Cardiol

A D V A N C E S   I N   C P R

Medical Grand Rounds

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When in the stream by accident, is found
A pallid body of the recent drown'd.
Tho ev'ry sign of life is wholly fled,
And all are ready to pronounce it dead,
With tender care the clay-cold body lay
In flannel warm, and to some house convey:
The nearest cot, whose doors still open lie
When mis'ry calls, will ev'ry want supply.

. . . But, ah! a fatal error oft has been,
When life, though latent, was not quickly seen.
Then thinking that the conflict all was o'er;
That life was fled, and could return no more,
Who much have wish'd, and yet despair'd to save,
Too rashly doom'd the body to the grave.
More patient thou, with ardour persevere
Four hours at least: the gen'rous heart will fear
To quit its charge, too soon, in dark despair;
Will ply each mean, and watch th' effect with care:
For should the smallest spark of life remain,
Life's genial heat may kindle bright again.

Rules of the Humane Society for Recovering Drowned Persons, 1767

The first written report of cardiopulmonary resuscitation may have been in the Old Testament when the prophet Elisha breathed life back into a child:

> *32 And when Elisha was come into the house, behold, the child was dead, and laid upon his bed*
>
> *33 He went in therefore, and shut the door upon them twain, and prayed unto the Lord.*
>
> *34 And he went up, and lay upon the child, and put his mouth upon his mouth, and his eyes upon his eyes, and his hands upon his hands; and he stretched himself upon the child; and the flesh of the child waxed warm.*[1]

This technique did not gain wide acceptance, possibly due to the long response time . . . two days.

Interest in resuscitation again appeared in the eighteenth century, probably due to the large number of drownings along the coast of the British Isles. In 1774 the official reports of the Society for the Recovery of Persons Apparently Drowned were published. This very detailed report teaches many lessons which are still important. This work states that utmost speed is essential if the attempts at resuscitation are to succeed. Detailed, excellent descriptions are given of mouth-to-mouth and mouth-to-nostril breathing. It was suggested in this work that "a handkerchief or cloth may be used to render the operation less indelicate." Rescuers were instructed to continue vigorous efforts for two hours before abandoning resuscitation. The techniques were recommended for anyone who collapses suddenly, not just drowning. One fascinating account describes a child who was successfully resuscitated using "electricity." In one case external cardiac massage was described as follows, "Having no apparatus at hand for inflating the lungs, I availed myself of the natural elasticity of the ribs by pressing forceably upon the sternum and then suddenly removing my hand . . . " Tobacco smoke was felt to be beneficial. If mouth-to-mouth breathing or the use of tobacco smoke failed, the rescuer was advised to use "a tube to be inserted through the mouth or nostrils to which could be attached a pair of bellows." If this method was also not successful, "it may be necessary to make an opening into the windpipe" into which a tube could be inserted. This eighteenth century report identified five key elements of resuscitation: 1) speed is essential, 2) attempts should be with vigor and not be prematurely abandoned, 3) ventilation must be assured, 4) external compression of the chest should be performed, and 5) electricity may be of value. Tragically these recommendations were lost for nearly two centuries, save for some use by the Britsh Navy.[2-3]

Over the next two centuries the techniques regressed with less effective methods assuming the forefront. In 1946 Dr. James Elam, who is currently on our faculty, helped bring back the use of mouth-to-mouth ventilation during the poliomyelitis epidemic in Minnesota where he performed mouth-to-mouth on several victims transiently due to the lack of an adequate number of tank respirators.[4] In the late 1950's external chest compression was reintroduced due to the work of Kouwenhoven et al.[5] Recognizing that there were more than 1,000 prehospital sudden deaths per day in the United States, in 1966 a National Academy of Sciences-National Research Council Conference on CPR recommended that external chest compression be taught to all health professionals according to the standards of the American Heart Association.[6-7] Gradually, education was begun not only for health professionals but also in a few limited cases for lay persons. In 1971-1972 Dr. Thomas Burnap, deceased of our faculty, who was chairing the CPR committee of the American Heart Association, with others set into motion the mechanisms for a national conference on CPR. During the years 1966 to 1973 training materials had been developed via the American Heart Association,[8-14] by the NAS-NRC[6-7] [15-20] by the reports of the Inter-Society Commission of Heart Disease Resources,[21-27] by governmental agencies,[28-33] professional medical societies,[34-38] and private groups.[39-45]

In 1973 a National Conference on Standards for CPR and ECC was cosponsored by the American Heart Association and the NAS-NRC which led to the publishing of the 1974 Standard as a supplement to JAMA in February, 1974.[46] In 1975 the AHA and the American Society of Law and Medicine cosponsored a conference on the Medicolegal Implication of Emergency Medical Care.[47] In 1976 the AHA, the NAS-NRC, the National Heart, Lung, and Blood Institute, and the American Red Cross cosponsored a conference on Emergency Airway Management to deal with airway obstructions.[48] In 1979 a second National Conference on CPR and ECC was held, and its findings were published as a supplement to JAMA in 1980.[49] These guidelines and standards have caused intense interest in CPR and have encouraged research and debate on their merits. This presentation will concentrate on changes and their rationale and on some areas of debate. The first portion will have to do with techniques, the second portion will have to do with drug therapy.

A. Airway obstruction caused by tongue.

B. Airway obstruction caused by tongue relieved by head tilt.

Figure 1. Airway obstruction and relief.[50]

Obviously a very important initial step in CPR is to adequately open the airway. In the unconscious person, the most common cause of airway obstruction is the tongue (Fig. 1A). As the tongue is attached to the mandible, maneuvers that move the mandible forward will move the tongue away from the posterior pharynx. If there is adequate muscle tone, tilting the head back will cause the mandible to move forward and will bring the tongue forward (Fig. 1B). However, if there is insufficient muscle tone, the mandible and tongue may not be brought forward adequately, causing a passive obstruction. Additional help may be obtained by using the chin lift or neck lift.[51-57]

Figure 2. Head tilt-neck lift maneuver.[50]

The method that has been taught primarily for the past two decades has been the head-tilt-neck lift maneuver (Fig. 2). One hand tilts the head back while the other hand flexes the neck forward. The head is extended on the cervical spine while the spinal extension is minimized by placing the hand as close to the occiput as possible. This maneuver may cause problems with cervical spinal injuries. The efficacy of this technique is attested by the fact that survivals up to 61% have been found in selected subgroups where lay persons initiated CPR with this technique.[58]

Figure 3. Head tilt - chin lift maneuver[50]

Another technique which has been used since as early as 1960 but has not been as widely taught and utilized is the head tilt-chin lift manuever (Fig. 3).[59-61] It has been shown that a greater opening of the airway can be accomplished using this technique.[61] The technique is performed by placing one hand on the forehead and the second and third fingers of the other hand on the mandible and extending the head. Care should be taken not to press on the base of the tongue and the soft tissues so as to produce obstruction. The thumb can be used to pull the lip down if needed to provide a wider opening of the mouth. The teeth should be brought nearly together with this technique. Loose fitting dentures can also be held in place. Dentures normally should be left in place as they keep the cheeks from collapsing, allowing a better seal.

Figure 4. Jaw thrust maneuver.[50]

Additional forward displacement of the mandible may be obtained using the jaw thrust maneuver (Fig. 4). The rescuer grasps the angles of the jaw between both hands and lifts the jaw forward while extending the head backward. The elbows should be resting on a hard surface to minimize fatigue. Mouth-to-mouth ventilation can be achieved by placing the rescuer's cheek against the victim's nostrils and ventilating as with other techniques. This technique is preferred if cervical spine trauma is suspected, as it can be accomplished with the head in a neutral position.

Guildner[51] has done excellent comparative studies of the various techniques for opening the airway. Comparisons of the techniques in apneic patients are shown in Table I on the next page.

Table I[51]

Subjective Evaluation of Effectiveness of Techniques On Patients Not Making Any Respiratory Effort

N = 120

Effectiveness	Neck Lift No.	Neck Lift %	Chin Lift No.	Chin Lift %	Jaw Thrust No.	Jaw Thrust %
Total Obstruction Unable to Ventilate	7	5.8	--	--	1	0.8
Partial Obstruction Inadequate Ventilation	8	6.7	2	1.7	2	1.7
Partial Obstruction Adequate Ventilation But With Difficulty	58	48.3	9	7.5	23	19
Good Airway Easy Ventilation	47	39.2	109	90.8	94	78

It is therefore apparent that in the apneic patient the chin lift and jaw thrust are superior to the neck lift in adequately opening the airway. In Table II Guildner reported 30 patient with airway obstruction but with spontaneous respiratory effort.

Table II[51]

Effectiveness of Techniques for Opening Airway
In Patients With Complete Respiratory Obstruction
But Making Spontaneous Respiratory Effort

N = 30

Effectiveness (Tidal Volume)	Neck Lift No.	Neck Lift %	Chin Lift No.	Chin Lift %	Jaw Thrust No.	Jaw Thrust %
0 - 50 ml	13	43.3	--	--	1	3.4
50 - 250 ml	9	30.0	2	67.0	3	10.0
250 - 400 ml	6	20.0	7	23.3	7	23.3
Over 400 ml	2	6.7	21	70.0	19	63.3

Hence, it is apparent from Guildner's works that the chin lift and jaw thrust maneuvers are superior to the neck lift. An additional advantage of the chin lift is that it is much less tiring than the other two maneuvers and is easier to use.

Obstructed Airway

One of the most controversial areas in resuscitation has been the proper managment of the obstructed airway. The American Red Cross and the American Heart Association had been teaching the use of back blows as the method of treatment. In 1974 Heimlich[62-64] popularized the use of the abdominal thrust. Because of Heimlich's fervor for his technique, controversy has occurred for the past eight years. I will try to give some perspective to this controversy.

First, foreign-body obstruction leading to death is relatively uncommon. In 1978, the latest year complete statistics are available, the National Safety Council reported 2,900 deaths from foreign body obstruction of the airway. During the same year there were more than 650,000 deaths from cardiac arrest in ischemic heart disease. Hence, the relative risk of airway obstructions is one in 200 compared to cardiac arrest. Hence, if someone is unconscious and arrested the odds are greater than 200 to one that no foreign body airway obstruction is involved. Foreign body airway obstruction usually is associated with 1) elevated blood alcohol level, 2) dentures, and 3) large poorly chewed pieces of food. This frequently happens in restaurants because people are talking and eating while intoxicated. Thus the term "cafe coronary" has been used.[65]

After Heimlich's initial publications,[62-64] he popularized his technique in the lay press. In 1976 a national conference was held to review Heimlich's data.[48]

In response to Heimlich, Archer Gordon et al[66] performed the following studies. He measured pressures and flows with open airways, partial obstruction of the airway, and complete obstruction of the airway. These studies were performed initially in dogs and repeated in human volunteers. He performed the following maneuvers. He performed back blows while sitting, while lying on the side, and in infants. He performed abdominal thrust with the victims standing or sitting, while in the lateral horizontal position, while astride a supine victim, and beside a supine victim. He also performed chest thrust from a lateral horizontal position and supine while laterally squeezing the chest. These maneuvers are shown in Figure 5.[66]

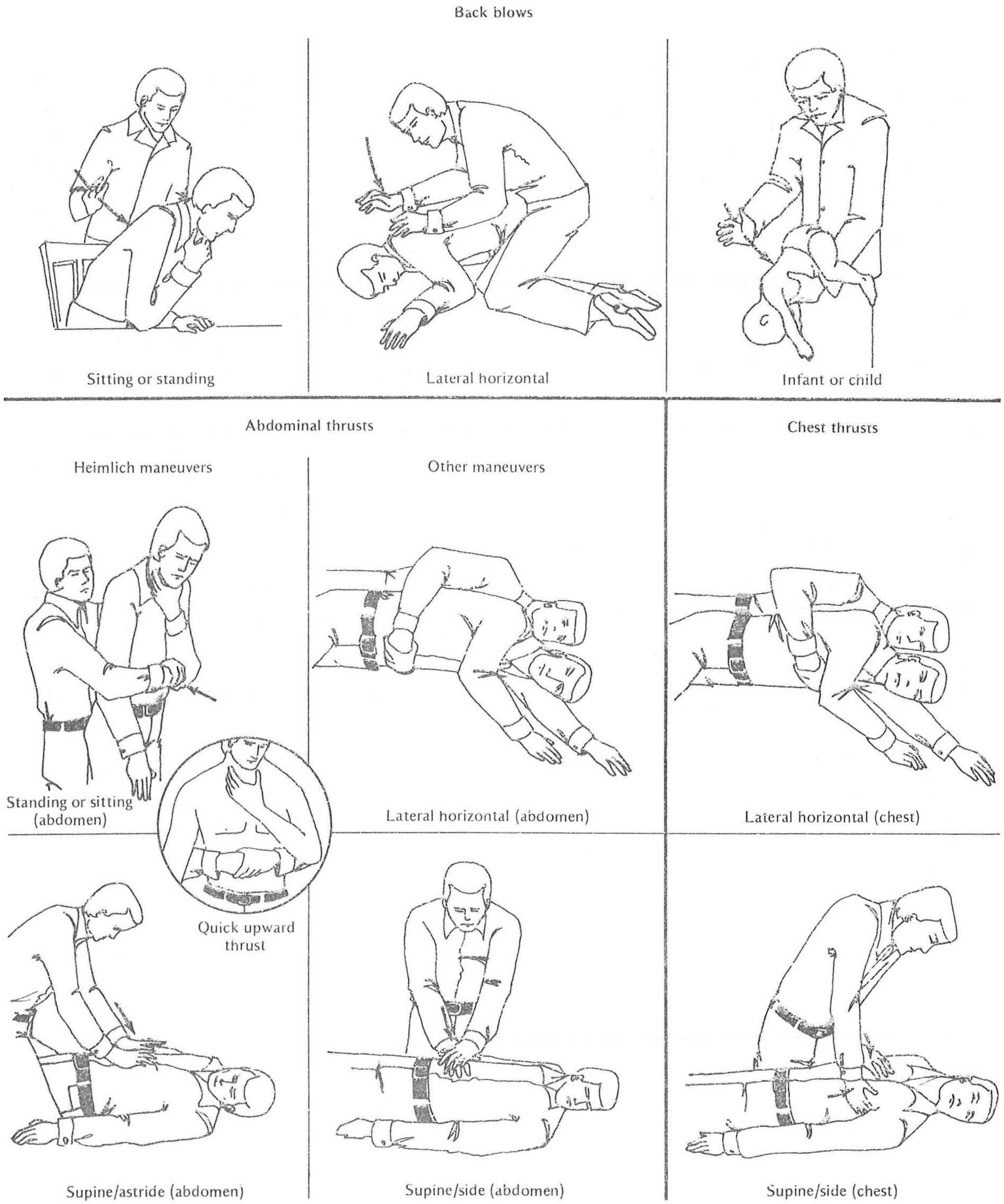

Figure 5. Artificial cough techniques studied in human volunteers

The data from the six normal human volunteers are shown in Table III[66]

Table III. Normal and Artificial Cough Measurements[a] [66]
(Mean values for six normal human subjects)

Methods Studied	Open Airway (15mm)[b]		Partial Airway (4mm)			Blocked Airway[c]
	Flow (ml/sec)	Volume (ml/breath)	Flow (ml/sec)	Volume (ml/breath)	Pressure (mmHg)	Pressure (mmHg)
Normal Cough (conscious)						
From normal resting level	3,300	550	1,800	380	55	72
From end inspiration level	6,300	1,650	2,700	800	78	115
Artificial Cough (unconscious and apneic)						
Back blows						
Sitting	650	70	200	25	25	35
Lateral horizontal	550	60	180	20	21	30
Abdominal thrusts						
Sitting or standing (Heimlich)	4,400	283	2,000	91	11	15
Lateral horizontal	4,300	415	2,100	140	10	12
Supine/astride (Heimlich)	3,900	316	2,400	182	10	13
Supine/side	4,300	346	2,200	211	10	12
Chest thrusts						
Sitting or standing	4,600	240	2,200	97	18	19
Lateral horizontal	4,600	352	2,200	110	14	14
Supine/astride (sides of chest)	4,800	322	2,000	147	14	16
Supine/side (sides of chest)	4,600	266	2,300	106	13	15
Other Techniques (unconscious)						
Precordial thump	750	90	200	15	11	15
External cardiac compression	4,500	305	2,000	111	11	17

[a] Flow measured with Gould-Statham SP 1007 ultrasonic spirometer. Volume integrated electronically from flow signal. Pressure measured with Gould-Statham P37 strain gage transducer. All signals recorded simultaneously on Gould-Brush Model 200 recorder.
[b] Pressure with open airway always measured less than 1.0 mmHg.
[c] No flow or volume when airway blocked.

