

INVESTIGATION OF UPPER AIRWAY PROBLEMS IN RESUSCITATION

1. Studies of Pharyngeal X-rays and Performance by Laymen

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SINCE 1958 coordinated studies at the Finsen Institute and Roswell Park Memorial Institute have sought the best layman's procedure for expired air resuscitation. The major incentive in these studies was the need for simpler alternatives in practical technique. During this time the procedures improvised by laymen were analyzed. Despite detailed instructions their common techniques did not involve the forward displacement of the mandible as practiced by anesthetists. Instead they somehow managed to extend the victim's head sufficiently to maintain an open air passage. This report summarizes trials of mouth-to-mouth and mouth-to-nose breathing by laymen and reviews of roentgenographic studies of head position in relation to upper airway patency. From these interdependent investigations the requirements in technique for a hyperextension maneuver were evolved. For two years this head-tilt method for resuscitation has been evaluated in Copenhagen, Buffalo, Karlskrona, Los Angeles, Baltimore, and New York City.¹

The major assets of oral resuscitation are availability of the rescuer's hands to manage the patient's airway and the versatility of his chest bellows. Reintroduction of expired air methods borrows three anesthetists' technique to support the upper airway by forward displacement or elevation of the mandible.

Techniques of Upper Airway Support.

(1) *Jaw-Lift Method:* lifting the mandibular

rami bilaterally as commonly practiced with an inhalation anesthetic given by mask. (2) *Chin-Lift Method:* lifting the chin with the thumb hooked behind the lower teeth, occasionally used in short intravenous anesthetics when a mask is not employed. (3) *Head-Tilt Method:* pulling the chin upward to produce maximal backward tilt of the head. Part of this technique is common in inhalation anesthetics given by mask. The rest of the maneuver depends upon additional extension of the head at the atlanto-occipital joint as will be described.

The jaw-lift and chin-lift maneuvers were initially used in resuscitation experiments on curarized volunteers.^{2,3} As both were effective they were advocated by general use.⁴ The chin-lift technique is now widely taught. Laymen have reported difficulties with chin-lift in rescues of near-drowned victims.⁵ Meanwhile evaluations of training and performance of resuscitation demonstrated several practical problems especially when challenging situations were simulated.

Difficulties Encountered in Lay Training and Performance. Following training sessions using movies, lectures, instruction booklets, and demonstration and practice on a manikin, lay trainees performed artificial respiration in 9 anesthetized curarized subjects.^{6,7,8} The 42 members of a Red Cross chapter (Copenhagen), 24 Boy Scouts, and 14 rescue squad members (Buffalo) were asked to provide ventilation for fasting subjects anesthetized with thiopental. Some subjects also received curare to simulate the flaccid stages of asphyxia. Others had apneic doses of meperidine or thiopental and their lungs were ventilated with oxygen during a sequence of carbon dioxide rebreathing which increased muscle tone and simulated the spastic stage of asphyxia. Ventilation was recorded by means of a calibrated pneumograph. Results

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showed failure of both techniques in about one-third of the trials⁸ for the same reasons Safar reported.² Inadequate force of blowing, obstruction when the rescuer pulled the mandible downward instead of upward, difficulty finding the angles of the jaw, underestimating the force necessary to lift the jaw, flexion of the victim's head when lower lip was retracted, and air leakage for a variety of reasons. In addition, after one month the details were forgotten by many trainees and failures increased.

In emergencies other obstacles are encountered. It is difficult to perform the jaw-lift or chin-lift methods on victims with trismus and attempting either method upon victims with clonic convulsions^{5, 9} is hazardous for the rescuer.

CASE REPORT: A chemical process operator, equipped with an air-supplied respirator, was cleaning out residues in a nine-foot still purged with nitrogen to avoid flash hazard. He suffered fulminating anoxia as a result of mask failure. His foreman witnessed the accident and the sudden onset of cyanosis, incoordination, unconsciousness, and collapse. He reached the victim within a minute and found his body was rigid. Wearing a mask the foreman moved him to fresh air. The victim was not breathing, and it was impossible to separate his clenched teeth. The foreman had learned mouth-to-nose technique, so he tilted the victim's head back and inflated his lungs through the victim's nose upon the first effort. After three breaths normal color returned. Within two minutes of mouth-to-nose breathing the victim recovered consciousness and his own respiration. He suffered no neurological sequelae.¹⁰ This case of anoxia with muscle rigidity illustrates one difficulty for the chin-lift method.

