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MANUAL ARTIFICIAL RESPIRATION

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The purpose of this communication is to review the present position of the various methods of manual artificial respiration, and to draw attention to a new and more efficient method of manual artificial respiration and urge its adoption by all individuals and organizations responsible for emergency resuscitation, under the direction of skilled medical tutors.

Recent History of Artificial Respiration

Before 1950 the most widely adopted method of artificial respiration in the UK and the USA was the Schafer method of prone pressure with the subject supine. During 1950 and 1951 groups of investigators in the USA published the results of detailed investigations into the Danish Holger Nielsen and other 'push-pull' two-phase methods.[1] This led to the adoption of the back-pressure arm-lift method on a national scale in the USA and firmly established the push-pull methods as superior to the Schafer and the rocking methods in adults.

In 1957, following further investigation into artificial respiration, a symposium was held under the auspices of the National Academy of Sciences and the National Research Council in the USA, with a distinguished panel. This group was of the unanimous opinion that mouth-to-mouth resuscitation (expired-air inflation) was superior to other methods. Its recommendations have been accepted by the American National Red Cross, for infants and children, and were published as a report to the Council of Medical Physics of the American Medical Association.[2] A review of the available evidence will show that *expired-air resuscitation* is the method of choice and should be universally adopted.

METHODS OF MANUAL ARTIFICIAL RESPIRATION

Manual artificial respiration may be defined as the performance of ventilation of a subject by an operator without dependence on mechanical or other devices. It is useful here to give a brief description of the more widely used of these methods before comparing their efficiency. They may be divided broadly into 3 categories:

1. *Single-phase (Push or Pull) Methods*

(*a*) *Prone-pressure method.* Schafer described the method of prone pressure over the lower ribs. This, with several variations, employs pressure (push only) in an upward direction with the thumbs together over the floating ribs of the prone subject. Pressure is applied for 2 seconds and then relaxed, the cycle being repeated every 5 seconds. A variation with pressure over the mid-thorax just below the scapulae (back pressure) is said to improve the tidal volume significantly.

(*b*) *Rib-traction method* and (*c*) *Chest-pressure method* (Howard) are similar in function (push or pull only) and are applied to a patient in the supine position.

2. *Two-phase (Push-pull) Methods*

(*a*) *Arm-lift back-pressure (ALBP, Holger Nielsen) method.* With the patient prone, his hands on top of each other and the face resting on them, the operator rests on one or both knees at the patient's head. The subject's arms are taken above the elbows and by rocking backwards the arms and chest are lifted, then replaced on the floor (Fig. 1). In the second phase (push) the operator moves his hands to below the scapulae and rocks forward, exerting back pressure (Fig. 2). The operator's arms are kept straight during both phases and the complete cycle is repeated 10-12 times per minute. This is a variation of the Holger Nielsen method which described pressure over the scapulae rather than back pressure below them.

(*b*) *Hip-lift back-pressure (HLBP) method.* With the subject prone as for the Schafer method, the operator, on one knee, straddles the patient at hip level. The hips are lifted 4 to 6 inches off the ground and then replaced (Fig. 3). The second phase consists of back pressure below the scapulae with the operator's arms straight (Fig. 4). The hip-lift pull causes inspiration as a result of descent of the diaphragm and hyperextension of the spine, while the abdominal contents sag.

(*c*) *Hip-roll back-pressure (HRBP) method.* Rolling the hips instead of lifting the hips substitutes a less tiring method. The hips are rolled onto the operator's knee or thigh so that both hips are off the ground. During all hip-lifting or rolling, and back pressure, the operator's arms are kept straight, the work being done by the shoulders and back, using the operator's weight. A towel or belt may be used to help lift or roll the hips.

(*d*) *Arm-lift chest-pressure supine (ALCP, Silvester) method.* With the subject supine and the head turned to one side, and the operator in the same position as for the Holger Nielsen method, the arms are lifted upwards by a backward roll of the operator until resistance is felt (Fig. 5). In the second phase (push) the operator, still grasping the subject's wrists, applies pressure over the lower chest by rocking forward (Fig. 6).

