THE IMMEDIATE TREATMENT OF RESPIRATORY FAILURE
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When a patient has stopped breathing, it is only a matter of a very few minutes before there occurs irreversible damage, which makes full recovery, or even survival, improbable. In general, therefore, treatment of the primary cause of the situation is often of much less urgency than symptomatic treatment, which necessarily includes the immediate initiation of artificial respiration.

Because of the urgency, the very first person who encounters a respiratory emergency must treat the patient. Generally the chance that a physician will find the victim is extremely small, so that methods applicable by laymen are of major importance. If resuscitation equipment does not happen to be actually on the spot of the accident, and the odds against this are great, then running for equipment would be wasting vital time. Therefore methods are needed which are not dependent on any device. This also means that in the field, a physician in this respect would be in much the same situation as a layman.

Laymen have most often been those involved in administering aid in respiratory emergencies. Associations in charge of teaching first-aid were until recently interested in the evaluation of methods of artificial respiration for field use, and have often taken advice from almost anyone who, with or without pertinent practical knowledge, expressed views about resuscitation. That this was a not very fortunate arrangement is apparent from the results found in testing these methods. Though some of the so-called manual methods, after investigations by Gordon et al. (1951) and Nimms et al. (1951), were preferred as being particularly satisfactory, a new opinion of their suitability was expressed when it was found that with none of these methods could an open airway be established with certainty. (Safar, Escarraga and Elam, 1958). A few years ago when anaesthesiologists took an active interest in the field, there took place a revision of the methods of resuscitation, resulting in the reintroduction of the ancient method of expired-air resuscitation (Safar, Escarraga and Elam, 1958; Safar, 1958; Gordon et al., 1958; Elam et al., 1958).

The widespread application of expired-air resuscitation and its general introduction, however, still presupposed the solution of several practical problems, which were then still involved in its use. Some of these are now discussed.

AIRWAY PROBLEMS

Failure to achieve an open air passage in the pharynx had been found to be the primary reason for the inefficiency of the manual methods (Safar, 1959). To establish an open passage, the common method of forward displacement of the mandible was incorporated in the technique of expired-air resuscitation when it was reintroduced. Two modifications were suggested, namely pushing forward behind both rami of the mandible, or pulling the jaw forward with a finger inserted in the mouth behind the lower front teeth (Safar, Escarraga and Elam, 1958; Safar, 1958). Simple as these manoeuvres may seem to the anaesthetist, it was soon found that they were only mastered with difficulty, if at all, by laymen (Elam et al., 1960). A simplification of the technique for this purpose was sought and resulted in the use of the head-tilt manoeuvre for opening the airways (Ruben, Elam and Ruben, 1959). This consists of the simple backward extension of the head, i.e., without additionally pulling or pushing forward on the mandible. If care is taken to produce the backward tilt of the head at the level of the uppermost articulations of the cervical spine, it causes such a movement of the mandible (because of its muscular attachment) that the tongue is pulled away from the posterior pharyngeal wall. The backward tilt may be performed with the patient’s mouth closed or open. In the first case, where the mandible is pulled up against the maxilla though, as mentioned, without forward displacement, an important advan-
The backward tilt of the head then produces a passage through the pharynx two or three times wider than when the mouth is left open (Ruben, Bentzen and Saev, 1960; Ruben et al., 1961; Morikawa, Safar and De Carlo, 1961). Furthermore, when studying the decreasing pharyngeal clearance which occurs when starting from the maximum backward tilt and flexing the head more and more, the clearance produced with the mouth closed is seen to be present through a much wider angle than with the mouth open (Ruben, 1961b). In the second case one needs a backward tilt within less than 15 degrees of the maximum possible to maintain an open air passage, but improper technique or tiredness may easily result in a failure to achieve or maintain this degree of tilt. With the mouth closed, on the other hand, a deficiency in tilt of a much larger angle, up to some 35 degrees, leaves an open air passage. Therefore the “closed mouth” tilt technique is the much lesser critical method, this being of particular importance when it is the method to be used by laymen.