Simulating the Rigid Apneic Victim. The tight jaw, although uncommon in anoxic complications during anesthesia, is occasionally observed when accidents produce acute asphyxia.^{11, 12} To simulate the spastic response in volunteers relaxants were abandoned and apnea was produced by meperidine or thiopental sufficient to elevate the subject's apneic threshold. Respiratory depression rendered the volunteer apneic at expired carbon dioxide concentrations below 7.5 per cent. After confirming this depression hyperventilation with oxygen in a closed circuit was carried out for five minutes to reduce expired carbon dioxide to 5 per cent. During

this interval the subject became moderately relaxed. At this juncture a sudden hypercapnea without hypoxia was induced to increase his muscle tone by carbon dioxide rebreathing, bypassing the absorber. In most instances the abrupt hypercapnea was attended by motor rigidity including trismus. When the end-expired carbon dioxide values reached 6.5 per cent within two to three minutes severe trismus made it impossible to separate his clenched teeth. Sometimes air could be blown through the teeth but often obstruction by the tongue was complete. These trials permitted analysis of the difficulties in resuscitating victims of acute asphyxia using the jaw-lift or chin-lift modifications. Failures of both maneuvers, attempted by eight laymen and six physicians in five volunteers, indicated that an alternate or more versatile technique was needed. The anesthetist separates tight jaws by inserting the index finger laterally between the gums and cheek and pries the gums apart by pressing downward on the chin. But there may be subsequent injury to the rescuer's thumb hooked under the victim's lower teeth. These experiments with rigid subjects emphasized the importance of the nasal route of inflation as an alternative to mouth-to-mouth techniques.

Following reports of biting lacerations of rescuers' thumbs in several successful resuscitations¹³ the search was continued for an alternative procedure for support of the victim's airway which would provide access to either the mouth or nose for inflation.

Trials of the Head-Tilt Modification: Several considerations led to the idea that a simple head-tilt maneuver might be applicable to expired air resuscitation. The experience of laymen using the self-refilling bag and mask¹⁴ in Europe had demonstrated satisfactory results in many emergencies. The only technique taught these rescue personnel for preventing obstruction had been hyperextension of the victim's head. During their training with the bag and mask unit it was stressed that the head must be initially tilted back fully and this position must be maintained by holding the mask with three fingers continually pulling upward on the victim's chin. The same maneuver is practiced in

inhalation anesthesia employing a face mask. Since the lips are usually closed under the mask, the primary air passage is nasal. Thus, hyperextension of the head and nasal breathing by intermittent positive pressure had already enjoyed common usage. It therefore appeared worthwhile to use hyperextension without a mask or other adjunct and inflate the lungs through the nose or the mouth. It was anticipated that the maneuver would not work in all cases since in some anesthetized patients obstruction is not prevented merely by pulling the chin upward, *i.e.*, the patient requiring an oral airway which, incidentally, does not differentiate between lip and pharyngeal obstruction.

In the next series of evaluations the head-tilt method using mouth-to-nose inflation was taught 20 lay trainees by means of demonstration and five minutes practice on a manikin. Subsequently these trainees were asked to apply the head-tilt method on an anesthetized volunteer. The calibrated pneumograph showed a minimum tidal volume of 460 ml., a maximum of 1,430 ml., averaging 727 ml. The average minute volume was 8 liters.

In another evaluation 42 Red Cross members performed mouth-to-mouth and mouth-to-nose techniques after training on a manikin. When the mouth-to-mouth method was performed on an anesthetized curarized volunteer, 37 of the rescuers obtained a satisfactory tidal volume but gastric inflation accompanied every adequate inflation of the lungs. Eight weeks later in another anesthetized curarized volunteer the results with the head-tilt mouth-to-nose method showed no failures, an average tidal volume of 916 ml. (range 180–2640 ml.) and an average minute volume of 13 liters (range 3.4 to 37 liters). Despite large inflations no observable gastric dilatation occurred with mouth-to-nose breathing but brief trials of mouth-to-mouth method again produced excessive gastric inflation.