(*e*) *Rocking or gravity (Eve) method.* By rocking the whole body of the subject a two-phase method of artificial respiration is produced by the upward and downward movement of the abdominal contents, which actuates the diaphragm and produces inspiration (head up) and expiration (head down). As a manual method, without the use of the rocking stretcher, it is most useful in children and infants,[3] especially when the subject can be held prone on the operator's forearm, the fingers of that hand holding the tongue forward and thereby ensuring a patent airway. The angle of rocking should be greater than 30° in each direction.

3. *Expired-air Inflation*

This term includes mouth-to-mouth resuscitation or breathing and its variants, viz. mouth-to-nose, and similar methods using adjunctive apparatus, i.e. mouth-to-mask, mouth-to-airway, and mouth-to-endotracheal-tube. Recent interest in this followed research into resuscitation during chemical warfare, when a method of resuscitation from gas mask to gas mask was suggested. Subsequent work established the scientific basis of this method and defined the technique.[2, 4-6] In brief, in the technique of mouth-to-mouth breathing the operator kneels at the side of the subject's head, uses one hand to elevate and protrude the jaw, thereby ensuring a good airway, closes the nose with the other hand, and expands the chest by blowing into the mouth. Expiration is allowed to take twice as long as inspiration and the rate is about 20 cycles per minute. A detailed description follows later.

COMPARISONS OF METHODS OF MANUAL ARTIFICIAL RESPIRATION

In 1951 several independent groups of workers compared the Schafer with the push-pull manual method[8,1(c-f)] to determine the relative (1) ventilatory efficiency, (2) circulatory effects, (3) 'teachability' and ease of adequate performance by lay personnel, and (4) fatigue and performance difficulty for the operator.

The investigations of physiological factors were performed on anaesthetized humans with endotracheal tubes in position. The results of all the experimental groups showed that:

1. Push-pull methods were capable of moving 2-3 times the tidal volumes that were achieved with the Schafer method, and minute volumes with push-pull methods were greater than estimated normal values.

2. In most cases the Schafer method was unable to maintain normal arterial oxygen saturations, whereas the push-pull methods ensured adequate pulmonary ventilation, though uneven ventilation sometimes caused a slight drop in arterial oxygen saturation.

3. The Eve rocking method was less efficient than push-pull methods in ventilating subjects and had no advantage in promoting circulation as judged by cardiac output and beat-to-beat blood-pressure recording.