As can readily be seen with an open airway, normal coughing, abdominal, chest thrusts, or external cardiac compression all produce very high flow rates; but coughing moves much larger volumes. Back blows and precordial thumps have relatively little flow or volume. With partial airway obstruction, natural coughs had as high or higher flow than any other techniques and several fold higher volumes and pressures. Hence, a natural cough is far superior to any other technique. Of the artificial maneuvers clearly abdominal and chest thrusts provided the highest flows and volumes. Back blows gave the highest pressures. With complete airway obstruction, the highest pressures were generated by natural coughing. Back blows delivered almost twice the pressure of other artificial techniques. In Figure 6 are shown flow, volume, and pressure tracings in the human studies in the three states.

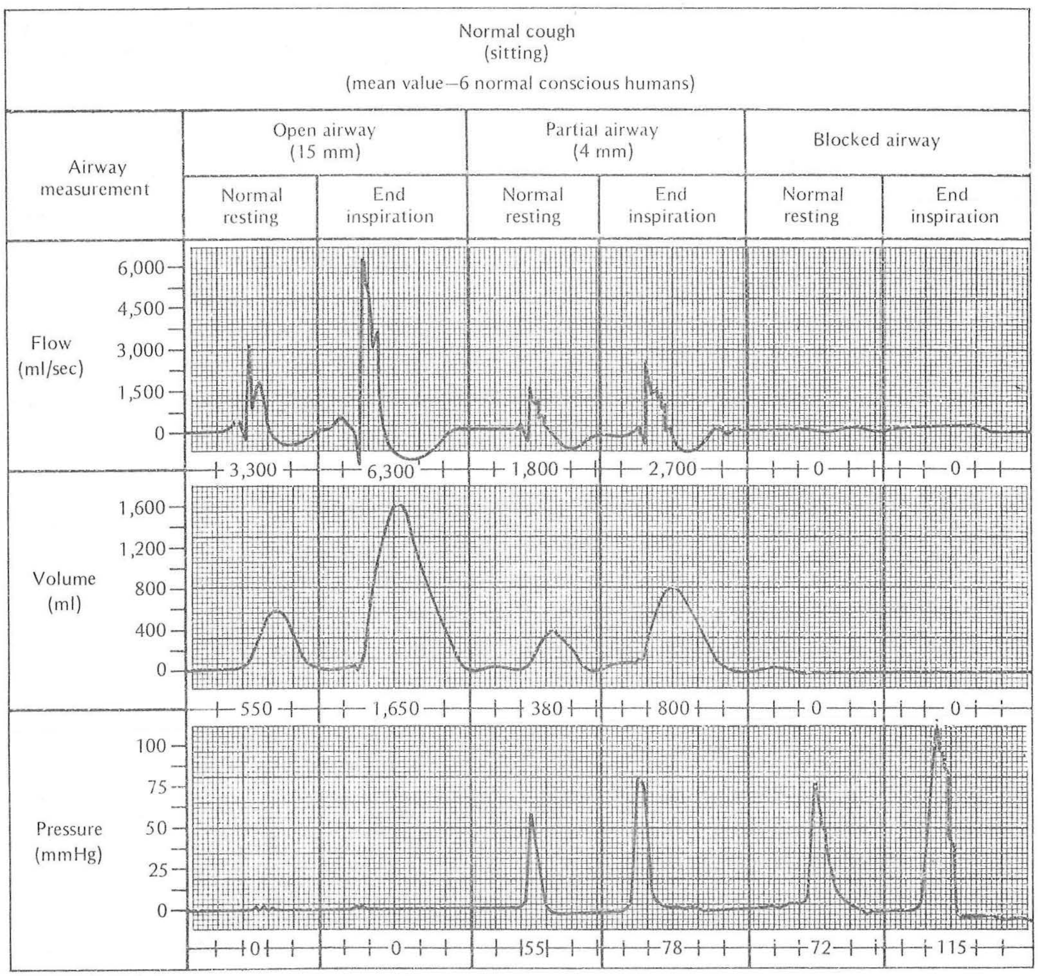

Figure 6. Mean air flow, volume, and airway pressure with normal cough in conscious volunteers [66]

Compare these tracings to the ones done with chest thrusts (Fig. 7). Note that volumes and pressures were not much better with natural coughs.

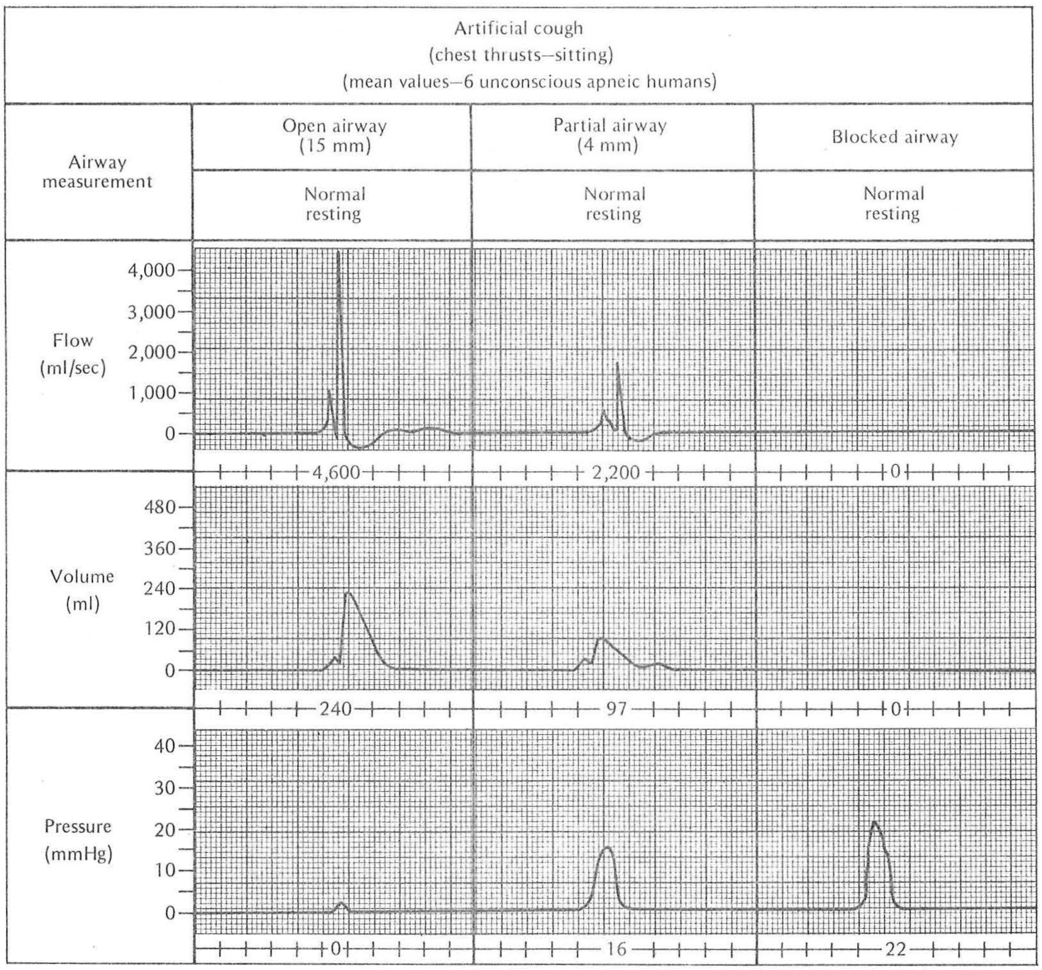

Figure 7. Mean air flow, volume, and airway pressure with chest thrusts in unconscious apneic volunteers[66]

As can be seen, the volumes and pressure are far superior with natural coughs. In Figure 8 are shown comparative tracings in one volunteer of back blows, chest thrusts on the side, abdominal thrusts, and chest thrusts to the sternum in a volunteer with complete airway obstruction.

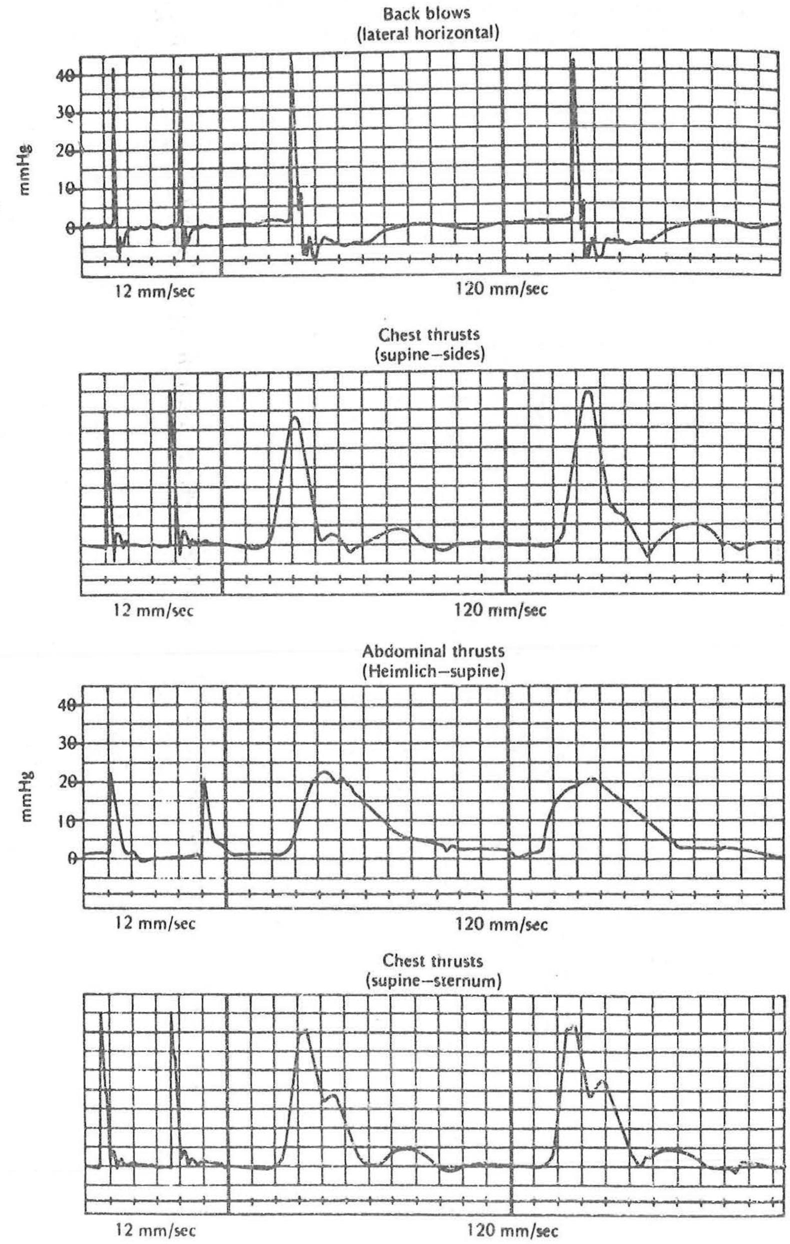

Figure 8. Force of expulsion, ie, airway pressures during complete upper airway obstruction developed by four different artificial cough techniques. Compare with 100 torr pressure produced by natural cough (Fig. 6)

Note that the pressure and rate of rise of pressure was greater with back blows and there were little differences between abdominal thrusts and the two types of chest thrusts.

Guildner et al[67] did a similar study with intubated volunteers and measured flows and pressures with abdominal thrusts, low chest thrusts (same area as for cardiac compression), and over the mid-sternum. The results are shown in Table IV.[67]

Table IV[67]

Exhaled Volume, Peak Air Flow Rates, ad Peak Airway Pressure
With Three Artificial Cough Maneuvers

	Open Endotracheal Tube		Obstructed Endotracheal Tube
	Exhaled Tidal Volume ml	Peak Flow Rate ml/sec	Peak Airway Pressure mmHg
Subject in Horizontal Position			
Abdominal Thrust	290 (80-740)	916 (600-1633)	17 (10-30)
Low Chest Thrust	350 (100-870)	1133 (550-1750)	25 (20-32)
Midchest Thrust	230 (80-540)	1000 (633-1383)	19 (18-21)
Subject in Sitting Position			
Abdominal Thrust	380 (80-920)	1083 (400-1617)	19 (10-29)
Low Chest Thrust	520 (170-1030)	1566 (883-2467)	32 (20-44)
Midchest Thrust	440 (180-840)	1650 (900-2567)	34 (26-42)

Hence, the national conference analyzing this data made the following recommendations:

1) If the victim was conscious and had an effective cough, he should be watched as he could obtain higher pressures and flows than through any other technique.

2) If the victim was unconscious or had an ineffective cough, back blows should be attempted first, as their pressures and rates of rise of pressures were greater; then they would be better at dislodging the foreign body.

3) Abdominal or chest thrusts provide better tidal volume than back blows; hence, if the object is dislodged they would be better at expelling the foreign body from the airway.

4) As mid-sternal chest thrusts were as good or better than low sternal or lateral chest thrusts and they should be safer, then mid-sternal chest thrusts were preferred.

5) As there was no data to say how many back blows or thrusts should be performed, the educators recommended four back blows, then four thrusts, as that would be easier to remember because in the unconscious victim they would follow the attempt to give four breaths.

Heimlich then began his media campaign, claiming that back blows were death blows. Heimlich over the next few years made multiple claims which cannot be substantiated. He has frequently misquoted positions of organizations and investigators. As an example, in print Heimlich has stated that Dr. Raymond Fink of the University of Washington has, through independent investigation, shown that back blows cannot dispel an obstructing bolus; Dr. Raymond Fink has stated he has never participated in any studies involving the Heimlich maneuver since the NRC meeting in June 1976[68] Requests for the data Heimlich claims he has has not been honored. To date the American Heart Association, the American Red Cross, the National Academy of Science, and the National Research Council have not been able to obtain any data from Heimlich.