Extensive trials of the head-tilt method were then carried out routinely with anesthesia inductions. As reported in 1959, the method failed in one per cent of over 300 cases, but the chin was not pulled upward in this series.⁸ These three failures were associated with severe cervical arthritis (one case) or extreme obesity (two cases). Subsequently

it was recognized that pulling the chin upward further improved the nasopharyngeal and pharyngeal airways. In further trials of the two-handed head-tilt method in over 1,000 patients the ventilation produced by this maneuver and mouth-to-mouth inflation was satisfactory.¹ In not a single case did the two-handed head-tilting fail to open the pharynx, and inflation through the nose revealed no limiting obstruction. When nasal expiratory obstruction was encountered exhalation through the mouth was always possible.

ROENTGENOGRAPHIC STUDIES OF THE UPPER AIRWAY

These studies were conducted in 31 anesthetized supine adults to measure the air clearance of the nasal, oral, pharyngeal, and laryngeal passages in relation to position of the head, neck, and jaw. Soft-tissue lateral roentgenograms, planograms, and serigrams were taken during apnea to see the effect of the jaw-lift, chin-lift, and head-tilt maneuvers upon the tongue, pharynx, soft palate, and epiglottis. The subjects' age range was 21 to 81 years. Both obese and thin patients were included. Half the group were of medium build. The weight range was 47 to 101 kg., height 1.5 to 1.8 meters.

Anesthesia was induced in all patients with 0.5 to 1.2 grams of thiopental. Nineteen subjects were also given apneic doses of *d*-tubocurarine averaging 35 mg. and the remaining 12 were given additional thiopental or meperidine to produce apnea. Both groups were given repeated doses of relaxant or anesthetic drug as necessary to maintain apnea during the eight-minute interval of positioning the patient's head and taking the films. Between exposures the subjects' lungs were ventilated with oxygen. All values have been corrected for the magnification obtained in the films.

Procedure for Head-Tilt Method. In all trials of the head-tilt maneuver the operator held the subject's head as illustrated in figure 1.

(1) From a suitable position the operator lifted the subject's neck, grasped the head at the vertex, and extended his head fully.

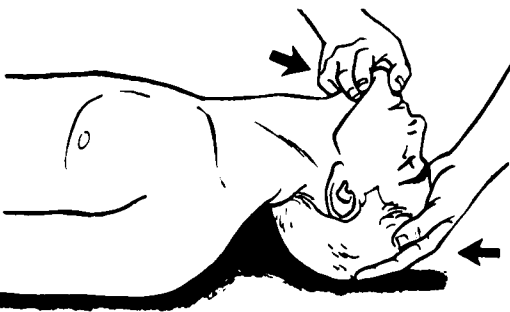


FIG. 1. Head-tilt method (two-handed hyperextension). This maneuver is comprised of two distinct counter-forces. First, one of the rescuer's hands grasps the victim's head at the vertex (as shown above) and hyperextends the head as the other rescuer's hand lifts the victim's neck. The extension should be sufficient to hold the victim's mouth open by stretching the anterior neck. The second part of the maneuver is closing the victim's mouth by pressing the mentum cephalad. This two-handed method is employed in the roentgenograms in figures 3 and 5.

The force applied at his vertex was maintained sufficiently to stretch the anterior neck and to open the subject's mouth.

(2) The operator then pulled the victim's chin upward to close the mouth. For mouth-to-nose breathing he held the subject's lips closed. The rescuer made a wide seal around the nose to avoid occluding the nares. For mouth-to-mouth inflations he held the victim's lips parted and sealed the nostrils with his cheek.



FIG. 2. Soft tissue roentgenogram in awake subject, head neutral. The air clearance at the base of the tongue is 3 mm. The widest space in this anterior-posterior view is at the hypopharynx near the laryngeal aditus.