4. The ALBP was second in efficiency to the HLBP method but less tiring.

5. ALBP was slightly more difficult to learn and perform correctly than the Schafer.

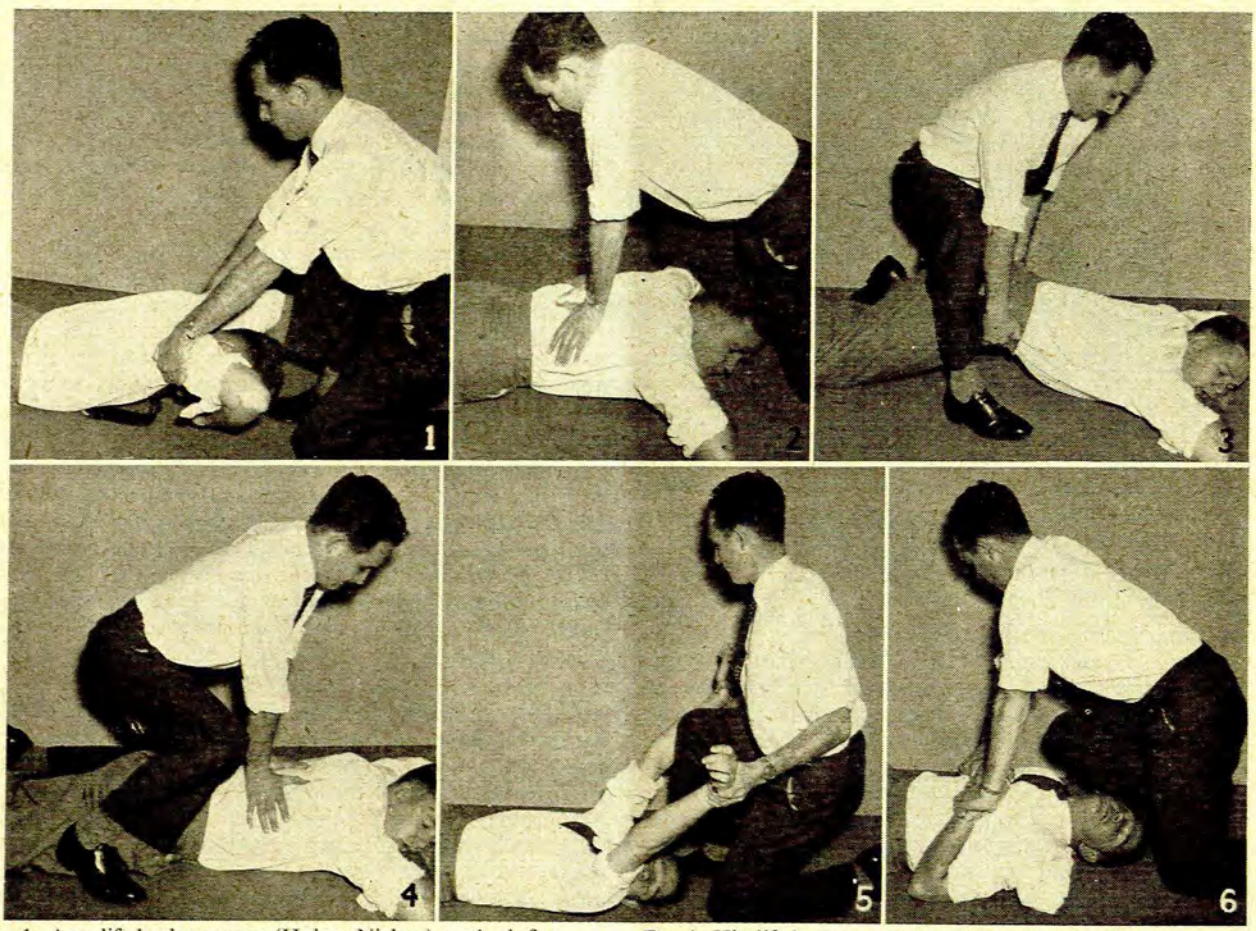

Fig. 1. Arm-lift back-pressure (Holger Nielsen) method, first phase.
Fig. 2. Arm-lift back-pressure (Holger Nielsen) method, second phase.
Fig. 3. Hip-lift back-pressure method, first phase.
Fig. 4. Hip-lift back-pressure method, second phase.
Fig. 5. Arm-lift chest-pressure supine (Silvester) method, first phase.
Fig. 6. Arm-lift chest-pressure (Silvester) method, second phase.

6. Frequent airway occlusion was noted with the supine (Silvester) ALCP method unless the patients were intubated.

Unanimous recommendations were made for the adoption of the ALBP method as the method of choice, and condemning the Schafer method as inefficient.

An excellent review of the physiology of artificial respiration to 1955 is contained in Whittenberger's report.[13]

Comparison of Push-pull Methods with Expired-air Resuscitation

With further study of artificial respiration it was found that, in patients who were unconscious, airway obstruction occurred in the majority of cases, so that the push-pull methods became ineffective.[6,8,14] The previous favourable results could not be repeated unless special attention was given to the airway, and usually endotracheal intubation was necessary for adequate ventilation.

More recently Safar (1958)[15] has shown that, in unconscious relaxed patients, the conventional ALBP and ALCP methods were ineffective (producing a tidal volume less than the dead space) in a very high proportion of cases (around 75%) owing to obstruction of the upper airway by the tongue. The prone position of the ALCP method is not advantageous, for it has been shown that it does not ensure an airway—the tongue does not 'fall forward' in every case.

Safar showed a significant reduction in the failure rate when modifications were introduced to extend the head. In the Holger Nielsen ALBP method. The head is fully extended and the jaw is held forward by the folded hands. In the ALCP Silvester method a folded cloth or bolster is placed under the shoulders to extend the head fully (Fig. 6).

Insertion of an artificial airway still further reduced the failure-to-ventilate rate, which was lowest in the ALCP method.