If the mouth is closed during the tilt, then nasal inflation becomes the natural route.

REGURGITATION PROBLEMS

Almost inherent in the use of expired-air resuscitation is the possibility of regurgitation of gastric contents, and therefore also the danger of aspiration into the lungs. This occurrence is known to have caused not only a failure of resuscitation, but even to be the direct cause of death (Matthews, 1960a, b; Philips, 1964). But the risk of occasional aspiration of gastric contents into the lung, it was said, was the price which had to be paid for the overall increased efficiency of expired air resuscitation when compared with the manual methods (Venn, 1963). Investigations performed on corpses into the regurgitation problem, however, showed how the risk could be minimized (Ruben and Ruben, 1962). Though other mechanisms may result in the expulsion of gastric contents into the pharynx (e.g. external pressure on the abdomen and active vomiting), inflation of the stomach with air was found to be an almost certain way of producing regurgitation of water instilled into the stomach. Therefore, the conditions for gastric inflation are of interest in the problem under discussion. Investigations performed on anaesthetized volunteers (Ruben, Knudsen and Carugatti, 1961) showed that gastric inflation depends on the pressure at which air is inflated during artificial respiration, and that regurgitation may be avoided by limiting inflation pressure. By exceeding a pressure of 25 cm H₂O, in most subjects gastric inflation was produced, while pressures below 15 cm H₂O, did not do so in any of the cases investigated. The latter is in agreement with clinical impressions previously reported (Mushin and Morton, 1958).

How to ensure a sufficient limitation in the inflation pressure then became another problem. Fortunately, clinical trials (Ruben, Elam and Ruben, 1959) indicated that when using the nasal route gastric inflation seemed to occur less often than when using the oral route. This is understandable since the greater resistance to inflation through the nose results in a pressure fall of the inflowing air by the time it reaches the pharynx. This is in effect very close to an automatic reduction to a suitable pressure since the more forceful inflation (which causes bigger airflow rates) the greater the relative reduction in the air pressure.

The above considerations may all appear of theoretical interest only. Recent reports from the use of expired-air resuscitation in actual emergencies have, however, shown that regurgitation is least apt to occur when the nasal inflation route is used (Seiler, 1963). Of 17 patients having mouth-to-mouth ventilation, 8 regurgitated, i.e. 48 per cent, while of 20 having mouth-to-nose ventilation, 3 regurgitated, i.e. 15 per cent of the patients.

Apart from the deliberate use of too high an inflation pressure, a high pressure would indirectly be produced by rapidly inflating relatively big tidal volumes against resistance. This would also result in gastric inflation. This might, for example, easily happen when an adult rescuer performs expired-air resuscitation on a child. Also in the case of increased airway resistance, e.g. in cases of spasm and oedema of the airways, gastric inflation would be more prone to occur. Unless tracheal intubation could be performed, which probably would not often be the case under field conditions, a relatively “slow” inflation rate
may serve to avoid this occurrence. Firm back-
ward pressure on the neck against the thyroid
cartilage may be another way to deal with this
problem (Herholdt and Rafn, 17%), just as
cricoid pressure is used to prevent regurgitation
during the induction of anaesthesia in the patient
with a full stomach (Sellick, 1961).

**CHOICE OF INFLATION ROUTE**

As well as the airway problem, the regurgitation
problem favours the choice of the mouth-to-nose
method rather than the mouth-to-mouth. There-
fore, it becomes of practical importance to take
the incidence of possible blockage of the nose into
consideration.

To investigate this, 3,676 subjects were ex-
amined for their ability to breathe through the
nose (Ruben, 1961a). A less than 2 per cent in-
cidence of nasal blockage was found, which is in
agreement with other findings (Buchanan, 1960).