TABLE 1

EFFECT OF HYPEREXTENSION OF THE HEAD AND ELEVATION OF THE CHIN ON PHARYNGEAL CLEARANCE IN ANESTHETIZED APNEIC PATIENTS
HEAD-TILT MANEUVER

Groups According to Curare and Presence of Teeth	Number of Patients	Age Range (years)	Pharyngeal Clearance (mm.)	
			Average	Range
No curare given; None edentulous	12	22-58	20	17-26
Curarized; None edentulous	8	31-68	15	12-21
Curarized; Edentulous	11	52-81	17	8-25
Total	31	22-81	18	8-26

RESULTS

The Effects of Hyperextension. The pharyngeal clearances accompanying flexed, neutral, and hyperextended positions are given in table 1. These clearances between the tongue and posterior pharynx were measured at the narrowest anterior-posterior diameter. Figures 2 and 3 reproduce the films in an awake subject with the head in neutral position (small clearance in pharynx) and then under anesthesia with the head held in hyperextension. This wide pharyngeal clearance

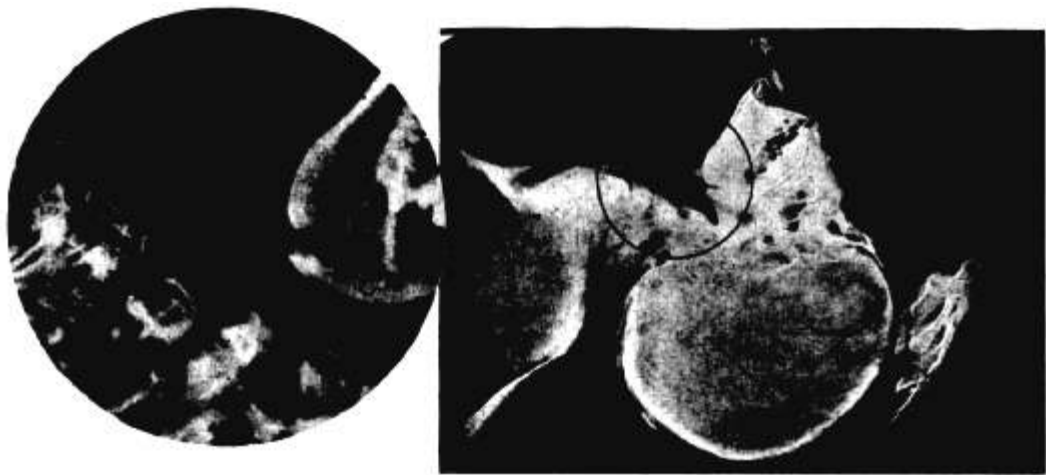


FIG. 3. Soft tissue roentgenogram of anesthetized apneic subject, head hyperextended. The two-handed hyperextension maneuver increased the clearance at the tongue base to 20 mm. (compare with figure 2). With hyperextension clearances appear at the soft palate and the posterior nasopharynx which are not discernible in figure 2.

produced by head-tilt is typical for all 31 subjects. The average clearance for these subjects was 18 mm. (range 8 to 26 mm.). If muscle tone was not diminished by curare the dimensions were greater by 16 to 20 per cent depending upon the presence of teeth. All films revealed that the hyperextension maneuver increased the entire pharyngeal clearance, particularly at the level of the epiglottis (figs. 3 and 5). To permit interpretation of these pharyngeal clearances films were taken in ten awake eupneic patients prior to anesthesia and following premedication with scopolamine alone. Table 2 shows

the average pharyngeal clearance of these conscious subjects with the head normally extended to be 11 mm. (range 5 to 17 mm.). This clearance in the pharynx is apparently maintained reflexly since flexion of the head in the conscious subject does not produce obstruction. Hyperextension produced average clearances similar to those for the entire group during anesthesia both with and without curare.

The effect of loss of muscle tone upon the pharyngeal space is also apparent in the values of ten patients during thiopental anesthesia and *d*-tubocurarine apnea (table 2).

TABLE 2
COMPARISON OF PHARYNGEAL CLEARANCE PRODUCED BY FLEXION AND HYPEREXTENSION OF THE HEAD OF PATIENTS AWAKE AND SUBSEQUENTLY ANESTHETIZED AND CURARIZED SHOWING EFFECT OF PULLING UP THE CHIN AS AN ADDITIONAL MANEUVER

Condition of Patients	Number of Patients	Age Range (years)	Pharyngeal Clearance According to Head Position (mm.)							
			Head Flexed		Head Extended		Head Hyperextended			
			Average	Range	Average	Range	Chin Not Pulled Up		Chin Pulled Up	
							Average	Range	Average	Range
Awake	10	31-81	10	6-16	11	5-17	17	12-21		
Anesthetized and Curarized			2	0-8	3	0-7	8	4-13	16	8-21