With mouth-to-mouth breathing an average tidal volume of 1,500 c.c. was achieved.[2] This was attributed to the advantage in the method that both hands are available to maintain the airway by extending the head and lifting the jaw and tongue away from the posterior pharyngeal wall. Further studies[2] confirmed the unequivocal superiority of mouth-to-mouth resuscitation over all other methods in all age-groups. It is the only technique which ensures adequate ventilation in all cases, chiefly by virtue of maintaining an adequate airway. Even compared with push-pull methods in intubated subjects, simple mouth-to-mouth breathing was nearly twice as effective. Re-oxygenation was possible with 4 inflations and within a circulation time arterial oxygen could be restored to normal. Theoretical objections to positive-pressure inflation of the chest on the basis of its effects on circulation (diminished venous return, fall in cardiac output) are met by clinical observations that, so long as mean airway pressure is kept low by keeping the period of inflation short and one-third of the duration of respiration, circulatory ill-effects are not seen.[2]

The supine position with positive-pressure ventilation was thought to be disadvantageous in that it would prevent drainage of drowning fluid from the air passages and mouth. However, mouth-to-mouth resuscitation permits full attention to the airway and respiratory obstruction is instantly detectable, so that its advantages outweigh its disadvantage. The work of Swann *et al.*[11,12] has shown that oxygenation is the first urgent consideration in drowning and that the amount of drowning fluid that can be drained from the lungs is in any case very variable and there is seldom so much that air would be prevented from entering the lungs and terminal air-passages.

Mouth-to-mouth resuscitation can be continued for long periods, frequently for an hour; once it was kept up for 4 hours by one operator. Of 164 untrained lay operators 90% performed the method after one demonstration. Women and children could adequately ventilate subjects twice their weight, in contrast to their failure with push-pull methods.[2] These studies compared methods of expired-air resuscitation and the technique was defined.

THE TECHNIQUE OF EXPIRED-AIR RESUSCITATION

Physiological Basis

The concentration of oxygen in expired air is dependent on the oxygen consumption, the ventilation of the lungs, and the concentration of oxygen in the inspired air (21%). Thus, if a man consumes 300 c.c. of O_2 per minute and inhales 5,000 c.c. of air per minute, he takes into his lungs 1,050 c.c. of O_2, extracts 300 c.c., and exhales 750 c.c. at a concentration of 15% in expired air. If he doubles his breathing volume his oxygen consumption is virtually unchanged. He therefore extracts 300 c.c. of O_2 from 2,100 c.c. of O_2 in inspired air, and exhales 1,800 c.c. at a concentration of 18%. Thus a hyperventilating operator can offer a non-breathing victim 1,800 c.c. of O_2 per minute. This adequately supplies the victim with his 300 c.c. per minute, and the O_2 content of his expired air is 15%. Similar calculations will show that adequate CO_2 elimination is also quite possible. It can also be shown that this hyperventilation is well within the limits of a healthy operator, leaving a margin for leakage from the contact; also that the pressure required to inflate another individual's chest allows the operator an adequate reserve for overcoming airway resistance.

Methods

The method in *mouth-to-mouth breathing* is as follows:

1. Place the subject supine and take position kneeling opposite his left ear.

2. Turn the victim's head to one side, open the mouth, and quickly clear the mouth and throat of any debris with

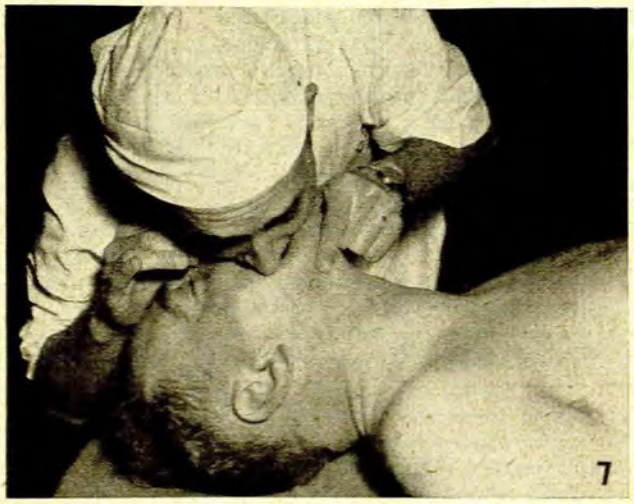

Fig. 7. Expired-air resuscitation, mouth-to-mouth breathing.

the fingers or a bit of cloth. Repeat this as necessary during the procedure.