The American Heart Association and the American Red Cross sent questionnaires to many health professionals asking for input. Joseph Redding[68] analized the data on 225 cases returned from health professionals. Thirty-four cases were in unconscious. In 116 cases only one method was used. In 29 cases more than one method was credited. The data is summarized in Table V.

Table V

Effectiveness of Food Choking Maneuvers

Maneuver	Attempts No.	Initial Success (Only Method Used) No.	%	Total Success (Only Meth.+ Comb) No.	%	Failure No.	%
Back Blows	109	22	(28)	53	(49)	56	(51)
Abdominal Thrusts	168	74	(67)	132	(79)	36	(21)
Chest Thrusts	25	9	(50)	16	(64)	9	(36)
Finger Probe	52	9	(29)	30	(58)	22	(42)
Instrumentation	18	2	(29)	13	(72)	5	(28)
CPR	14	0	(0)	12	(86)	2	(14)

From this data it is obvious that as a single maneuver abdominal and chest thrusts were best. But combined maneuvers were always better. In Table VI are shown the results after initial failure with another maneuver.

Table VI[68]

Effectiveness of Subsequent Maneuvers
After Initial Failures

Technique	Initial Failures Number	Successful Subsequent Maneuvers: Back Blows	Abdominal Thrusts	Chest Thrusts	Finger Probes	Instrument	CPR	Combination
Back Blows	56	-	38	4	5	4	0	1
Abdominal Thrusts	36	14	-	2	5	6	0	3
Chest Thrusts	9	2	0	-	2	3	1	0
Finger Probe	22	4	7	2	-	4	0	1
Instrumentation	5	0	0	0	1	-	0	1
CPR	2	1	0	0	0	0	-	0

Hence this data supports the original recommendation of back blows, thrusts, and finger probes. It should be pointed out that this data is annectdotal in character, not prospectively obtained, and unverifiable. Due to the small number of deaths caused by foreign body obstruction of the airway and the large number of rescuers, it is impossible to design a well controlled study in actual victims.

In July 1982 the furor errupted anew with the publication of three articles in *Pediatrics*.[69-71] The first was a review which concurred with the 1976 National Conference position.[69] The second was a new paper by Day, Crelin, and DuBois.[70] The third was an editorial by Heimlich replete with misquotations and falsehoods. A review of the article by Day et al[70] is in order to understand the latest furor. Day et al used an accelerometer attached to the external neck of a test subject. While sitting back blows straightened the spine and tended to move the head backwards and bring the throat headward (Fig. 9).

Thus they assumed that if the throat externally moved forward then inertia would move the foreign object deeper down the trachea. However, they ignored the fact that the lungs are a closed system and the increase in intrathoracic pressure would be delivered to the obstructing body forcing it in an outward direction. When they performed the same maneuver in the supine position the throat moved forward (Fig. 10).

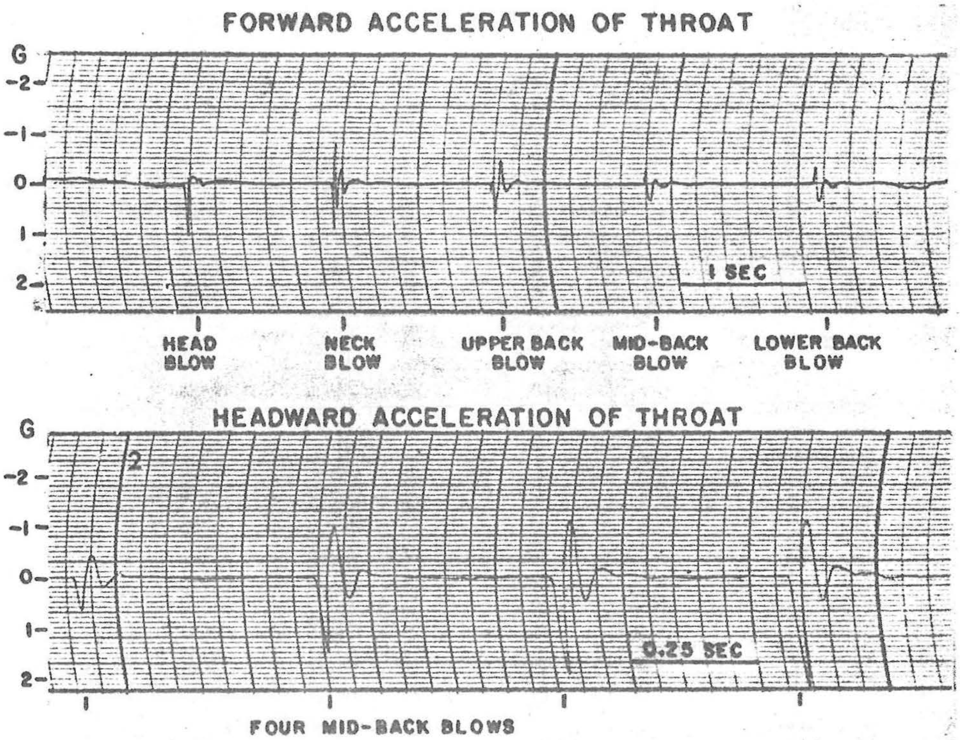

Figure 9. Accelerometer records showing forward motion of throat (top) in response to blows delivered to head or upper back. Inertia of foreign body contained in throat would displace it backward in throat during forward acceleration of throat. When accelerometer was pointed headward (bottom) acceleration of throat in upward direction would have displaced a foreign body downward, relative to throat, after blow to midback. Four such blows, of moderate force, are shown.[70]

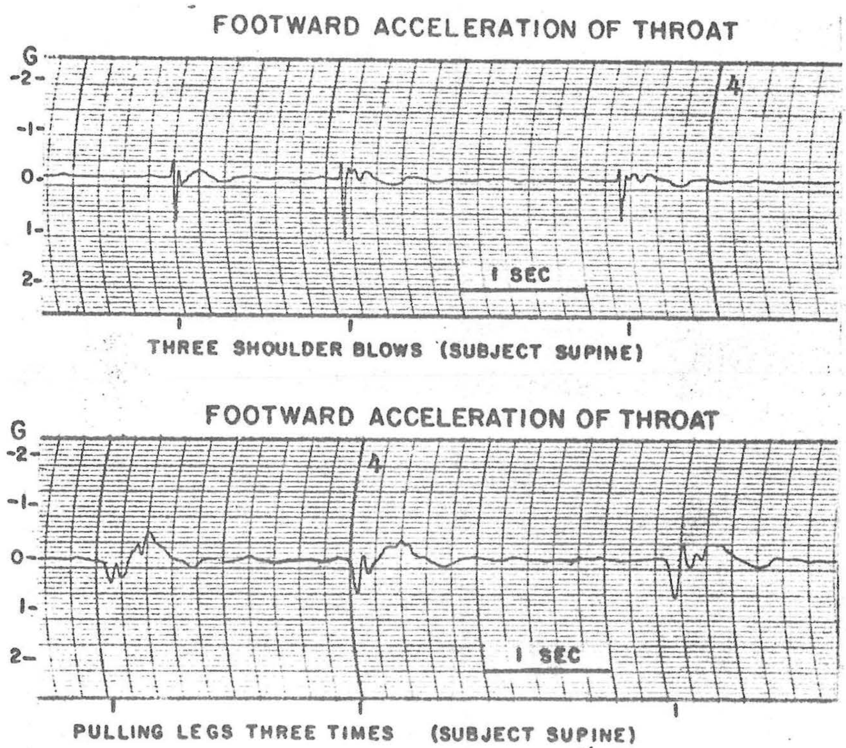

Figure 10. Accelerometer, taped to throat, showed footward acceleration during shoulder blows, or after legs were pulled, in supine subject.[70]

In addition they had a volunteer connected to a curved tube with a ball bearing and performed back blows and "Heimlich" (Fig. 11). It is of interest that this showed the foreign body moved out of the airway contrary to their discussions. They used this data to support that "Heimlich" produced more pressure; this device is influenced more by volume in a closed system than by pressure. This is contrary to all direct pressure measurements.

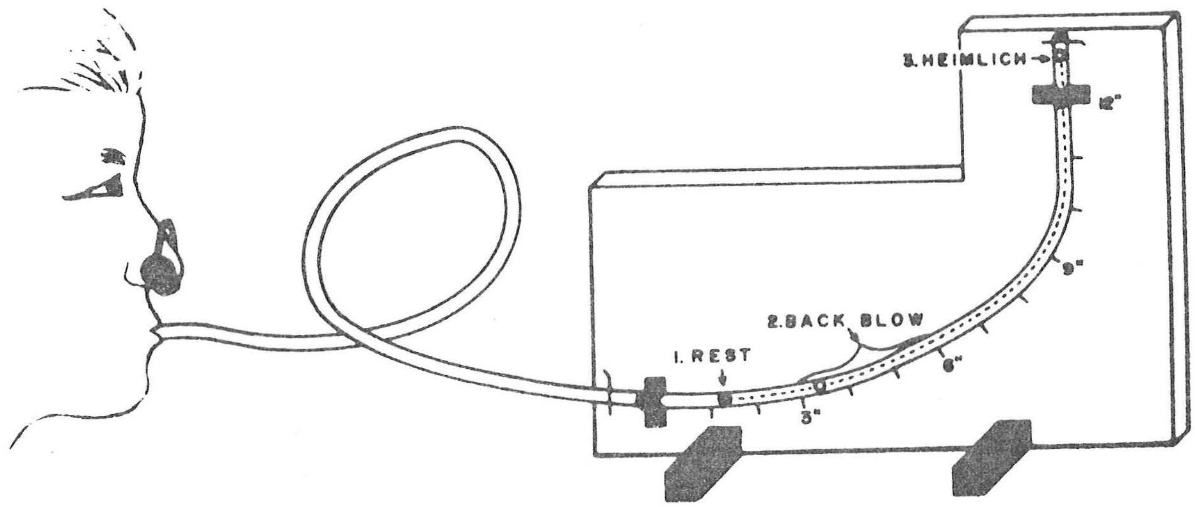

Figure 11. Ball bearing rolling in curved tube.[70]

Hence, this study was poorly conceived and the conclusions are not justified.

In the last eight weeks Archer Gordon (personal communication) has repeated these studies with an accelerometer in an obstructing meat bolus using an animal model. He showed that back blows caused the bolus to move upward and out of the airway. He got much higher headward acceleration of the bolus with back blows than with abdominal thrusts.

The issue is not resolved due to the lack of sufficient data in people with true obstruction. It is doubtful whether any controlled study can be achieved. In the absence of controlled data the recommendations of the National Conference remain the most reasonable approach to the problem.

Chest Compression

Since the work of Kouwenhoven et al[72] more than 20 years ago, it has been assumed that the heart is being squeezed between the sternum and the spine. While the heart is being squeezed the mitral valve is closed and the aortic valve is open. During relaxation the aortic valve closes. This concept has been taught for the past two decades.

This explanation appeared to be inconsistent with observations in animals[73] and in man.[74] Weale et al[73] had shown that the arterial and venous pressures were virtually identical. Both Weale et al[73] and MacKenzie et al[74] felt that these high venous pressures might be injurious to the brain and they might be a negative factor with external massage.

In 1976 Criley et al[75] published a paper on "cough CPR." These observations were made in individuals undergoing coronary angiography who suffered ventricular fibrillation, thus having pressure lines in place. The summary results for these patients with cough induced CPR and five with only external compression are shown in Table VII.[75]

Table VII[75]

Comparison of Cough-Induced Cardiac Compression And External Cardiac Massage

Patient/Age Year/Sex	Diagnosis*	Duration of Ventricular Fibrilation,sec	Average Peak Aortic Pressure mmHg: During Cough Induced Compression	Average Peak Aortic Pressure mmHg: During External Massage
Cough-Induced Cardiac Compression				
1/50/M	Postop CAD and RHD with prosthetic aortic valve and mitral disease	24	133	--
2/45/M	Postop CAD	29	146	75
3/45/M	Postop CAD	39	140	73
External Cardiac Massage				
4/45/F	Chest pain with normal coronary arteriogram	34	---	42
5/56/F	RHD with mitral stenosis	21	---	55
6/75/F	Prinzmetal variant angina	28	---	73
7/49/F	Chest pain with normal coronary arteriogram	30	---	60
8/56/M	Cardiomyopathy	45	---	47
	Mean±standard error	31.3±2.8	139.7±3.8 (P<.001)	60.7±5.1

* Postop CAD indicates postoperative coronary artery disease with saphenous vein bypass graft; RHD, rheumatic heart disease.

As can be seen, cough induced compression had far higher pressures than external CPR. In Figure 12 are shown the hemodynamic tracings from this patient.

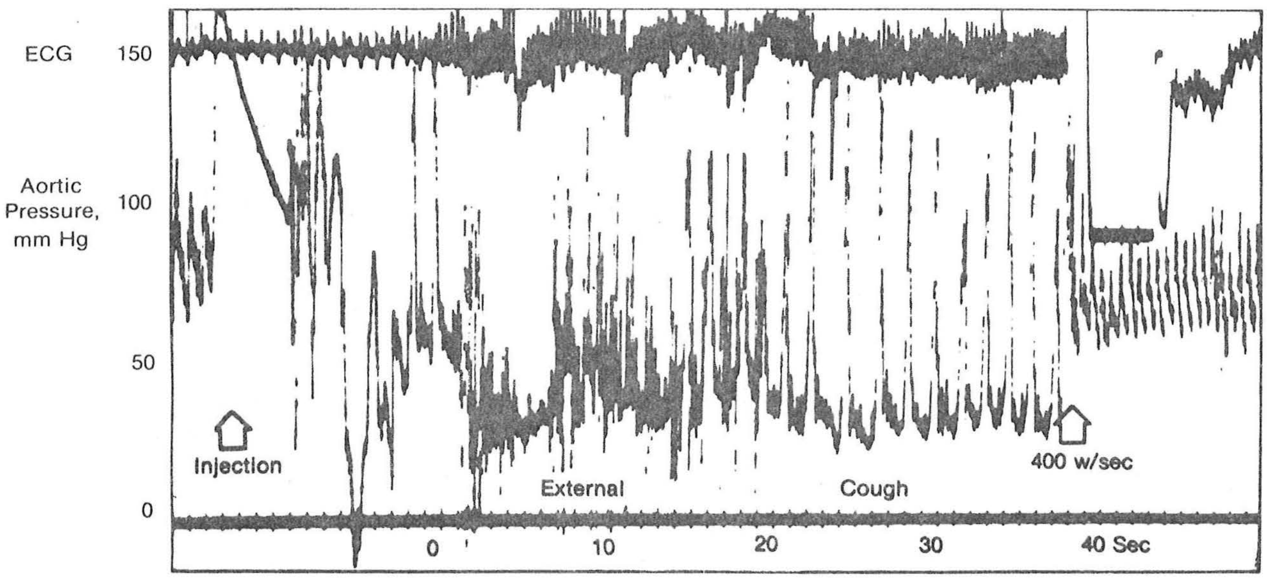

Figure 12. Electrocardiogram and aortic pressure in patient 3 (Table VI). Ventricular fibrillation followed right coronary injection. Patient remained conscious for 39 seconds with external followed by cough-induced cardiopulmonary resuscitation and conversion to sinus rhythm was achieved with 400 w/sec shock.[75]

Figures 13 and 14 show expanded scales of the external compression and the cough induced compression.