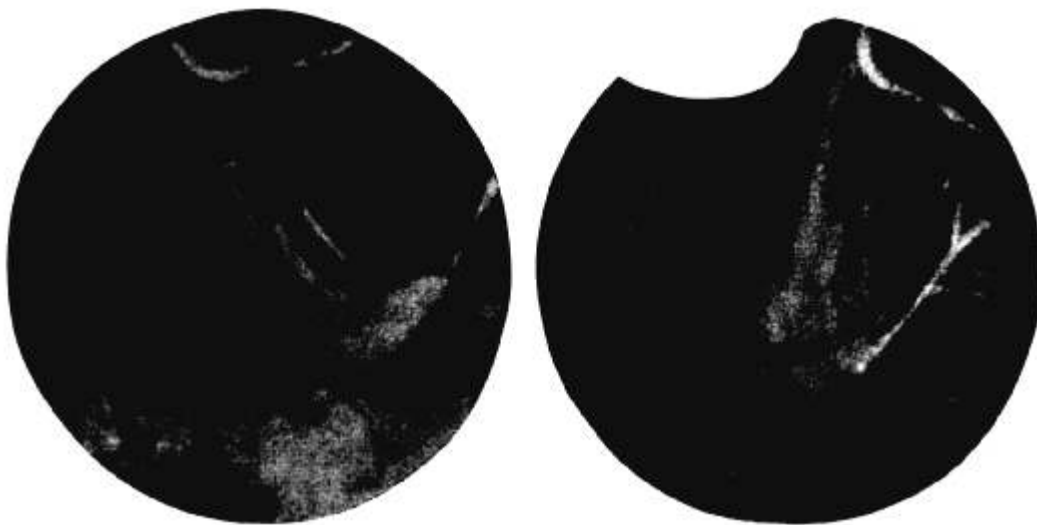


FIG. 4. Soft tissue roentgenogram in anesthetized apneic patient, head moderately extended by one hand on the vertex. At the uvula the posterior clearance is 4 mm. and at the tongue base, 10 mm. The effect of additional extension is shown in figure 5.

FIG. 5. Soft tissue roentgenogram of patient, head hyperextended by one hand on the vertex and the other hand on the chin (white area is leaded glove). At the uvula the posterior clearance is 8 mm. and at the tongue base, 23 mm.

Curare reduced the clearance by 55 per cent. Hyperextension by one hand on the vertex produced a pharyngeal clearance of 8 mm. (range 4 to 13 mm.). Despite this collapse the use of the operator's second hand to pull the chin upward increased the clearance to an average of 16 mm. (range 8 to 21 mm.). The latter agree with the values obtained in table 1. The curare effect was maximal when the head was flexed or neutral, giving an average clearance of 2.5 mm. (range 0 to 8 mm.) or about one quarter of the averages obtained in these patients awake.

Effects of Extension and Hyperextension. Figures 4 and 5 show how progressive extension of the head increased the pharyngeal clearance at the tongue base. These are two of 12 seriograms taken in a 58 year old anesthetized apneic patient as his head was hyperextended from a neutral position. In figure 4 moderate extension provided a clearance of 4 mm. between uvula and posterior pharynx and 10 mm. between the tongue base and posterior pharynx. With hyperextension these clearances were increased to 8 and 23 mm. respectively.

Extension with only one of the rescuer's hands on the crown of the subject's head

opened the subject's mouth and produced a clearance in the pharynx which was approximately half that obtained by the foregoing two-handed hyperextension maneuver with additional chin-pull. Although these two maneuvers produced significantly different clearances the extension maneuver alone produced an adequate clearance in all subjects.