3. Place the thumb of the left hand between the teeth (if necessary wrapped for protection in a handkerchief), grasp the mandible at the midline and hold it forcefully forward (upward) so that the lower teeth are leading. Extend the subject's head into a 'sniffing' position.

4. Close the subject's nose with the fingers of the right hand.

5. Take a deep breath, place the mouth over the mouth of the victim and blow, forcefully in adults and gently in children, maintaining the lift of the jaw with the thumb still in the subject's mouth (Fig. 7).

6. Watch the expansion of the chest and the epigastrium for distension of the stomach.

7. Remove mouth and allow passive expiration.

8. Repeat about 20 times per minute.

It is important that the operator should not hold his breath before inflation.

For infants and small children. In children less than 3 years old the thumb in the mouth will interfere with contact; therefore the method is varied as follows:

1. The right hand of the operator protrudes the child's jaw by pressure behind the angle of the jaw on the right (until the lower teeth lead).

2. The mouth is placed over the mouth *and* nose of the child in order to inflate by blowing gently. Or the nose is occluded by the operator's cheek, while blowing into the mouth.

3. The left hand of the operator rests gently on the epigastrium to prevent gastric distension.

The *advantages* of mouth-to-mouth breathing are as follows:

1. Full emphasis is on care of the airway. The hands are free to maintain a clear airway, without which no artificial respiration is ever effective.

2. Increased inflation pressure will compensate for any remaining airway obstruction by the tongue or from, say, water in the air passages.

3. By watching the rise of the chest, adjustments are made, even by beginners at the method, for increased resistance to inflation, for leaks, and for minor airway obstruction. It is the only method of artificial respiration which permits breath-by-breath evaluation of the efficiency of one's methods.

The following are the *disadvantages*, which are unimportant and easily overcome:

1. *Aesthetic.* In one series, using 167 untrained rescuers including policemen, housewives, boy scouts, medical students, nurses and doctors, only 3 refused to take part—all medical students who said they would perform the method only in an emergency. These objections can largely be overcome by the use of a special airway (to be described), or an anaesthetic mask between the operator and the subject.

2. *Gastric distension* may occur, especially in children when the inflation pressure used is too high or airway obstruction is present. It can be prevented by a hand on the stomach, or treated by gentle gastric pressure between inflations. In a drowned person this might eject fluid into the pharynx, which would have to be cleared.

3. *Hyperventilation syndrome* in the operator, which may give rise to dizziness. He may then slow down the rate from 20 per minute to about 12 per minute, or pause once a minute for normal breathing.

4. *Fatigue* may occur of the hand holding up the jaw and from the position on the floor. This is considerably less exhausting than any other method of artificial respiration, for the muscular exertion is far less, with the operator performing well within his limits, unlike the push-pull methods.

Variations of Expired-air Resuscitation

1. *Mouth to Nose*

Mouth-to-nose resuscitation is less satisfactory from every point of view and is only recommended for small children (when the mouth and nose are covered by the operator's mouth), and in adults where the jaw cannot be opened. Here the operator covers the subject's mouth with a finger and blows into the patient's nose.

2. *Mouth to Airway*

An airway (Fig. 8) has been described[2,7,8] which has the following advantages:

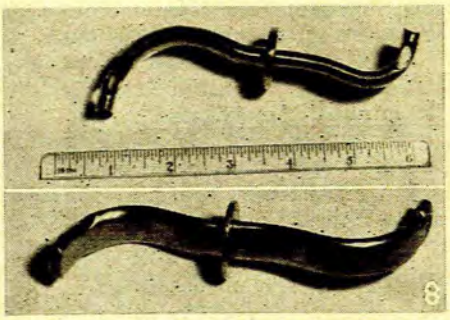

Fig. 8. Two sizes of airway for expired-air resuscitation. Convenient sizes for the large airway are nos. 3 and 4 and for the smaller nos. 1 and 0.

(*a*) Mouth-to-airway resuscitation is easier, less tiring and more effective, with less gastric distension.

(*b*) It ensures a good airway even in the few patients where other measures would fail.

(*c*) It is easy to insert, even for laymen. (No layman took longer than 40 seconds after one demonstration.)

Fig. 9. Expired-air resuscitation, mouth-to-airway breathing.

(*d*) It removes aesthetic objections to mouth-to-mouth resuscitation.

