Obviously, with the use of either respirator a patient-triggered alarm system should be provided.

Patients treated by intratracheal intermittent positive pressure ventilation had a higher survival rate than those treated in the tank respirator, and this was not due to increased severity of disease of patients treated by the latter means. There were 6 patients treated by intratracheal intermittent positive pressure ventilation who were still completely apneic after four months of artificial ventilation, while almost all patients who survived the acute phase in the tank respirator had some spontaneous respirations.

The safety of prolonged intermittent positive pressure ventilation lies in the following factors: (1) adequate ventilation to keep the patient comfortable, alert and well supplied with oxygen, (2) meticulous tracheotomy care with utmost attention to both sterility and avoidance of trauma; (3) maintenance of ciliary function by maximal humidification of the inhaled air with a heated humidifier; (4) artificial sighing and coughing maneuvers to counteract atelectasis; (5) frequent changes of posture to prevent hypostatic pulmonary congestion; (6) support of circulation, and (7) uninterrupted ventilation with hand-operated equipment when the respirator is disconnected.

Summary and Conclusions

The use of the tank respirator should be reserved for the rare apneic patient with "dry" lungs who does not need tracheotomy.

The principal advantages of intratracheal positive pressure ventilation over tank respiration are greater accessibility and mobility of the patient and the increased ventilatory reserve.

Intratracheal intermittent positive pressure ventilation produces better ventilation than tank respiration for the patient with abnormal lungs and the patient who is heavy and short.

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