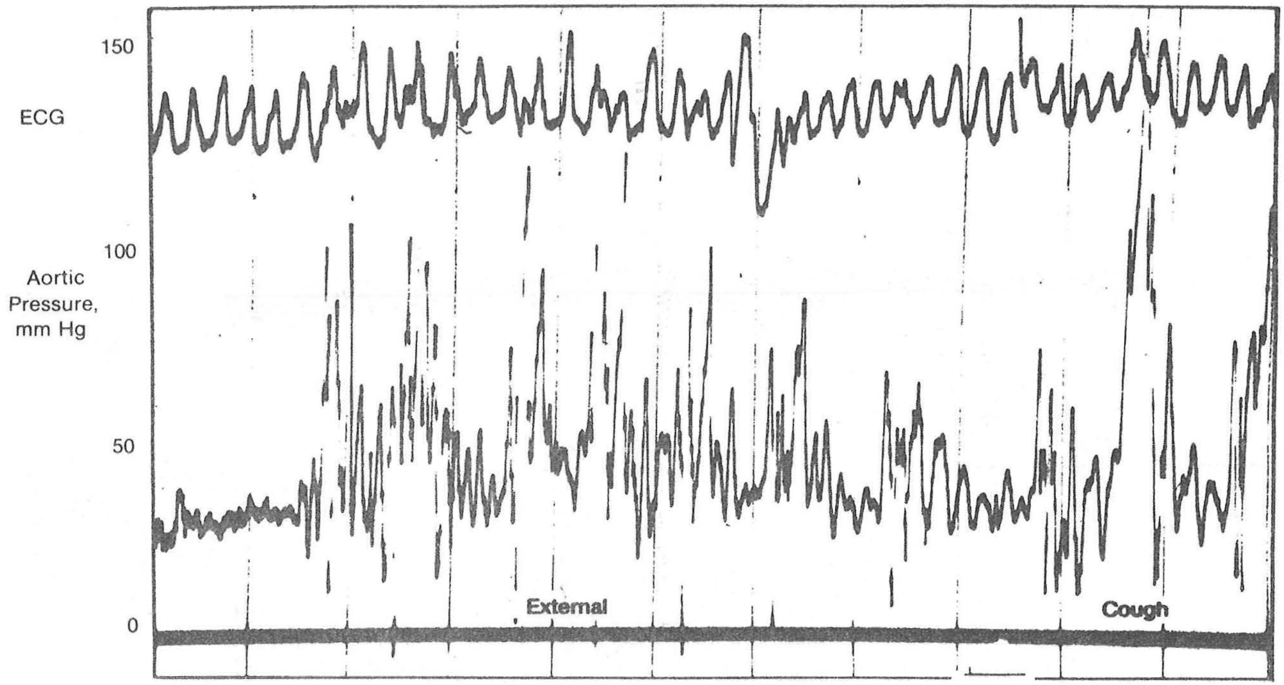

Figure 13. Expanded time scale recording of patient 3 (see Fig. 12) demonstrating ventricular fibrillation and poor pressure response to external massage, followed by onset of cough-induced cardiac massage at right side of figure. Time lines equal one second.[75]

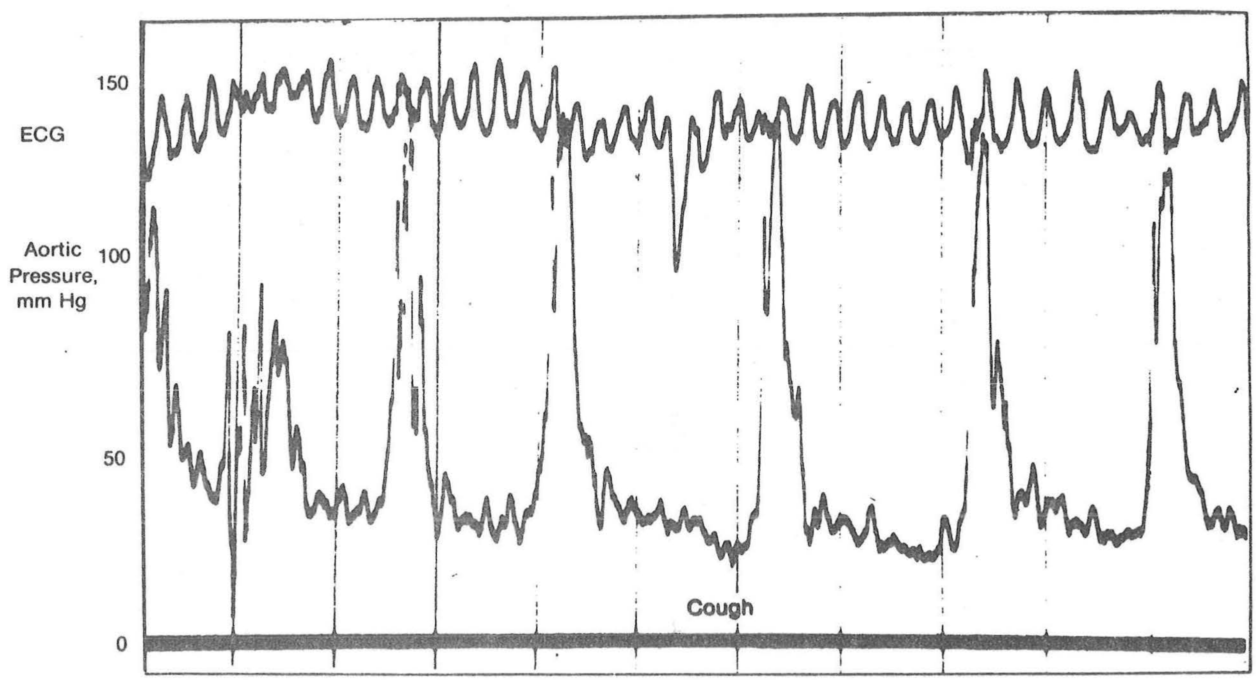

Figure 14. Expanded time scale recording of patient 3 demonstrating improved aortic pressure response to cough-induced cardiac massage (compare with Fig. 13). Time lines equal one second.[75]

Hence cough-induced CPR had higher pressures than external compression. But what about the mechanism of cough-induced CPR? Certainly it was not compressing the heart between the sternum and spine. Further insight has been given to this question through the work of Chandra and Weisfeldt and their coworkers.

Rudikoff, Weisfeldt et al[76] using large dogs found that with chest compression during cardiac arrest there were essentially equal rises in central venous, right atrial, pulmonary artery, and aortic pressures. Diastolic pressures were only slightly higher in the aorta than in the right atrium. The vascular pressures were equal to the esophageal pressures. Forward carotid flow only occurred during chest compression.

For the heart to be pumping blood there must be a large gradient between the aorta and the venous bed. As Weisfeldt has shown, no gradient occurs at the time of carotid flow; hence, there must be another mechanism. Similar results have been shown in several other series.[75-85] Cineangiograms have shown that the aortic and mitral valves do not close during CPR but lay in a neutral position.

Hence, what is the mechanism of CPR? Probably three mechanisms are important during closed heart compression: 1) various venous valving mechanisms are operating, 2) peripheral venous capacitance is greater than arterial capacitance, and 3) arterial resistance to collapse is greater than venous resistance.[86]

The venous values are the easiest to understand. There are anatomical valves at the thoracic inlet and in other veins leading from the brain which prevent retrograde flow while the intrathoracic pressure is increased.[87-90] These valves keep the extrathoracic brachiocephalic venous pressure low (see Fig. 15).

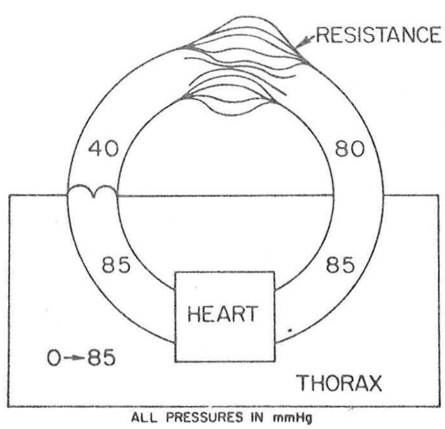

Figure 15. Representative pressures recorded during conventional CPR with forward carotid flow. Pressures are those recorded during compression. Intrathoracic pressures were indexed from esophageal pressures. There is no significant pressure gradient across the heart. The extrathoracic arterial pressure is similar to the intrathoracic aortic pressure. The extrathoracic venous pressure is markedly lower than the intrathoracic venous (right atrial) pressure. There is an extrathoracic arterial-venous pressure gradient that results in forward flow.[86]

Hence, there is a tendency for the aortic pressure to force flow from the arterial system to the low pressure extrathoracic brachiocephalic venous system.

A second mechanism is the greater venous capacitance as compared to arterial capacitance. If the valves were incompetent and pressure forced blood from the thorax, the extrathoracic venous pressure would be lower due to the greater capacitance. In other words, if 100 ml of blood were pumped out of the thorax into the extrathoracic venous system and 100 ml of blood was pumped into the extrathoracic arterial system, due to venous capacitance the venous pressure would be lower than arterial pressure and flow would occur from the arteries through the resistance vessels to the veins to equalize the extrathoracic pressure. Flow back into the thorax is blocked as long as pressure is applied to the chest. This mechanism is the only one that can explain the small flows present in the abdomen during CPR.[82 86]

The third factor that is important in pumping blood is the greater resistance of the arteries to collapse from external pressure. If pressure is applied externally to both arteries and veins, veins tend to collapse easier due to less rigidity in the vessel. This may cause the superior vena cava and the brachiocephalic veins to collapse but not the arteries. This has been shown to occur at the thoracic inlet.[91-92] The administration of vasoconstrictors further increases the resistance of the arteries to collapse.[93]

During chest compression, the extrathoracic venous pressure rises as blood flows from the arteries to the veins.[76] With relaxation an extrathoracic to intrathoracic pressure gradient appears and blood flows into the chest. Whether direct compression plays a role in pulmonary flow has not been determined.

Both in man and in some animals, direct compression may also play a role. A small number of patients and animals develop a marked arterial venous gradient inside the thorax. There individuals have a much higher radial artery pressure than most victims undergoing CPR, frequently greater than 100mmHg. The method by which the intrathroacic pressure is raised is unimportant. Many observations have shown the same result whether the mechanism of increased intrathoracic pressure is sternal compression, lateral chest compression, intrapulmonary pressure increase (via endotracheal tube), cough, or vest constriction of the chest. Interestingly, the compression may be of just the vasculature, as the same effect exists when both lungs are connected to open chest tubes allowing open pneumothoraces during compression.[76-101]

As there are no valves and no collapse of the inferior vena cava in the abdomen with CPR, methods of abdominal binding might diminish the to and fro movement of blood in the inferior vena cava. Abdominal binding or the use of MAST (medical antishock trousers) has been shown to augment pressure and flow. Typical pressure tracings are shown in Figures 16 and 17.

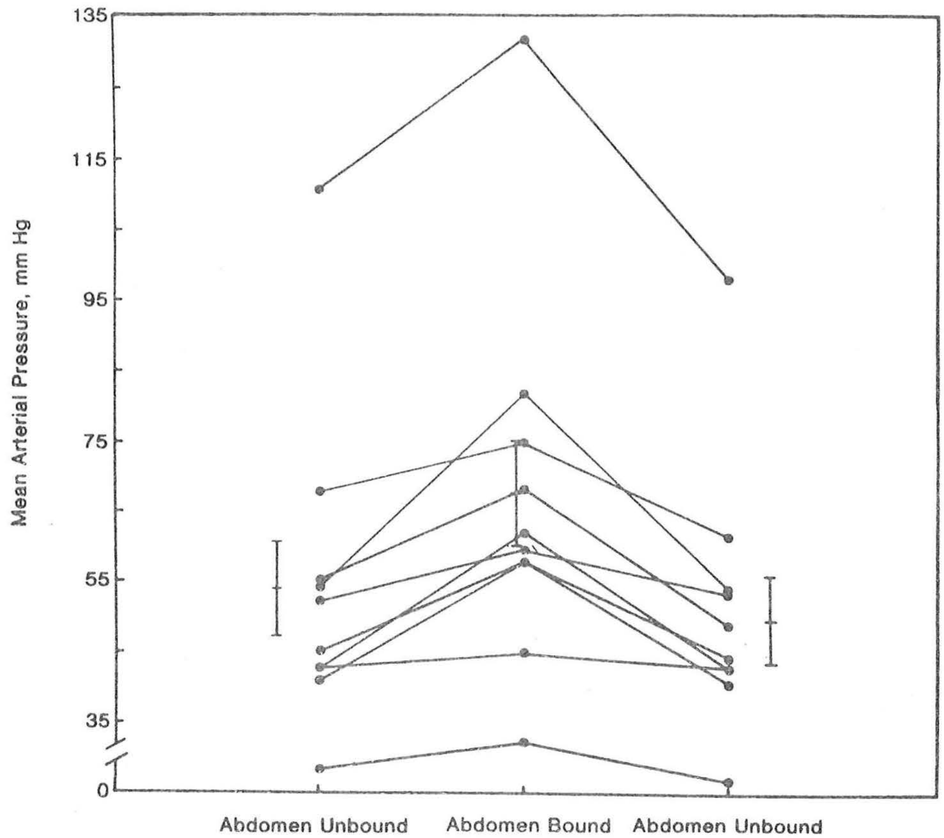

Figure 16. Change in mean arterial pressure with abdominal binding during cardiopulmonary resuscitation (CPR). Mean arterial pressure during CPR was 49.5±4.3 mmHg, increasing to 64.9±5.8 mmHg with abdominal binding (P<.001, n=15). There was no significant difference in pressure before and after abdominal binding.[102]

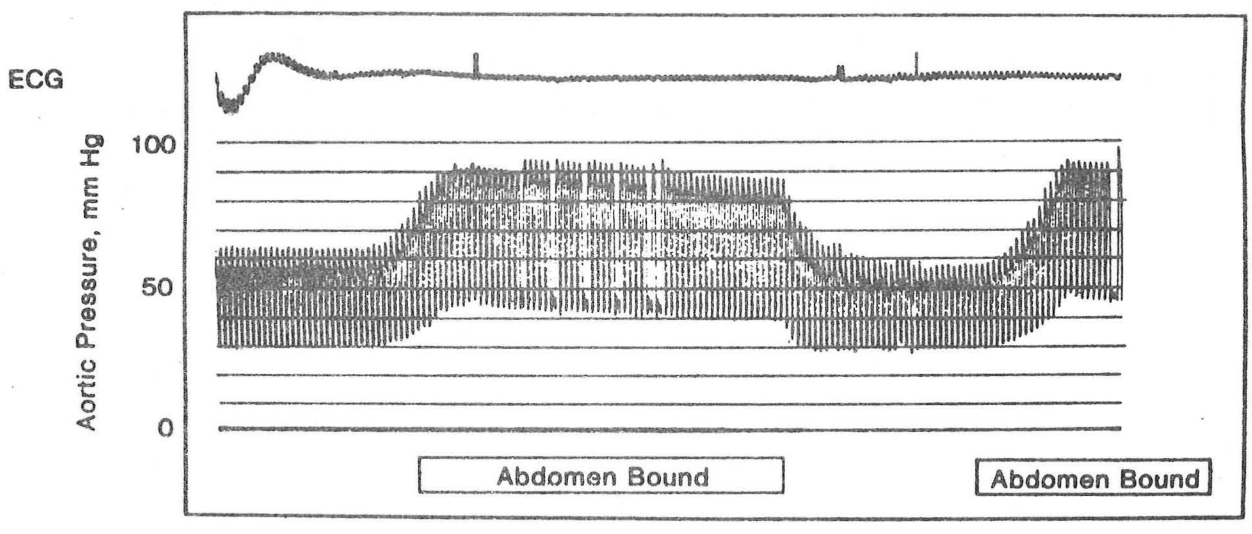

Figure 17. Effect of abdominal binding on aortic pressure during cardiopulmonary resuscitation (CPR). Patient had suffered a myocardial infarction with cardiogenic shock and arrested during cardiac catherization, with micromanometer catheter in descending thoracic aorta at time of arrest. Cardiopulmonary resuscitation was instituted and aortic pressure increased from 64/30 mmHg during CPR to 94/44 mmHg with addition of abdominal binding.[102]