(*e*) It is very cheap, easily transportable, and virtually indestructible.

The operator kneels behind the victim's head facing the feet and inserts the airway. Holding the jaw up with both hands at the angles of the jaw, he occludes the nostrils and corners of the mouth with his thenar eminences and thumbs and blows into the airway (Fig. 9). Resuscitation can be easily maintained for 30 minutes at a stretch. The airways can be of metal welded together (Waters) or of rubber (Guedel type) where the metal inserts are soldered together and in addition the rubber flanges may be vulcanized together. The airway would be easy to mass-produce in plastic at low cost. Plastic airways in two sizes are now available from Messrs. Johnson & Johnson (Pty.) Ltd.

DISCUSSION

In this review an attempt has been made to summarize the considerable body of work done in recent years on artificial respiration. Every investigator who has repeated the orginal work has come to the same conclusion, viz. that expired-air resuscitation is the most effective, if not the only effective, emergency method of ventilation, both in lay and medical hands.[12] It is easy to teach and to learn and has already been adopted in the USA by the Red Cross, hospitals, fire-fighting organizations, and the armed forces.

The push-pull methods, even with special attention to the airway obstruction which frequently exists, and with the modifications described by Safar of extending the head, are at best less effective and will fail in a high proportion of cases to ventilate the victims at all. That an effective method should be widely known is an undoubted fact. Figures available from the UK and the USA[9,10] show that drowning accounts for the third largest number of accidental deaths in persons of all ages, and that 25% of drownings occur under 10 years of age.

Electrocution is another common accidental cause of apnoea. Poisoning is an increasingly common accident in children, and in adults a common form of attempted suicide. Insecticide poisoning which results in muscular paralysis and respiratory failure is becoming commoner. In hospital practice outside the operating theatre an increased awareness of the possibility of resuscitation following cardiac arrest leads to a search for a readily available emergency method of performing positive-pressure artificial respiration. A practitioner may be confronted by apnoeic patients suffering from a host of conditions, from head injury to poliomyelitis or myasthenia gravis.

In all cases of acute respiratory failure cardiac arrest will rapidly ensue if oxygenation is not immediately carried out. The work of Swann *et al.*[11,12] on acute anoxic states has shown that, while in some conditions such as fresh-water drowning and some forms of electrocution, circulatory arrest may precede respiratory arrest, circulatory and respiratory arrest usually occur at about the same time. These workers have also shown that, after anoxia for varying periods, a critical point is reached after which the blood pressure rapidly falls and circulatory arrest follows. Resuscitation is usually only effective if oxygenation is achieved before hypotension and circulatory failure supervene. The emphasis should therefore be upon urgency in artificial respiration, since only a few seconds may mean the difference between a successful resuscitation and death.

In rescue from drowning, resuscitation should commence if possible in the water while the victim is being brought to dry land. This is perfectly feasible in children especially, when either rocking or, preferably, mouth-to-mouth breathing could be begun at once. There is never time to remove a patient from an uncomfortable or unsuitable situation to another. In resuscitation the first seconds and minutes count, and delay in instituting ventilation will render any subsequent attempts valueless. The use of a mechanical apparatus invariably means a delay of minutes, at least. It is strongly urged that every medical man, nurse, medical student and hospital worker should be taught mouth-to-mouth breathing. The medical profession as a whole should be giving the lead to the various excellent lay organizations responsible for teaching first aid and resuscitation, which all too often have difficulty in obtaining sound advice on these problems from specialists in the fields.

SUMMARY

The available methods of manual artificial respiration are discussed in relation to their relative effectiveness.

Expired-air resuscitation (expired-air inflation, mouth-to-mouth breathing) is the most effective method, being superior in all respects to the two-phase push-pull methods.

The two-phase methods, especially the arm-lift back-pressure (Holger Nielsen) and arm-lift chest pressure (Silvester) methods are improvements on the single-phase push (Schafer) and pull methods.

The Safar airway is a cheap, portable adjunct to expired-air inflation, and in mouth-to-mouth airway resuscitation is the method of choice, being applicable to the widest variety of emergency situations.

Since expired-air resuscitation is very effective, easy to teach, and applicable to most emergency situations, its principles and practice should be advocated by the medical profession to all organizations responsible for teaching resuscitation to the public.

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