A question of particular interest for the treat-
ment of drowning subjects is whether, after sub-
mergence, swelling of the nasal mucous membranes
would make the nasal route of inflation inapplic-
able. Investigations into this (Ruben et al., 1962)
were performed on conscious volunteers. After
instillation into the subject's nose and naso-
pharyngeal cavity of respectively fresh water for
10 minutes in five persons, and 4 per cent saline
for 5 minutes in four persons, rhinoscopy did
not show any signs of hyperaemia or oedema
of the nasal mucous membrane. All the subjects
were also breathing freely through the nose after
the experiment. In case of necessity, the mouth-
to-nose method would still be fully applicable in
every single case.

Though the incidence of nasal blockage varies,
total blockade must be relatively rare. The
examinations and investigations seem to warrant
the conclusion that it would not be unrealistic
to make a first choice of the nasal inflation route
for expired-air resuscitation. But when nasal
blockage is present, then inflation would have to
be done through the mouth. The head-tilt
method, of course, is still usable in such an event.
To avoid unnecessary narrowing of the pharyn-
geal air passage one should, however, not let the
mandible sag fully but only open the mouth
slightly.

By reserving the mouth-to-mouth technique as
second choice, this method becomes particularly
simple. Because the use of the oral route means
that the nose is blocked, no efforts to pinch the
nostrils or rest the cheek against the nostrils need
be taken to prevent air leaking through them
during inflation. Thereby the technique of the
mouth-to-mouth method becomes essentially the
same as the mouth-to-nose technique, includ-
ing hand-position and backward tilting of the
head. The only difference actually consists of
"blowing through the other hole". Such simpli-
city, of course, is of particular advantage in teach-
ing laymen.

**PROBLEM OF WATER IN THE LUNGS**

A problem specially concerned with drowning is
whether or not one should try to empty water out
of the lungs before starting artificial respiration.
To solve this, investigations have been under-
taken on warm corpses (Ruben and Ruben, 1962).
After instilling amounts of up to 1.9 litres of
water into the lungs through a tracheal tube,
forceful pressure was applied (a) on the chest and
abdomen of the supine corpses, (b) after turning
them into the prone position, and (c) at the back
of the body placed in a jack-knife position with its
upper part in a steep head-down position. It was
found that in most cases it was possible to empty
only an insignificant part of water from the
lungs, namely between 5 and 75 ml. In the
occasional case, where more ran out than corres-
ponded to what had stayed in the airways, the
process took several minutes, and afterwards
large amounts of water still remained in the lungs.
In an actual emergency it is certain that too much
valuable time would have been wasted over the
emptying procedure. It is possibly of interest
that one could inflate the lungs with up to 1 litre
of air, even when they contained between 1 and
1.9 litres of water. Such circumstances, of course,
demanded an inflation pressure greater than that
normally required.

It appears that water seen running out from
the mouth during emptying efforts had come
mainly from the stomach. Emptying manoeuvres
have not only wasted time, but possibly have also
promoted the additional risk of aspiration of
gastric contents into the lung.
TEACHING PROBLEMS

In assessing the value of a method, problems of teaching and achievement of performance are important, and especially so if intended for use by laymen. Even after a suitable technique has been arrived at, the problem of how to teach expired-air methods still remains. The manual methods can be taught and learned by having one person practise the manoeuvres on his fellow. Soon after its introduction this method was actually used to teach expired-air resuscitation also, but was soon found inadvisable. Apart from the limitation which this would mean to the widespread teaching of the method, it also carries the risk of disseminating disease (e.g. general colds, pneumonia, meningitis). Another limitation is that a conscious person cannot simulate the airway obstruction of a deeply unconscious person needing artificial respiration.

The need for a teaching model, therefore, soon became apparent, and as a result the AMBU manikin together with other teaching aids was devised in 1958 (Ruben, 1958) and introduced the following year (Der Lebensretter, 1959; Ruben et al., 1960).