Another way to increase intrathoracic pressure would be to simultaneously inflate the chest and perform cardiac compression. In Figure 18 is shown the results of simultaneous ventilation-compression in dogs by Weisfeldt et al.[105]

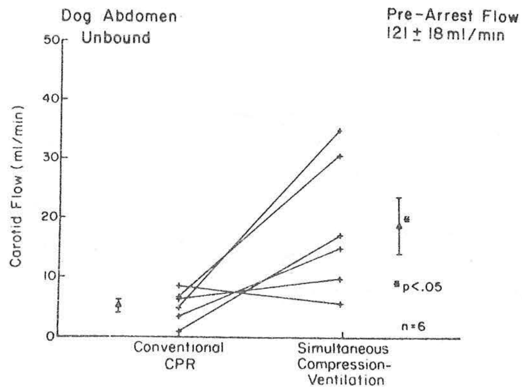

Figure 18. Net carotid blood flow toward the head during conventional cardiopulmonary resuscitation (CPR) and simultaneous compression-ventilation resuscitation at high airway pressures in six dogs. The abdomen of the animals was not bound. Flow increased from 5.1 ± 1.08 to 18.7 ± 4.7 ml/min with simultaneous compression-ventillation resuscitation, although flow in one dog was lower during this method because of carotid arterial collapse. Carotid arterial flow before cardiac arrest was 121.3 ± 18.4 ml/min in these dogs. Values in this and subsequent figures are mean values ± standard error of the mean.[105]

As can be seen simultaneous ventilation-compression greatly increases carotid flow in the majority of dogs, with only one dog showing a decline in flow. In Figure 19 are shown the results with abdominal binding combined with simultaneous compression-ventilation.

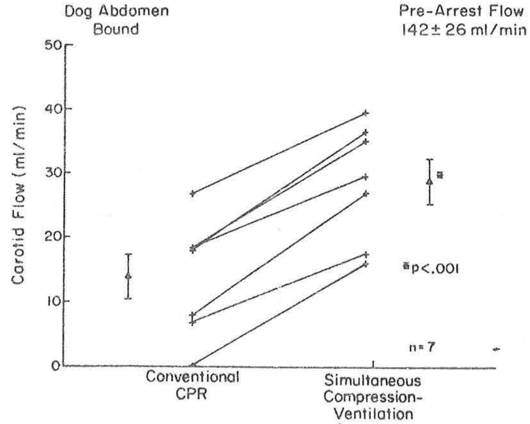

Figure 19. Net carotid blood flow toward the head during conventional cardiopulmonary resuscitation (CPR) and simultaneous compression-ventilation resuscitation at high airway pressure in seven dogs. The abdomen of the dogs was bound during both procedures. Flow increased from 13.8 ± 3.4 to 28.6 ± 3.5 ml/min ($p<0.001$) with simultaneous compression-ventilation resuscitation. Carotid arterial flow before cardiac arrest in these dogs was 142 ± 26 ml/min.[105]

When both abdominal binding and simultaneous compression-ventilation are combined there is further augmentation in carotid flow. Sample pressure tracings are shown in Figure 20.

Figure 20. Carotid flow, intrathoracic vascular pressures (right atrial and aortic), extrathoracic intravascular pressures (carotid arterial and jugular venous) and airway pressure during conventional cardiopulmonary resuscitation in the dog with the abdomen unbound. Net flow toward the head occurred only during the compression after ventilation (see airway pressure trace). During the compression after ventilation right atrial and aortic pressures are similar. Carotid arterial (A) pressure exceeds jugular venous pressure, resulting in anterograde flow. The net carotid arterial flow was 0.2 ml/min with conventional cardiopulmonary resuscitation with a flow value before cardiac arrest of 90.5 ml/min.[105]

When airway pressure is increased at the start of cardiac compression there is an immediate increase in carotid artery, aortic, and right atrial pressures and a marked increase in carotid flow. Sample tracings are shown in Figure 21 for continuous use of sulmultaneous compression-ventilation.

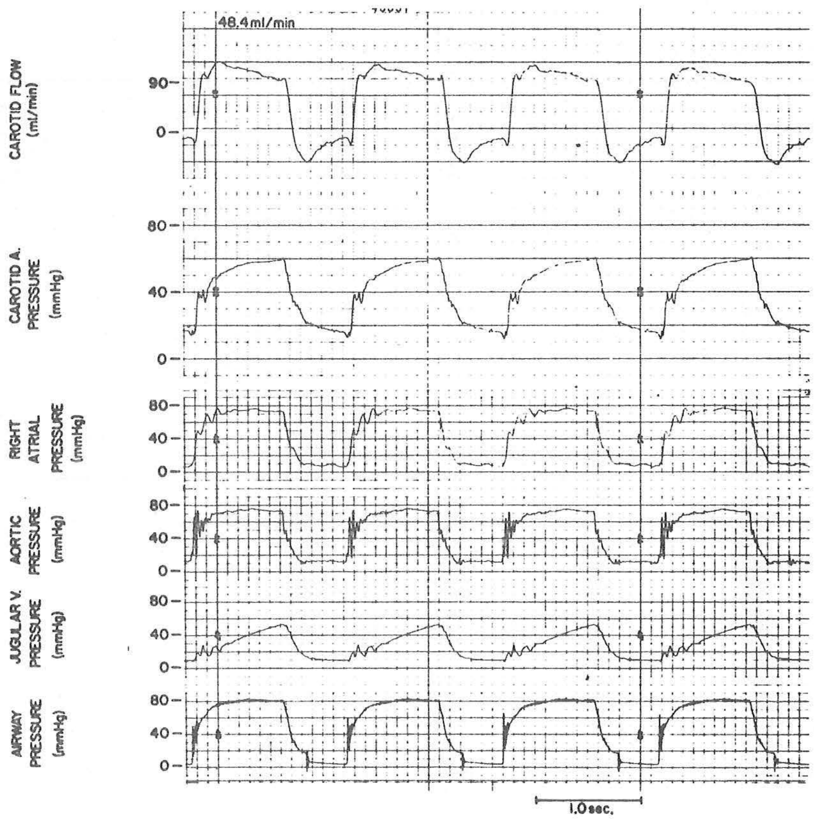

Figure 21. Carotid arterial flow and pressure from the same dog as in Figure 20 now with the abdomen bound during simultaneous compression and ventilation at high airway pressure (80 mmHg). Net anterograde carotid arterial blood flow is 48.8 ml/min (flow before cardiac arrest 90.5 ml/min). Forward flow occurs as airway pressure rises with simultaneous compression-ventilation resuscitation. Aortic and right atrial pressures during compression are again similar to airway pressure. Peak carotid pressure is 18 mmHg less than aortic pressure but greater than jugular venous pressure.[105]

Note the very high flows, more than 50% of normal, that are generated by simultaneous compression-ventilation. As is shown right atrial and aortic pressures are identical; however, jugular venous pressure starts out low and slowly increases while compression is being held, showing that a valving effect is seen in the jugular venous system.

Hence simultaneous compression-ventilation can greatly augment carotid blood flow and therefore might be beneficial. However it remains to be seen whether this method can increase survival. It may be that a lower flow may be all that is needed to keep the brain alive and the additional flow will not increase survival; this is highly speculative and remains to be proven. To perform simultaneous compression-ventilation requires endotracheal intubation so that gastric distention does not occur. In addition the synchronization of compression and ventilation is critical and can only be performed on a mechanical resuscitator. These studies raise fascinating questions but are not ready to be used clinically at the present time.

The flow in the inferior vera cava is very low with preferential flow going to the brachiocephalic trunk.[81-85] Flow to kidneys and heart are essentially zero during CPR even with augmentation.[81 105] As there is virtually no flow in the inferior vena cava drugs given from the femoral or leg may not reach the central circulation. Drugs given into the high SVC appear to be delivered to the central circulation the quickest. A central line placed in the right atrium may well jet into the IVC and not get into the central circulation quickly.

Epinephrine

Epinephrine is the most important drug for use in resuscitation. The beneficial effects of epinephrine in resuscitation has been described since 1896.[106 107] As early as 1906 Crile and Dolley[108] described the importance of keeping diastolic pressure above 30 and preferably above 40 mmHg. This requires vasoconstriction. Though the chronotropic and inotropic effects of the catecholamines are felt to be very important, it is the vasoconstrictive properties which are more important. Chest compression alone is not able to maintain a diastolic pressure above 30 mmHg without the administration of epinephrine. Many investigators over the last 80 years have pointed out the necessity of vasoconstriction. With vasoconstriction there is a transient decrease in perfusion to most of the body, but a substantial increase in diastolic pressure.[109 110] As the miniscule blood flow to the heart itself during CPR is probably important, the increase in diastolic pressure is probably essential to getting any oxygenation to the myocardium. The importance of the vasoconstrictive properties of epinephrine was recently pointed out in a nice animal study using blocking agents.[111] In these animal models, when alpha adrenergic blocking agents were used with epinephrine the resuscitation failed; while when beta adrenergic agents were used with epinephrine, the resuscitation efforts were uniformly successful. This study nicely points out that it is the vasoconstrictive properties that are most important. Drugs whose main action is inotropic and/or chronotropic such as isoproterenol, dobutamine, or calcium salts have been shown to be useless and may be harmful.[109-116] Alpha receptor agonists, such as phenlyephine or methoxamine have been shown to be as effective as epinephrine in successful resuscitation.[109-117] A recent study comparing dopamine to epinephrine suggests that it may be as effective as epinephrine.[113] In this study 1 mg epinephrine, 40 mg dopamine, and 50 mg dobutamine given IV bolus were compared in arrested dogs. The results are shown in Table VIII.

Table VIII[113]

Resuscitation Results From Asphyxial and Fibrillatory Arrests

	Asphyxial Arrest		Fibrillatory Arrest	
	Number Successful	Number Attempts	Number Successful	Number Attempts
Dopamine	10	10	9	10
Dobutamine	2	10	2	10
Epinephrine	9	10	10	10
Control	0	10	3	10

As can be seen, dopamine appeared to be as good as epinephrine in resuscitation. It should be noted that this dose of dopamine has a marked vasoconstrictive effect. However when the amount of energy required for cardiovert from fibrillation was compared, epinephrine seemed to be more effective than dopamine as shown in Table IX.

Table IX[113]

Success of Defibrillation After Initial Countershocks

	7 Joules/Kg		10 Joules/Kg	
	Number Dogs	Percent Success	Number Dogs	Percent Success
Dopamine	10	60	4	75
Dobutamine	10	40	7	71
Epinephrine	10	90	1	0
Control	10	40	7	85

Hence, epinephrine may be slightly more effective. Results of dopamine in other models or in man are not known. Therefore the drug of choice is clearly epinephrine.

The route of administration should be intravenous or if no IV line is available, down the endotracheal tube. Intracardiac administration should be avoided except as a last resort when no other routes are available.[107, 113] Other drugs may be given by endotracheal tube after 10 fold dilution include epinephrine, phenylephrine, methoxamine, atropine, lidocaine, naloxone hydrochloride, and diazepam.[107, 113]

Recommendation: Epinephrine 0.5-1 mg of 1:10,000 dilution should be given intravenously or endotracheally every five (5) minutes as long as the heart is arrested.

Sodium Bicarbonate

Sodium bicarbonate has been given in excessive doses during cardiac arrest for many years. As is widely known, anaerobic metabolism rapidly causes a metabolic acidosis after a cardiac arrest. It has been widely recommended that large, early doses of bicarbonate be given to reverse the harmful effects of acidosis. In experimental animals, the pressure effects of catecholamines are reduced by acidosis; and in calves the hypotension induced by infusion of hydrochloric acid was reversed by bicarbonate.[118-120] Experimentally the susceptibility of the heart to ventricular fibrillation with metabolic acidosis was reduced by bicarbonate.[107] However, more recent studies have raised questions. As a single drug, bicarbonate is ineffective in restoring cardiac contractility. Administration of bicarbonate failed to potentiate suboptimal doses of epinephrine, and epinephrine 1 mg was just as effective in severe acidosis as at optimum pH in resuscitating animals.[121]

Sodium bicarbonate does have many unwanted adverse effects such as hyperosmolar states, a leftward shift of the oxyhemoglobin dissoication curve with consequent impairment of tissue oxygenation, and failure to reverse rapidly the CSF acidosis causing a disequilibrium state.[122-124] With adequate CPR from the time of the arrest, acidosis may not occur for 5 - 10 minutes. If acidosis is suspected, then sodium bicarbonate may be given.

Recommendation: If profound acidosis is found on blood gases or is suspected, administer sodium bicarbonate 1 meq/Kg. Repeat doses should be determined by blood gases. If no blood gases are available, then 1/2 meq/Kg may be administered every 10 - 15 minutes with caution.

Calcium

Calcium is probably the most overused drug in cardiac arrest with the least evidence of efficacy. It is certainly used in far excessive doses. Calcium has long been known to increase the force of contraction.[125] Due to its role in myocardial excitation-contraction coupling,[126 127] it has been postulated to have a role in asystole.[128] However, there is virtually no experimental data to support that hypothesis.[129] Even low doses of calcium causes markedly elevated levels of serum calcium.[130 131] Five ml of 10% calcium chloride (1/2 ampule) given as an intravenous bolus during cardiac arrest raises the mean calcium to 15.3 ml/dl at five minutes (range 12.9 to 18.2 ml/dl) and 11.2 ml/dl at ten minutes.[130] Recently calcium antagonists have shown some ability to preserve brain functions;[132] hence, calcium may well be harmful. The only evidence of beneficial effects of calcium are in the setting of administration of large amounts of citrated blood and hyperkalemia.[107] In digitalized patients calcium administration is particularly hazardous.