Comparison of Head-Tilt, Chin-Lift, and Jaw-Lift Maneuvers. Pharyngeal clearances were compared in six patients (table 3). Three operators were equally proficient in all

TABLE 3
COMPARISON OF PHARYNGEAL CLEARANCES PRODUCED BY HEAD-TILT, CHIN-LIFT, AND JAW-LIFT MANEUVERS IN ANESTHETIZED CURARIZED PATIENTS

Maneuver	Number of Patients	Age Range (years)	Pharyngeal Clearance (mm.)	
			Average	Range
Head-Tilt	6	46-81	16	13-25
Chin-Lift			15	10-24
Jaw-Lift			17	9-25

maneuvers which were applied in the same manner they are used in resuscitation, *i.e.*,

- (1) *Chin-Lift*: thumb hooked under teeth, other hand pinching nostrils;
- (2) *Jaw-Lift*: fingers under rami of mandible, thumbs on chin to open mouth;
- (3) *Head-Tilt*: one hand on vertex, the other pulling the chin up (fig. 1).

Head-tilt produced an average clearance of 16 mm. (range 13 to 25 mm.), chin lift a clearance of 15 mm. (range 10 to 24 mm.), and jaw-lift a clearance of 17 mm. (range 9 to 25 mm.). The differences are not meaningful.

When chin-lift or jaw-lift positions were exaggerated by maximal hyperextension clearances were increased by 3 to 6 mm. Unlike head-tilt these exaggerated positions were difficult to maintain and are not ordinarily used in resuscitation. On the other hand when the head-tilt procedure was done with only moderate head extension the clearance was reduced by 4 mm. Head-tilt depends primarily upon hyperextension. Jaw-lift and chin-lift depend primarily upon forward displacement of the mandible and, as practiced, obtain moderate extension of the head, seldom hyperextension. Technique was important for all these maneuvers.

DISCUSSION

These studies demonstrate that the widest airway is consistently achieved when two hands are used to maintain hyperextension of the patient's head. When only one hand is used to maintain extension a lesser though satisfactory pharyngeal clearance was observed unless pressure by a face mask interfered. The efficacy of pulling upward on the chin is recognized in anesthesia as well as the lip obstruction which may occur under a mask. Without adjuncts the head-tilt technique opens the mouth and as the added force is applied at the patient's chin the pharyngeal clearance is maximal. These two counter forces applied at the vertex and chin hyperextend the head sufficiently to insure a wide separation of the tongue and pharyngeal wall, usually about two centimeters. Lip obstruction is prevented by retraction of the lower

lip by the rescuer's thumb. This two-hand maneuver cannot be practiced or evaluated in inhalation anesthesia when one hand compresses the breathing bag and a mask depresses the jaw.

New consideration may be given this technique for preventing airway obstruction during rescue breathing since the relationship between the degree of head-tilt and the patency of the pharynx has been established. A simple procedure may be recommended for laymen as soon as the difference between hyperextension and moderate extension of the head is appreciated. Adoption of the head-tilt maneuver can avoid confusion among rescue organizations who need unified, brief, all-purpose techniques as free of details and variations as possible. The advantages of the simplified head-tilt procedure for training laymen have been apparent since December 1958 and over 30 successful field rescues have been reported. In many instances the more complicated jaw or chin-lift maneuvers have been abandoned and many rescuers have independently improvised the head-tilt method.⁵

Perhaps the professional rescuer should be taught all the airway-supporting maneuvers. However, the training of the occasional or chance rescuer may be limited to the head-tilt method since laymen forget lessons in airway anatomy and all but a few points in technique. To simplify and minimize the subject matter taught the lay trainee instructions may be reduced to four brief essentials: "Tilt the head back fully and blow air through the nose or mouth. One hand pushes the forehead back, the other pulls the chin up."

A 21-month trial of the head-tilt method has extended the technique to several thousand laymen without extensive indoctrination. Brief practice on a manikin¹⁵ after a 15-minute lecture demonstration is sufficient for most laymen. Evaluations subsequently of their proficiency by trials in anesthetized subjects have demonstrated satisfactory performance. Unlike other maneuvers the head-tilt modifications are workable in flaccid, rigid, and convulsive states.^{6, 7, 8} The versatility of the method permits optional use of oral or nasal routes of inflation.