The AMBU manikin consists of a torso, which has a movable head and neck. Obstruction of its airway to the lung results unless the head is tilted backward or its jaw is lifted, or a combination of these manoeuvres is accomplished. It is realistic in its relative resistance encountered during inflation. Thus it also has increased resistance to inflation through the nose. The compliance of its chest is variable through the normal and abnormal range. Inflation of the stomach is simulated when too large a volume or too high a pressure is used, so that it duplicates the decreased tendency of stomach inflation when blowing through its nose as compared with oral inflation.

It is of particular importance that spread of infection from one trainee to another does not result through the use of manikins. Therefore, the AMBU manikin has an exchangeable mouth/nose piece, which is changed after each trainee has used it. This removable portion allows easy mechanical cleaning and sterilization of its cavities, e.g., by boiling. Also the manikin's airway tubing system is easily removed for sterilization and its lung and stomach consist of disposable plastic bags.

Another training aid which has proved to be important is an extremely simplified sagittal model of the head (Ruben, 1958; Der Lebensretter, 1959) which displays the appropriate anatomical structures. It is used to demonstrate to laymen in an easily understandable way how and why the airway in the pharynx is obstructed, and how obstruction is relieved by head positioning and/or elevation of the jaw.

To evaluate the importance which training has for the performance of laymen, several groups, after having been taught expired-air resuscitation, have had their ability assessed on anaesthetized volunteers (Ruben et al., 1960; Elam, Ruben and Bittner, 1961). These assessments and another (Lind, 1961) are in accordance with the general impression gained by first-aid teachers, namely that the single most important factor in learning expired-air resuscitation is the practice on a manikin. He who has had a chance to assess his performance practically, is better prepared to deal with an apnoeic emergency than an untrained person, who must improvise completely or who may hesitate from lack of knowledge and assurance, with the result that those valuable first minutes are lost. The importance placed on training in expired-air resuscitation with a manikin is seen from the fact that manikins have now been introduced on a bigger scale in schools, in first-aid training, and in similar courses in many countries.

Also concerned with the problems of teaching is the question of whether laymen should be taught one method only—expired-air resuscitation—or in addition, one or more manual methods. This question needs an answer not only with regard to an aesthetic aversion to expired-air resuscitation, but also because this method, without interposed adjuncts, is not safe for the operator where poisoning with cyanide, nicotine or other very potent poisons has occurred. It may well be that it should not be used in cases of known serious infections (e.g. cavernous tuberculosis, epidemic meningitis, poliomyelitis), though cases are known where, in spite of this, first-aiders have used the expired-air method (and this without serious sequelae). No general agreement exists...
on this, but the teaching of the manual methods has now practically been given up in Denmark by most organizations responsible for teaching artificial respiration. Only expired-air resuscitation is taught, the mouth-to-nose technique being used as a first choice and the mouth-to-mouth technique when the former is not applicable. The method is described in the Appendix.

AESTHETIC PROBLEM

Aesthetic objections to the expired-air resuscitation methods need hardly be mentioned any more as a problem, though it was possibly the most important problem in 1958, when it seemed to be a serious hindrance to its introduction. The willingness of almost everybody to use expired-air resuscitation in actual emergencies, when it really counts, has been impressive.

ADJUNCTS TO EXPIRED-AIR RESUSCITATION

Direct contact between the mouth of the operator and the face of the patient may be avoided by using special adjuncts. Sometimes a handkerchief placed on the face of the patient has been used for this purpose. Devices (Lee, Tarrow and Ward, 1959; Elam, Brown and Elder, 1954; Safar, 1957; Brook and Brook, 1960; Elam et al., 1956; Tomashefski and Oliver, 1960) may be applied externally on the face, i.e. masks covering the mouth and the nose, or only the nose or the mouth. Others are inserted into the airways through the nose or the mouth, being either modified nasopharyngeal tubes, or oropharyngeal airways, or ordinary tubes. The oral tubes which are either single or coupled in pairs are designed to end behind the tongue deep in the pharynx, or more superficially somewhere in the oral cavity behind the teeth.