Recommendation: Calcium should rarely be used. It may be of benefit after large amounts of citrated blood or in hyperkalemia. If calcium is used in asystole or EMD, 2 1/2 - 5 ml of $CaCl_2$ 10% should be given initially and repeated one time only at ten minutes. However, there is no evidence favoring its routine use.[107]

Bretylium

Bretylium tosylate has been shown to be effective in ventricular arrhythmias and in the prevention and treatment of ventricular fibrillation. It is particularly beneficial in ventricular arrhythmias resistant to lidocaine and procainamide. It has been shown to be as effective as lidocaine in preventing ventricular fibrillation.[133-135] It also has been shown to cause chemical cardioversion as well as to facilitate electrical cardioversion.[135-140]

Bretylium tosylate is a preganglionic blocker which functions with initial norepinephrine release followed by prevention of reaccumulation of norepinephine. The post ganglionic receptors are unaffected. Hence, early (the first 15 minutes) increased sympathetic tone is seen. This usually results in a 10-20 mmHg increase in blood pressure in people with an intact circulation and a 10-20 beat/minute increase in heart rate. After 15 minutes there is diminished sympathetic tone with a 10-20 beat/minute decrease in heart rate and a 5-15 mmHg decrease in blood pressure. There is peripheral vasodilation. The more important effects of bretylium tosylate are on the membrane. Like other antiarrhythmics, bretylium alters the fibrillation threshold so that it takes more current than normal to induce fibrillation, in spite of the fact that ischemia causes a detrimental change in fibrillation threshhold. In fact, bretylium causes more alterations in fibrillation threshhold than any other artiarrhythmic agent in common usage. Bretylium also has an antifibrillatory property that is poorly understood. The antifibrillatory effect begins within minutes, generally 10-15 minutes. The antifibrillatory effect persists in denervated hearts. the antifibrillatory effect persists in spite of catecholamine depletion. It also persists when the adrenergic blockade is reversed by tricyclics. Bretylium has been shown to be very effective in many studies at either chemically defibrillating the heart or improving the ability of electrical defibrillation to be successful. The only good comparative study was done by Leonard Cobb and associates in a randomized protocol and showed that bretylium was approximately equal to lidocaine in the ability to defibrillate the patient and in short term and long term survival.[133-140]

Finally, one paper deserves special comment because it is being widely quoted. Nowak et al reported in 1981 that bretylium given first in asystole, EMD, or ventricular fibrillation increased survival. The protocol basically was that bretylium or placebo in a double blind manner was given as the patient arrived in the emergency room. No previous drugs had been given. In Table X are shown the distribution of rhythms prior to the administration of bretylium or placebo.

Table X[141]

Initial Rhythms in Bretylium and Saline Groups*

Initial Rhythm	Bretylium (%)	Saline (%)
VF	18 (62)	11 (39)
AS	5 (17)	5 (18)
EMD	3 (10)	7 (25)
PIVR	3 (10)	5 (18)

* All P > 0.05, Fisher Exact test (two-tailed)

VF = Ventricular Fibrillation
AS = Asystole
EMD = Electrical Mechanical Dissociation
PIVR = Pulseless Idioventricular Rhythm

As can be seen, the bretylium group is loaded with patients more likely to be resuscitated (ventricular fibrillation 62% bretylium vs 39% in placebo). The placebo group was loaded with patients least likely to be resuscitated (EMD and PIVR 43% placebo vs 20% bretylium). The authors make the point that these differences are not statistically significant. While the distribution is not statistically significant due to small numbers, it is very medically significant; from previous work you would expect the survival to be twice as high in the bretylium group just due to patient distribution. In Table XI are shown the survival statistics.

Table XI[141]

Outcome of Resuscitation in Bretylium and Saline Groups

	Bretylium		Saline		
Presenting Rhythm	Number Patients	Survival (%)	Number Patients	Survival (%)	Significance*
All Patients	29	9 (28)	28	2 (11)	P < 0.1
VF or AS	23	8 (35)	16	1 (6)	P < 0.05
VF	18	7 (39)	11	1 (9)	P < 0.13

* Computed using the Fisher Exact test (one-tailed). Results using the two-tailed Fisher Exact test: All patients - P < 0.18; VF or AS - P < 0.056; VF - P < 0.2.

It is interesting to note that survival was not statistically significant for all the patients or any single subset. However, when two subsets are combined, ventricular fibrilation or asystole, statistical significance is reached. This is a bizarre perversion of statistical analysis which has no medical validity. To further compound the problem, those items known to improve survival in arrested patients, i.e. lidocaine, epinephrine, and defibrillation, were used in a greater number of cases with bretylium. In the placebo group more patients received isoproterenol, which has been shown to decrease survival (Table XII).

Table XII[141]

Other Resuscitative Maneuvers Used In
Bretylium and Saline Groups

Drug or Defib	Bretylium (%)	Saline (%)	Significance*
Lidocaine	15 (52)	8 (29)	$P < 0.07$
Epinephrine	28 (97)	26 (93)	NS
Dopamine	16 (55)	19 (68)	NS
Isoproterenol	3 (10)	7 (25)	$P < 0.13$
No. Patients Defib	22 (76)	20 (71)	NS
Avg. No. Shocks/ Patient	4.0 ± 0.7	3.3 ± 0.4	NS

* Computed using Fisher Exact text (one-tailed).

Hence, this paper is fatally flawed and should not be considered. A larger study is needed to prove or disprove this point.

It should be pointed out that bretylium is a preganglionic blocker. Hence orthostatic hypotension is the rule and supine hypotension may occur. Epinephrine must be given with bretylium to maintain the diastolic pressure at 30-40 mmHg.

Recommendation: Bretylium is often effective in the control of ventricular fibrillation. It should be attempted after initial attempts at defibrillation, epinephrine administration, and probably lidocaine administration. The initial dose of bretylium is 5 mg/Kg with a 10 mg/Kg repeat in 10-15 minutes.

Sample protocols from the American Heart Association are shown on the next few pages. I have attached an appendix which is exerpted from the *Basic Life Support for Physicians* text, by permission, if you wish to review the techniques for basic life support.

American Heart Association
ADVANCED CARDIAC LIFE SUPPORT

ALGORITHMS FOR CARDIAC DYSRHYTHMIAS -- ADULT

Unmonitored Ventricular Fibrillation

Recognition: unresponsive, apneic, pulseless
↓
Call for help; initiate CPR
↓
ECG monitor available
↓
Ventricular fibrillation — No → to Asystole or Electromechanical Dissociation Algorithm
Yes
↓
Defibrillate 200 to 300 joules delivered energy
↓
Check pulse
↓
Change in rhythm? — Yes → to appropriate algorithm
No
↓
Recharge defibrillator immediately 200 to 300 joules and defibrillate
↓
Check pulse
↓
Change in rhythm? — Yes → to appropriate algorithm
No
↓
Continue CPR; place IV line; intubate trachea if necessary
↓
Epinephrine 0.5 to 1.0 mg IV or intratracheal
+
Sodium bicarbonate 1 mEq/kg (75 mEq initial dose -- average-size adult)
or, preferably, according to ABGs
↓
† Defibrillate 360 joules delivered energy (maximal output)
↓
Check pulse
↓
Change in rhythm? — Yes → to appropriate algorithm
No
↓
CPR
↓
Defibrillate 360 joules delivered energy
↓
Check pulse
↓
Change in rhythm? — Yes → to appropriate algorithm
No
↓
CPR

or ← Lidocaine 50 to 100 mg ↓ after CPR for 2 minutes ↓ Defibrillate 360 joules

or → Procainamide 500 to 1000 mg ↓ after CPR for 2 minutes ↓ Defibrillate 360 joules

or ↓
Bretylium 350 to 500 mg or 5 mg/kg IV bolus
↓
after CPR for two minutes
↓
Defibrillate 360 joules of delivered energy
↓
Check pulse
↓
Change in rhythm? — Yes → to appropriate algorithm
No
↓
CPR
↓
Bretylium 700 to 1,000 mg or 10 mg/kg IV bolus
↓
CPR; sodium bicarbonate IV according to ABGs or one-half original
dose if no ABGs available (if 10 minutes have elapsed)
↓
Defibrillate 360 joules delivered energy
↓
Check pulse
↓
Change in rhythm? — Yes → to appropriate algorithm
No
↓
CPR
↓
Repeat epinephrine 0.5 to 1.0 mg IV every five minutes and bicarbonate at
one-half dose or according to ABGs
and/or
Repeat bretylium 10 mg/kg IV bolus every 15 minutes

† Reference point for Monitored Ventricular Fibrillation Algorithm

ALGORITHMS FOR CARDIAC DYSRHYTHMIAS -- ADULT

Monitored Ventricular Fibrillation

Monitored Arrest

Ventricular fibrillation? —— No → to appropriate algorithm

↓ Yes

Establish unresponsiveness and pulselessness

↓

Call for help; precordial thump

↓

Check pulse

↓

Change in rhythm? —— Yes → to appropriate algorithm

↓ No

Defibrillate 200 to 300 joules delivered energy

↓

Check pulse

↓

Change in rhythm? —— Yes → to appropriate algorithm

↓ No

Recharge defibrillator immediately 200 to 300 joules delivered energy and defibrillate

↓

Check pulse

↓

Change in rhythm? —— Yes → to appropriate algorithm

↓ No

CPR, place IV line, and intubate trachea if necessary

+

Epinephrine 0.5 to 1.0 mg IV or intratracheal + ? bicarbonate IV

↓

To † in Unmonitored Ventricular Fibrillation Algorithm

American Heart Association
ADVANCED CARDIAC LIFE SUPPORT

ALGORITHMS FOR CARDIAC DYSRHYTHMIAS -- ADULT

Asystole*

CPR

↓

Intubate, ventilate, establish IV if necessary

↓

Epinephrine 0.5 to 1.0 mg IV or intratracheal
Repeat at five-minute intervals as needed

↓

Sodium bicarbonate 1 mEq/kg (or 75 mEq IV as initial dose average-size adult); repeat at ten-minute intervals at one-half original dose or, preferably, according to ABGs

|

CPR

↓

Atropine 1.0 mg IV

|

CPR

↓

Check pulse

↓

Change in rhythm? —— Yes → to appropriate algorithm

|

No

↓

CPR

↓

Calcium chloride 10% solution 5 mL IV; repeat every ten minutes as needed ???

|

CPR

↓

Check pulse

↓

Change in rhythm? —— Yes → to appropriate algorithm

|

No

↓

CPR

↓

Repeat epinephrine IV, bicarbonate IV, calcium chloride IV as above

↓

Consider isoproterenol infusion 2 to 20 μg/min

|

CPR

↓

Check pulse

↓

Change in rhythm? —— Yes → to appropriate algorithm

|

No

↓

Repeat epinephrine IV, bicarbonate IV, calcium chloride IV as above

↓

Consider pacemaker

*If patient is hypothermic, core temperature should be normalized.

Be aware that what appears to be asystole may be fine ventricular fibrillation and could respond to countershock.

American Heart Association
ADVANCED CARDIAC LIFE SUPPORT

ALGORITHMS FOR CARDIAC DYSRHYTHMIAS -- ADULT

Electromechanical Dissociation

Consider hypovolemia, cardiac tamponade, rupture, or tension pneumothorax as cause. Reassess ventilation, oxygenation.

CPR

↓

Epinephrine 0.5 to 1.0 mg IV or intratracheal
Repeat at five-minute intervals as necessary

↓

Sodium bicarbonate 1 mEq/kg (or 75 mL IV initial dose average-size adult)
Repeat at ten-minute intervals at one-half original dose or, preferably, according to ABGs

↓

Change in rhythm
and/or return of pulse? — Yes → to appropriate algorithm

No

↓

CPR

↓

Calcium chloride 10% solution 5 mL
Repeat at ten-minute intervals as needed ???

↓

Change in rhythm
and/or return of pulse? — Yes → to appropriate algorithm

No

↓

CPR

↓

Repeat epinephrine IV, bicarbonate IV, calcium chloride IV as above

↓

Isoproterenol infusion 2 to 20 µg/min
(Despite presence of rhythm, continue CPR if no palpable pulse present)
Consider trial of volume infusion

American Heart Association
ADVANCED CARDIAC LIFE SUPPORT

ALGORITHMS FOR CARDIAC DYSRHYTHMIAS -- ADULT

Ventricular Tachycardia

Patient with pulse → No → (Precordial thump and immediate countershock if monitored) → CPR → Countershock 200 joules delivered energy -- otherwise same as for ventricular fibrillation

Patient with pulse → Yes → Conscious

Conscious → Yes:
- Precordial thump
- Check pulse
- Change in rhythm? — Yes → to appropriate algorithm
- No → Lidocaine 100 mg IV (or 1 mg/kg)*
- Check pulse
- Reversion to normal rhythm? — Yes → lidocaine infusion 2 to 4 mg/min*
- No → Cardioversion 20 to 100 joules delivered energy
- Check pulse
- Reversion to normal rhythm? — Yes → lidocaine infusion 2 to 4 mg/min*
- No → Algorithm below

Conscious → No:
- Precordial thump
- Check pulse
- Change in rhythm? — Yes → to appropriate algorithm
- No → Lidocaine 100 mg IV bolus (or 1 mg/kg)* + Cardioversion 200 joules delivered energy
- Check pulse
- Reversion to normal rhythm? — Yes → lidocaine infusion 2 to 4 mg/min*
- No → Bretylium 350 to 500 mg IV or 5 mg/kg over eight- to ten-minute period
- Check pulse
- Reversion to normal rhythm? — Yes → lidocaine infusion 2 to 4 mg/min*
- No → Cardioversion 200 joules delivered energy
- Check pulse
- Reversion to normal rhythm? — Yes → lidocaine infusion 2 to 4 mg/min*
- No → Algorithm below

*A second loading dose of 0.5 mg/kg should be given in 5 to 10 minutes.

Recurrent Ventricular Tachycardia
(after maximum lidocaine infusion)

Procainamide 20 mg/min IV - up to 100 mg/5 min until --
- dysrhythmia suppressed
- or hypotension ensues
- or QRS widens by 50%
- or total of 1 g administered

Follow with infusion of procainamide 1 to 4 mg/min
- Check pulse
- Reversion to normal rhythm? — Yes → Continue procainamide 1 to 4 mg/min
- No → Bretylium
- Overdrive pacing

or

Bretylium 5 mg/kg IV bolus followed by infusion -- 1 to 2 mg/min
- Check pulse
- Reversion to normal rhythm? — Yes → continue bretylium infusion 1 to 2 mg/min
- No → Bretylium 10 mg/kg IV bolus. May repeat if needed
- Overdrive pacing

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Prevention of Cardiac Arrest

As important as it is to provide emergency treatment for the cardiac arrest victim, it is equally important for us to remain aware that, however effective and idealized emergency cardiac care for the prehospital cardiac arrest victim can become, prevention of cardiac arrest is a far more desirable approach. A shift in the burden of responsibility to the layperson very likely will prove an essential element in effective coronary heart disease mortality reduction. Control of recognized risk factors is very much dependent upon the willingness of the public to accept the responsibility and consequences of its behavior. Part of this acceptance may depend upon the amount and kind of exposure to risk factor information and the extent to which the layperson can be brought to appreciate the personal relevance of risk factor change. Evidence now exists that community-wide campaigns can be effective in reducing cardiovascular risks.[83]

In addition educational efforts should be directed toward overcoming patients' intrinsic denial of early evidence of cardiac disease as well as encouraging rapid entrance into the emergency care system when symptoms of coronary heart disease develop.

Technical Aspects of Cardiopulmonary Resuscitation Performance

Introduction

To achieve the outstanding results obtained in the Sweden and Seattle studies,[78,79] every person in the emergency medical system should use the same techniques. In order to transfer patients from one level of care to the next, ie, from layperson bystander to paramedic to physician, each rescuer needs to know the same basic CPR techniques. The AHA has developed performance standards that minimize the probability of injury and maximize the probability of favorable outcome. Participants of national conferences held in 1966, 1973, and 1979 examined data and scientific studies relating to ECC. Results of the conferences were published as "standards" representing the best judgment of experts in the field of resuscitation.[84,85] It matters not *who* is performing CPR but *how* it is performed; therefore, everyone who performs CPR, including physicians, should be performing according to the same standards.