Others have reported similar roentgeno-

graphic findings of the human pharynx. Fink reported roentgenographic examinations of the pharynx in relation to obstruction by the tongue and epiglottis. He observed that the epiglottis often sags into the laryngeal aditus whether or not a conventional oral airway is used. He modified the Guedel airway with an extension of the tip to project into the vallecula and deflect the epiglottis upward out of the air stream.¹⁶ He also recommended hyperextension as a maneuver to prevent obstruction by the tongue.¹⁷

Safar studied head position and airway obstruction in the supine and prone positions and reported that extension of the head produced partial or complete obstruction in 48 to 52 per cent of the cases. His findings do not necessarily conflict with the present studies which add the chin pull action to increase the pharyngeal clearance. Our findings agree consistently with the roentgenograms published by Safar showing wide pharyngeal clearance of a patient in the prone position with his head held in moderate extension (see figure 4 of Safar's paper).¹⁸ We also find an increased incidence of partial obstruction when the patient's head is extended no more than can be achieved with either chin-lift or jaw-lift maneuvers with mouth-to-mouth breathing. Proper hyperextension sufficient to always open the pharynx is difficult or impossible if (1) one of the rescuer's hands is on the mouth and his other hand pinches the nostrils of the victim or (2) both of the rescuer's hands support the rami of the mandible. Neither of these maneuvers applies the force at the vertex of the head and the counter force upward on the chin which produce maximal extension. Both counter forces are essential parts of the head-tilt maneuver. On the other hand obstruction may occur when only one hand is used on the vertex if a face mask is applied, pushing the mandible downward and the tongue against the posterior pharyngeal wall.

Asmussen and associates¹⁹ reported a pharyngeal clearance of 2.5 cm. at the tongue base for prone anesthetized patients with the head maximally extended at the atlanto-occipital joint. The present findings are in general agreement and indicate further that some extension of the upper cervical spine

also contributes to the opening effect in the pharynx.

Recently Buchanan²⁰ and Ulmer²¹ have also reported roentgenographic studies which confirm the adequacy of the head-tilt maneuver in providing a free airway. In the present study the roentgenograms of the pharynx of all anesthetized subjects gave the narrowest dimension of 8 mm. clearance with two-handed hyperextension. This clearance was sufficient for the expired air inflation through the subject's nose or mouth. The average of 18 mm. pharyngeal clearance produced by the head-tilt maneuver exceeded that during conscious breathing. An increase from 15 to 20 mm. average pharyngeal clearance reflected the influence of muscle tone, the greater clearance occurring in subjects not given curare.

It must be emphasized that the counter forces applied at the chin and vertex to maintain the hyperextension and elevation of the mandible must be sufficient to hold the mouth closed and the anterior neck stretched. During inflation the common error of the rescuer is in not opening his own mouth sufficiently and thereby occluding the victim's nostrils with his lips. Alternatively for mouth-to-mouth inflation with the head-tilt method the patient's lips are held parted by the rescuer's thumb and during inflation the nostrils are occluded with his cheek (not by the fingers of the other hand which must instead maintain the counter forces on the patient's vertex).

The hyperextension or head-tilt maneuver simplifies the management of airway support in the care of the unconscious apneic patient particularly in the hands of laymen and emergency rescue personnel. It is recommended for the transport of any unconscious patients except in cases suspected of having sustained a fracture of the cervical spine. The head-tilt maneuver is the technique of choice for laymen to use in performing expired air resuscitation by the mouth-to-mouth and mouth-to-nose methods.

SUMMARY

Three common airway-clearing maneuvers have been evaluated by analyses of field use, ventilation produced by laymen in anesthe-

tized subjects, and pharyngeal x-rays of anesthetized subjects. Chin-lift, jaw-lift and head-tilt maneuvers all produce a satisfactory upper airway in flaccid subjects. The head-tilt method is preferable when the mouth-to-nose procedure is indicated, *i.e.*, trismus, convulsions, and gastric distension. All three maneuvers should be mastered by expert rescuers. For the chance rescuer the head-tilt method is simpler, safer, more versatile, and less apt to aggravate complications involving gastric contents. Hyperextension of the patient's head by one hand on the forehead and the other on the chin is recommended for both mouth-to-mouth and mouth-to-nose resuscitation by laymen.

These studies were supported in part by the King Christian X Foundation and the Danish Red Cross, Denmark, and Contracts DA-49-007-MD-507 and DA-49-193-MD-2021 with the Research and Development Command, Office of the Surgeon General, Department of the Army, Washington, D. C., and the Harry M. Dent Foundation, University of Buffalo.

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