The masks as well as the tubes may be modified by incorporating a valve which lets the operator blow into the lungs of the patient, but conducts the patient’s expired air into the atmosphere in such a way that it does not reach the end of the tube through which the operator blows.

With all the adjuncts mentioned, the rescuer avoids direct oral contact with the victim’s face, but, on the other hand, they do not help to establish a better air passage than may be accomplished without their use. Adjuncts, which reach deep into the pharynx, may induce vomiting in patients recovering their reflexes, the danger of which in the unconscious victim is obvious. Therefore, the use of airways by laymen is not advocated (Collins and Salland, 1960; Recommendations by Symposium on Emergency Resuscitation, 1961.)

Special advantages were obtained with more elaborate adjuncts for expired-air resuscitation. One type consists of two facemasks connected by a corrugated tube and incorporating a valve system. Because of the interposed tubing, a certain freedom of movement becomes possible. A special modification of this device may be used in gas contaminated areas, as it is furnished with gas-masks and filters at the patient’s and operator’s ends (Elam et al., 1956). Difficulty may arise during the use of expired air, because of discrepancies between the volume of air needed by the operator and the patients. This is especially the case when the patient is a child or when the operator is performing work or just moving. It becomes exaggerated when increased resistance to the breathing system exists, as when gas filters are in use (Greene, Elam and Bunnell, 1959). All adjuncts share with resuscitative equipment the need to be available on the spot, if they are to be of value in any first-aid measures to be undertaken. They are cheaper than respirators, but, apart from those to be used in gas contaminated areas, are generally of no greater advantage than the direct methods of expired-air resuscitation.

DEVICES USING ATMOSPHERIC AIR

While, as the source of energy for artificial respiration, the methods mentioned have all required the operator’s expiratory power, the type of resuscitators now to be described are based on the use of the muscular force of his arm and hand. They incorporate a bellows (Kreiselman, 1943; Macintosh, 1953; Lucas and Whitcher, 1958) or a bag (Ruben and Ruben, 1957), which during compression expels atmospheric air. Some of the devices offer an option for enrichment with oxygen from an oxygen cylinder.

The inspiration of the patient is accomplished by manually compressing the bellows or the bag.
During the expiration of the patient, his exhaled air is led to the ambient atmosphere either by lifting the facemask or by opening a hole on a connection piece which is kept closed by a finger during inflation. In most resuscitators a small valve automatically leads the expired air to the atmosphere (Kreiselman, Porton, AMBU). While the patient exhales, the bellows or the bag is expanded, thereby sucking air into the interior. This in some resuscitators is accomplished by a positive effort by the operator (Kreiselman, Porton, Oxford Inflating Bellows); in others it happens automatically through the recoil of the wall of the bag (AMBU).

The obvious advantage of using a resuscitator is that a more comfortable position for the operator is possible, and that the work is less tiring to perform. These factors mean that it is easier to produce sufficiently good artificial respiration for a prolonged time, and particularly during transportation, circumstances in which their use may well enhance the chance of recovery.

These types of respirators are comparatively easy to use and have found widespread use in the hands of others besides anaesthetists, both doctors and lay-rescuers.