One-Person CPR

Summary of Steps

1. Establish unresponsiveness (tap or gently shake and shout).
2. Call out for help.
3. Position the patient.

Then proceed with the ABCs of CPR:

4. **A**irway
   a. Open the airway
   b. Establish apnea (look, listen, feel)
5. **B**reathing
   a. Perform rescue breathing (mouth-to-mouth)
   b. Manage foreign-body airway obstruction if present
6. **C**irculation
   a. Establish presence or absence of pulse
   b. Activate EMS system
   c. Begin chest compression (if pulse absent)

Establish Unresponsiveness

Establish a diagnosis of unconsciousness by gently shaking and shouting — "Are you OK?" This initial step may prevent unnecessary and potentially harmful resuscitation maneuvers.

Call Out for Help

If the patient does not respond to arousal attempts, call out for help from bystanders. (Even if no one is in sight, call out in the hope that someone will hear.)

Position Patient

If the patient is prone prior to beginning CPR, he must be placed in a supine position. Assessment of possible trauma must be made and precautions taken for suspected neck or spinal injury. The patient must be turned as a unit so that the head, shoulder, and torso move simultaneously with no twisting. Kneel beside the patient, place the hands to support the neck, and roll the patient toward the rescuer. This can be accomplished by raising the patient's arm nearest the rescuer and straightening it out above the head. Adjust the legs to nearly straight or bent only slightly at the knees. Place one hand on the back of the patient's head and neck to prevent twisting. With the second hand, grasp the patient under the other arm to brace the shoulder and torso. This is the major point where pull will be exerted to roll the body. Pull steadily and evenly to move the weight without twisting the body.

A. Airway obstruction caused by tongue.

B. Airway obstruction caused by tongue relieved by head tilt.

Fig 7. — Airway obstruction and relief.

Open Airway

The most important action for successful resuscitation is immediate opening of the airway. The tongue is the most common cause of airway obstruction in the unconscious victim (Fig 7A). Since the tongue is attached to the mandible, moving the mandible forward will lift the tongue away from the posterior pharynx opening the airway. As long as there is enough tone in the muscles attached to the mandible, tilting the head back will cause the mandible to move forward opening the airway (Fig 7B). In the absence of sufficient muscle tone, head tilt alone may be insufficient to open the airway, and a technique that will move the mandible forward will be necessary. In addition to passive obstruction by the tongue, another important mechanism of airway obstruction by the tongue is the negative pressure created in the airway during inspiration. The tongue in an unconscious person making inspiratory effort and creating negative airway pressure may act as a valve and occlude the airway. Even though the head is tilted back and the neck extended, the mandible may need support to adequately lift the tongue and provide an open airway. Head tilt combined with neck lift has been the principal method taught to open the airway. Head tilt with chin lift has been used successfully in place of neck lift and has significant advantages.[86,87]

Head Tilt. — Head tilt is the initial and most important step in opening the airway and is augmented by either chin lift or neck lift.[88-92] Head tilt is accomplished by placing the hand on the patient's forehead and applying firm, backward pressure with the palm resulting in tipping the head maximally backward. Since optimal and effective head tilt may be difficult to obtain using one hand on the forehead, additional assistance is gained by use of either chin lift or neck lift.

Fig 8. — Head tilt-neck lift maneuver.

Head Tilt-Neck Lift. — The rescuer places one hand on the forehead to apply backward pressure and the other hand beneath the neck to lift and support it upward (Fig 8). Excess force in performing this maneuver may cause cervical spine injury. Since the specific movement used is extension of the head at the junction of the cervical spine rather than hyperextension of the cervical vertebrae, the hand lifting the neck should be placed close to the occiput to minimize cervical spine extension. Emphasis should be placed on the need for gentleness when lifting the neck. If loose dentures are a problem, they may be managed with head tilt-chin lift or may be removed. The fact that layperson-initiated CPR employing neck lift may be associated with a survival rate as high as 61% in selected subgroups attests to the efficacy of head tilt-neck lift.[93]

Fig 9. — Head tilt - chin lift maneuver.

Head Tilt-Chin Lift.[94-96] — Evidence was offered as early as 1960 that head tilt-chin lift offered a greater opening of the airway than head tilt-neck lift (Fig 9).[96] It has been demonstrated in the unconscious, apneic patient that a greater airway opening can be achieved by chin lift when compared with head tilt-neck lift. In the unconscious patient making spontaneous respiratory effort, chin lift combined with head tilt is highly effective in opening the airway when used initially. In addition evidence has been offered suggesting that head tilt-chin lift may open the airway in some persons in whom head tilt-neck lift was not successful.[86] Support of the mandible may be accomplished by lifting the chin. The tips of the fingers of one hand are placed under the mandible near the chin bringing the mandible forward in a supporting fashion helping to tilt the head back. The fingers must not compress the soft tissues of the neck possibly creating airway obstruction. The other hand continues to press on the patient's forehead to tilt the head back. The mandible should be lifted so the teeth are brought nearly together, but the rescuer should avoid closing the mouth completely. The thumb is rarely used when lifting the mandible and then only to slightly depress the lower lip so that the mouth will remain open. If the patient has loose dentures, this technique may hold them in position making obstruction by the lips less likely. If rescue breathing is needed, the mouth-to-mouth seal is easier when dentures are in place. If dentures cannot be managed in place, they should be removed.

Jaw Thrust. — Additional forward displacement of the mandible may be required. It can be accomplished by the jaw-thrust maneuver (Fig 10). The rescuer grasps the angles of the mandible and lifts with both hands, one on each side, displacing the mandible forward while tilting the head backward. The rescuer's elbows should rest on the surface on which the patient is lying. If mouth-to-mouth breathing is necessary, close the nostrils by placing the cheek tightly against them.

Figure 10. — Jaw thrust maneuver.

The jaw-thrust technique is the safest first approach to opening the airway of a patient who has a suspected neck injury because it usually can be accomplished without extending the neck. The head can be carefully supported without tilting backward or turning from side to side. If this is unsuccessful, the head should be tilted back very slightly and another attempt made to ventilate.

In a study published in 1976[86], the effectiveness of the three techniques (head tilt combined with neck lift, chin lift, and jaw thrust) was compared. Results suggested that the chin lift technique consistently provided the most adequate airway. Two points are of particular note in the study: (1) The head tilt-chin lift technique consistently provided a more effective method of opening the airway in the unconscious apneic patient and in the unconscious patient making spontaneous respiratory efforts. (2) Both neck lift and jaw thrust were consistently more tiring than chin lift-head tilt.

Loose dentures pose a serious problem in mouth-to-mouth rescue breathing. They frequently become loose and produce a worsening airway obstruction problem when mouth-to-mouth contact is made for rescue breathing using the head tilt-neck lift technique. However, head tilt-chin lift supports the lower jaw bringing the teeth almost to occlusion making a mouth-to-mouth seal much easier and more effective.

Establish Apnea

While maintaining the open airway position, the rescuer assesses respiratory activity and air exchange by placing his ear over the mouth and nose while looking toward the patient's chest and abdomen. Opening the airway may relieve obstruction and result in resumption of breathing. Airway maintenance as well as monitoring of vital signs may be all that is required. If apnea is present, ventilation (rescue breathing) must be instituted as the second important aspect of the ABCs of CPR.

Rescue Breathing

With the thumb and index finger of the same hand maintaining head tilt for the patient, the rescuer gently pinches the nostrils closed. The rescuer takes a deep breath, opens his mouth very wide, and places it around the outside of the patient's mouth to create an airtight seal. Air is blown into the patient's mouth while assessing chest expansion (Fig 11).

Fig 11. — Rescue breathing using head tilt-chin lift maneuver.

Four quick, full breaths are given initially without allowing time for complete lung deflation between breaths. After delivering each breath, the rescuer quickly turns his head toward the patient's chest to take a breath. Throughout the time of giving four breaths, positive pressure is maintained in the airway. This technique theoretically helps restore functional residual capacity.

Tidal volume for rescue breathing should not exceed 2 L. Volumes in excess of this amount are likely to be associated with pharyngeal pressure exceeding the esophageal opening pressure and can result in gastric distention. Ventilation should be limited to that required for chest expansion.

In most adults a minimum tidal volume of approximately 800 cc should be used; an adequate ventilation does not need to exceed 1200 cc. A ventilation volume below 800 cc is probably inadequate.

Establish Pulselessness

Diagnosis of cardiac arrest is confirmed by finding no palpable pulse. The carotid pulse is the most accessible, most reliable, and most easily learned position. Use of the femoral arterial pulse is equally satisfactory especially for the hospitalized patient.

While the rescuer kneels at the patient's side with one hand on the forehead to maintain head position, the other hand is used to palpate the carotid pulse. The pulse should be palpated on the side of the neck nearest the rescuer at the level of the thyroid cartilage.

Five to ten seconds should be used to assess the pulse and diagnose the patient's condition. Performing CPR on a patient who has a pulse may result in medical complications and medicolegal problems. If a pulse is present but there is no breathing, rescue breathing should be initiated at a rate of 12 times per minute. If no pulse is palpated, the diagnosis of cardiac arrest is confirmed, the emergency medical service (EMS) system should be activated, and external chest compression should be begun.

Activate EMS System

If the rescuer is not alone, one person should call the emergency telephone number to activate the EMS system. The shorter the time interval between cardiac arrest and initiation of BLS and ACLS, the greater the likelihood of survival of the cardiac arrest victim. If the rescuer is alone, CPR should be performed for approximately one minute and then, if a telephone is immediately available, help summoned. If no telephone is available, the only option is for the rescuer to continue CPR.

Fig 12. — External chest compression: locating costal margin.

External Chest Compression

The patient must always be in the supine position when external chest compression is performed. The upright position during cardiac arrest, even during properly performed external chest compression, results in inadequate cerebral blood flow.

Proper Hand Placement. — Hand position is established by the following guidelines:

1. With the middle and index fingers of the hand nearest the patient's feet, the rescuer locates the lower margin of the rib cage on the side next to the rescuer (Fig 12).

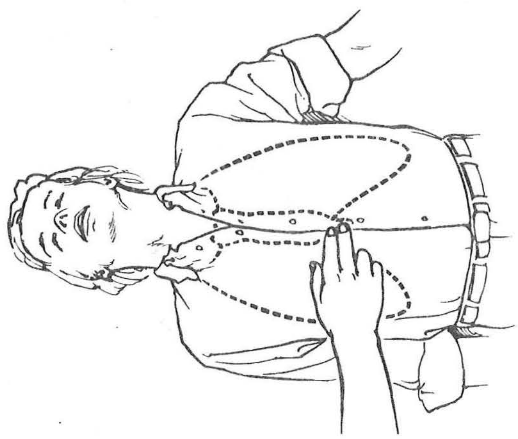

Fig 13. — External chest compression: locating xiphoid process.

2. The fingers are then run up the rib cage to the xiphoid process.
3. With the middle finger on the xiphoid process, the index finger is placed next to the middle finger on the lower sternum (Fig 13).

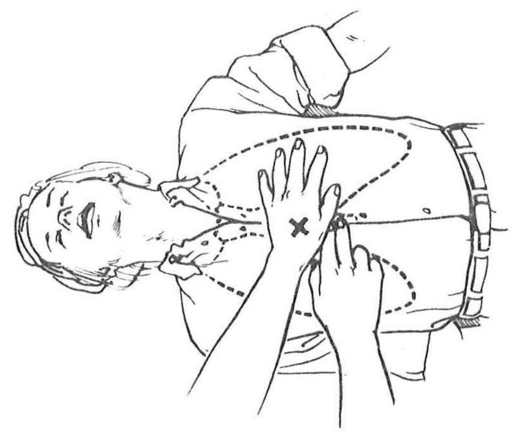

Fig 14. — External chest compression: locating correct hand position on lower half of sternum.

4. The heel of the hand nearest the patient's head is placed on the lower half of the sternum next to the index finger. The long axis of the heel of the hand should be placed on the long axis of the sternum to keep the main line of compression force on the sternum and decrease the chance of rib fracture (Fig 14).
5. The hand used to locate the xiphoid process is then placed on top of the chest (Fig 15).
6. The fingers may be either extended or interlaced but must be kept off the chest.
7. An alternate acceptable hand position for rescuers with arthritic problems of the hand and wrist is to grasp the wrist of the hand on the chest with the hand which located the lower end of the sternum.

Proper Compression Techniques. — Effective compression is accomplished by attention to the following guidelines:

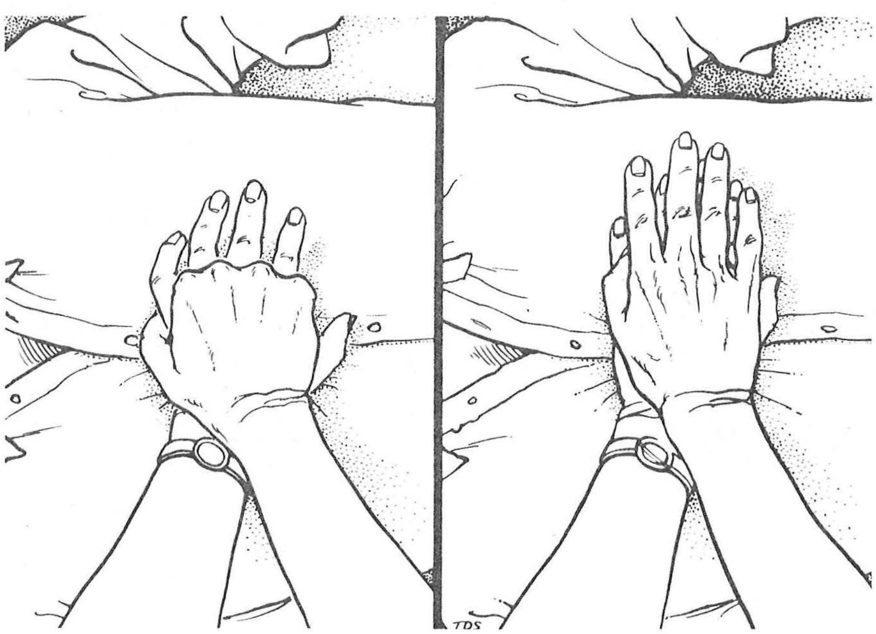

Fig 15. — External chest compression: correct hand position on lower half of sternum with fingers either interlaced or extended.

Fig 16. — External chest compression: rescuer's shoulders directly over patient's sternum with elbows locked.

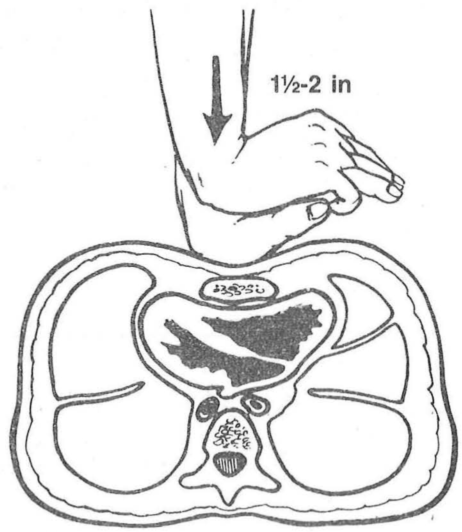

Fig 17. — External chest compression: sternum is compressed to depth of 1½ to 2 in (3.8 to 5.0 cm).