To hinder the production of dangerously high pressures in the lungs, resuscitators have been fitted with safety valves. They are set at a limited blow-off pressure, usually about 25 cm H₂O. The blow-off function may, however, in case of increased airway resistance, result in a deficient inflation pressure. In the AMBU resuscitator no such valve is necessary. When the bag is compressed with one hand, only a limited pressure can be produced with it, partly because of the resiliency of the wall of the bag, and partly because of the capacity which is given to the bag. Omission of the safety valve means that with the AMBU resuscitator no air is wasted when the maximum pressure is obtained. One can, however, if it is found necessary, increase the maximum pressure to a sufficient degree, which is of particular importance in cases of severe bronchospasm or oedema. In such circumstances the bag, still with one hand, is compressed against the cheek of the patient or, with his head turned to one side, against its support. While ordinarily functioning as a pressure-limited respirator, the AMBU resuscitator is in such cases converted to a volume-limited respirator. These factors are essential in the hands of the inexpert user. The expert user, on the other hand, gains through its use the advantage that he with his fingers, through the soft wall of the bag, can feel changes in resistance to inflation (e.g. accumulation of secretions) and therefore take measures to handle the situation properly.

During compression of the bellows-type resuscitator, pressure is exerted against the support of the bellows. With the Kreiselman resuscitator this means that force is directed against the mandible, tending to push it backwards and produce obstruction. In the Porton resuscitator this has been overcome by designing a special mask, which lets the pressure of compression extend the head backwards and thereby help the maintenance of an open airway. With the Oxford Inflating Bellows this problem does not exist, because the bellows with its valve system is placed at a convenient distance from the facemask. On the other hand, the bellows with its mount is much bigger and heavier than the other resuscitators mentioned here. Other bellows-resuscitators (Dräger, Emerson) have solved this problem by attaching the bellows to the belt of the operator, so that the counter-pressure is made by his body. The pressure problem does not exist with the AMBU bag resuscitator, because it is used either as the anaesthetist's bag-and-mask device or with a corrugated tube interposed between the valve and the bag. In the latter case the bag may be carried in the hand compressing it, or fixed to the belt of the operator. The latter arrangements are particularly useful when the victim is carried on a stretcher, or during transportation in an ambulance.

**THE ANAESTHETIST AND THE FIELD OF FIRST-AID**

Obviously an anaesthetist would not himself encounter many cases where he would have to perform emergency resuscitation outside of the hospital. On the other hand, he is in possession of experience and knowledge which nobody else can contribute in the treatment of unconscious, apnoeic subjects. For example, it may possibly seem too obvious for an anaesthetist to speak
about the paramount importance of a permanently open airway. Nevertheless this had to be “revealed” by anaesthetists before the quite recent change-over to an efficient method of artificial respiration. Quite apart from the interest of the study of the problems of resuscitation for those concerned with it, the impression that anaesthetists feel it a civic duty to show and take an interest in these matters makes it natural that those in charge of teaching the laymen should seek our advice. It is certain that this would not only result in personal satisfaction to those involved in the activities but also lead to a higher regard for the specialty of anaesthesia in the eyes of the population and the authorities.

APPENDIX

Example of short instruction in expired-air resuscitation for laymen.

1. Place the victim on his back and yourself kneel on both knees at the side of his head.

2. With one hand under his chin, closing the mouth, the other on top of his head, tilt the victim’s head back as far as possible (without exerting undue force), thereby maintaining an open air passage to the lungs (fig. 1).

3. Inspire deeply and blow through the victim’s nose (fig. 2)—with your mouth wide open to avoid pinching his nostrils. If his nose is blocked, blow through his mouth, slightly opened.

4. When the chest rises, remove your mouth and let him exhale, while you yourself inhale from the atmosphere. Alternate between blowing and letting him exhale 15 to 20 times a minute, until he can breathe for himself.

REFERENCES


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NOTICE

THE CZECHOSLOVAK SOCIETY OF ANAESTHESIOLOGY has convened an International Symposium on “Respiratory Problems in Anaesthesia and Resuscitation”.

The Symposium will take place in Prague between August 17 and August 20, 1965.

The working languages of the Symposium will be Czech, Russian, English and German. Provision will be made for simultaneous translation.

A preliminary programme will be circulated in the autumn of 1964.

For further details please contact the Scientific Secretary, Dr. Pavel Scheck, Anesteziologické oddelení, Nemocnice Bulovka, Praha 8.