1. The elbows are locked, the arms are straightened, and the shoulders of the rescuer are positioned directly over the hands so that the thrust for external chest compression is straight down on the sternum. If the thrust is other than straight down, the torso has a tendency to roll, part of the force is lost, and chest compression may be less effective (Fig 16).
2. To achieve the most pressure with the least effort, the rescuer leans forward until the shoulders are directly over the outstretched hands (that is, leaning forward until the body reaches natural imbalance — a point at which there would be a sensation of falling forward if the hands and arms were not providing support). The weight of the rescuer's back creates the necessary pressure making compressions easier on the arms and shoulders. Natural body weight falling forward provides the force to depress the sternum.

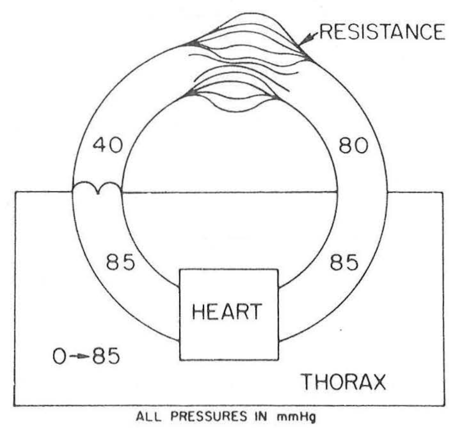

Fig 18. — Effect of increasing intrathoracic pressure on extrathoracic vessels. (Reproduced, by permission, from the *Annual Review of Medicine,* vol 32, p 437. © 1981 by Annual Reviews Inc.)

3. The sternum must be depressed 1½ to 2 in (3.8 to 5.0 cm) for the normal-size adult (Fig

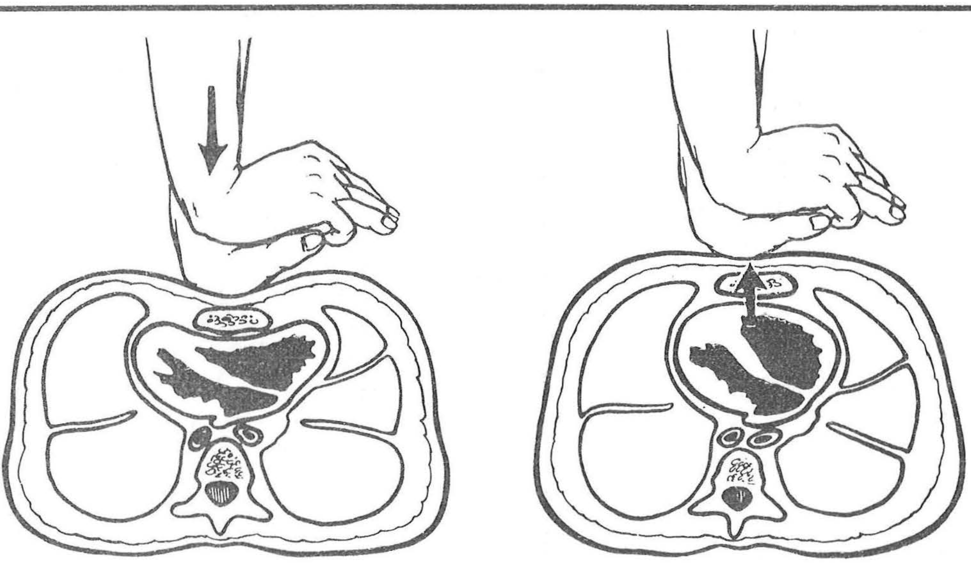

Fig 19. — External chest compression: compression-relaxation duration must be 50:50 for effective flow to occur.

17). External chest compression is effective in providing cerebral and systemic circulation as a result of a generalized increase in intrathoracic pressure. This pressure is transmitted into the extrathoracic arteries to a greater extent than the veins, creating a pressure gradient and, therefore, systemic blood flow[97] (Fig 18). The factors contributing to the arterial venous pressure gradient include (a) a venous valving mechanism, (b) the peripheral venous capacitance being greater than arterial capacitance, and (c) arterial resistance to collapse being greater than venous resistance to collapse.
4. The external chest compression pressure must be released to allow blood to flow into the heart. The pressure must be released completely and the chest allowed to return to normal position after each compression. The time allowed for release should equal the time required for compression. Do not pause between compressions (Fig 19).
5. The hands should not be lifted from the chest or the position changed in any way or correct hand position may be lost. Bouncing compressions are less effective, more likely to cause injury, and must be avoided.
6. Artificial circulation is not as effective as normal circulation; it generates only about 30% of normal cardiac output. With each compression adequate blood flow must be maintained, then the pressure released to allow the heart to refill. Any interruption in compression results in a drop in blood flow to zero.

Proper Sequencing of Steps in One-Person CPR (Fig 20)

1. Perform 15 chest compressions at a rate of 80 per minute. Count "one and two and three and four and five and six and seven and eight and nine and ten and eleven and twelve and thirteen and fourteen and fifteen." Alternate methods of counting are acceptable as long as 15 compressions are achieved within the optimal 11 seconds.
2. Move to the head, open the airway, and deliver two rescue breaths in five seconds.
3. Move back to the chest, locate proper hand position, and begin 15 more compressions at a rate of 80 per minute.
4. Repeat the above cycle.
5. After four cycles (approximately one minute) assess respirations and check the carotid pulse.
6. If breathing and pulse are still absent, give two quick breaths and resume single-person CPR.
7. If single-person CPR is continued, stop and check for return of spontaneous breathing and pulse every few minutes.

Fig 20. — One-person CPR. Fifteen compressions are alternated with two ventilations.

Two-Person CPR

Advantages

Since artificial circulation must always be combined with artificial ventilation, it is preferable to have two rescuers. One person positions himself at the patient's side and performs external chest compression while the other remains at the patient's head maintaining an open airway and ventilating the patient. The compression rate for two-person CPR is 60 per minute. When performed without interruptions, this rate can maintain adequate blood flow and pressure and will allow cardiac refilling. This rate is practical because it avoids fatigue, facilitates timing at a rate of one compression per second, and allows optimal ventilation and circulation by permitting the swift interposition of an inflation at the upstroke of each fifth compression without any pause in compressions (5:1 ratio). The rate of 60 compressions per minute allows breaths to be interposed without any pause.

Fig 21. — Two-person CPR: entry of second person. Check for effectiveness of compressions.

Fig 22. — Two-person CPR: external chest compression and ventilation during fifth upstroke.

Second-Rescuer Entry

When a second person becomes available, he should identify himself as a qualified rescuer who is willing to help. Without stopping CPR, the single rescuer lets the second rescuer know that he wants assistance and is ready to switch to two-person CPR. (A logical place in the sequence to begin the switch procedure is immediately after the first rescuer has completed a cycle of 15 compressions, two ventilations, and has resumed compressions.) The second rescuer will need to check the patient's pulse to assure that the first rescuer has correctly interpreted the patient's condition. He should kneel by the patient's side opposite the first rescuer in position for ventilation and palpate the carotid pulse (Fig 21). If compressions are adequate, a pulse should be felt; if no pulse is felt, the compressor's technique should be reevaluated. When the second rescuer can feel a pulse with each compression, he calls out, "Stop compression." The first rescuer stops compressing for five seconds so that the second rescuer can check for a spontaneous pulse. If no pulse is found, the second rescuer should deliver a breath to the patient immediately and then state, "No pulse, resume CPR."

This entire process, from the moment the second rescuer arrives to the point where he delivers the breath, should be done in as little time as possible to insure that CPR continues effectively. As soon as this breath is delivered to the victim, the first rescuer changes to the two-person rate (60 compressions per minute). Ventilation is then interposed during the upstroke of each fifth chest compression (Fig 22).

Fig 23. — Two-person CPR: compressor and ventilator exchanging positions.

Switch Procedure

The CPR can be performed more smoothly and effectively when the two rescuers are on opposite sides of the victim. They can then exchange positions when necessary without serious interruption in the 5:1 sequence. The switch is initiated when the rescuer performing compressions directs that a switch take place at the end of a 5:1 sequence. The rescuer who is performing the ventilations, after giving a breath, moves into position to give compressions. The rescuer giving compressions, after the fifth compression, moves to the patient's head and checks the pulse for five seconds (Fig 23). If no pulse is felt, the rescuer at the head gives a breath and tells the rescuer at the chest to "continue CPR." If there is a pulse but no breathing, he should so indicate and continue appropriate ventilation.

Foreign Body Airway Obstruction

Introduction

Upper airway obstruction can cause unconsciousness and cardiopulmonary arrest, but far more often upper airway obstruction is caused by unconsciousness and cardiopulmonary arrest.

Management of upper airway obstruction should be taught within the context of basic life support. The leading cause of cardiopulmonary arrest is coronary heart disease accounting for more than 500,000 deaths annually.[1] Foreign body airway obstruction (inhalation and ingestion of food and other objects) accounted for approximately 3,060 deaths in 1978 according to the National Safety Council.[98]

Factors Associated with Choking

Foreign body obstruction of the airway usually occurs during eating. In adults meat is the most common cause of obstruction although a variety of other foods and foreign bodies have been the cause of choking in children and some adults. Common factors associated with choking on food include large, poorly chewed pieces of food, elevated blood alcohol, and upper and/or lower dentures. Symptoms of this emergency have been mistaken for a heart attack giving rise to the name "cafe coronary."

The following precautions are recommended to avoid airway obstruction: (1) Cut food into small pieces; chew slowly and thoroughly especially if wearing dentures. (2) Avoid laughing and talking during chewing and swallowing. (3) Avoid excessive intake of alcohol before and during meals. (4) Restrict children from walking, running, or playing with food or foreign bodies in their mouths. (5) Keep small foreign objects such as marbles, beads, and thumbtacks away from infants and small children.

An unconscious person can develop airway obstruction because the tongue falls back into the pharynx obstructing the upper airway. Regurgitation of stomach contents into the pharynx can occur during a cardiopulmonary arrest or during resuscitative attempts. Head and facial injuries may result in upper airway obstruction by blood clots particularly if the patient is unconscious.

Recognition of Foreign Body Airway Obstruction

The key to successful management of airway obstruction is early recognition of the condition. It is important to differentiate this emergency from fainting, stroke, heart attack, epilepsy, drug overdose, or other conditions which cause sudden respiratory failure and which are managed differently.

Partial Airway Obstruction. — Foreign bodies may cause either partial or complete airway obstruction. With partial airway obstruction the victim may be capable of either "good air exchange" or "poor air exchange." With good air exchange the victim can cough forcefully although frequently there is wheezing between coughs. As long as good air exchange continues, the victim should be allowed and encouraged to persist with spontaneous coughing and breathing efforts. At this point *do not* interfere with his attempts to expel the foreign body.

Poor air exchange may occur initially, or good air exchange may progress to poor air exchange as indicated by a weak, ineffective cough, high-pitched "crowing" on inspiration, increased respiratory difficulty, and possibly cyanosis. At this point manage the partial obstruction as though it were a complete airway obstruction.

Complete Airway Obstruction. — With complete airway obstruction the victim is unable to speak, breathe, or cough and may clutch his neck (the universal distress signal). Air exchange will be absent requiring prompt action. Alveolar oxygen is rapidly depleted resulting in cerebral hypoxia, unconsciousness, and ultimately death unless treated.

Management of Obstructed Airway

Manual Maneuvers. — Three manual maneuvers are recommended for relieving foreign body airway obstruction: back blows, manual thrusts, and finger sweeps. The following provides a description of each maneuver with the recommended position and method of application.

Back Blows. — This maneuver consists of four sharp blows delivered rapidly with the heel of the hand over the spine and between the shoulder blades. It serves as a part of the mechanism to dislodge a foreign body. Back blows should be applied forcefully in rapid succession and may be administered with the victim sitting, standing, or lying. Each back blow should be delivered with the intent of relieving the obstruction without having to complete the full series.

Fig 24. — Back blow administered to conscious victim of foreign body airway obstruction.

Patient Standing or Sitting (Fig 24)

1. The rescuer should be positioned at the side and slightly behind the patient.
2. Place one hand on the chest for support.
3. Deliver four sharp blows with the heel of the other hand over the spine between the shoulder blades.

Whenever possible, the head should be lower than the chest to make use of the effect of gravity.

Fig 25. — Back blow administered to unconscious victim of foreign body airway obstruction.

Patient Lying (Fig 25)

1. Kneel and roll the patient onto his side, facing the rescuer, with his chest against the rescuer's thigh.
2. Deliver four sharp blows to the back as described above.

Manual Thrusts. — The manual thrust maneuver consists of a rapid series of four thrusts to the upper abdomen (abdominal thrust) or lower chest (chest thrust). Air is forced out of the lungs creating an artificial cough intended to move the foreign body. Each thrust should be delivered with the intent of relieving the obstruction without having to complete the full series. There are no significant differences in airway flow, pressure, or volume between abdominal and chest thrusts. An important consideration in either thrust maneuver is damage to thoracic or abdominal viscera.

Fig 26. — Abdominal thrust administered to conscious victim of foreign body airway obstruction.

Abdominal Thrust (Fig 26)

Patient Standing or Sitting

1. The rescuer should stand behind the patient and wrap his arms around the waist.
2. Grasp one fist with the other hand and place the thumb side of the fist against the abdomen in the midline between the umbilicus and the rib cage.
3. Press the fist four times into the abdomen with a quick inward and upward thrust.

Fig 27. — Abdominal thrust administered to unconscious victim of foreign body airway obstruction: aside position.

Patient Lying (Fig 27)

1. Position the patient lying on his back. The rescuer's knees should be close to the patient's hips. Open the airway and turn head up.
2. Place the heel of one hand against the abdomen in the midline between the umbilicus and the rib cage. The second hand is placed on top of the first.
3. Move forward so that the rescuer's shoulders are directly over the patient's abdomen.
4. The rescuer may do this maneuver in either of two positions described:

   Rescuer alongside patient (Fig 27). The rescuer's knees are close to the hips on either the right or left side of the patient.

   Rescuer astride patient (Fig 28). The rescuer straddles the hips or one thigh of the supine patient.
5. Press into the abdomen with four quick inward and upward thrusts. Do not press to either side.

Patient Alone

The patient who is alone can perform the maneuver on him/herself in the following manner: Press a fist into the upper abdomen with a quick upward thrust as described for the *patient standing,* or lean forward and press the abdomen quickly over a firm object such as the back of a chair, a table, or porch railing.

Fig 28. — Abdominal thrust administered to unconscious victim of foreign body airway obstruction: astride position.

Fig 29. — Chest thrust in conscious victim of foreign body airway obstruction.

Chest Thrust (Fig 29)

As an alternate technique to the abdominal thrust, this maneuver may be applied to the chest. It is particularly useful when the abdominal girth is so large the rescuer cannot fully wrap his arms around the patient's abdomen as with gross obesity or when pressure applied directly to the abdomen is likely to cause complications, as in advanced pregnancy.

Patient Standing or Sitting

1. Stand behind the patient, place arms directly under the armpits, and encircle the chest.
2. Place the thumb side of the fist on the middle of the sternum but not on the xiphoid process or the costal margins.
3. Grasp one fist with the other hand and exert four quick, backward thrusts.

Fig 30. — Chest thrust in unconscious victim of foreign body airway obstruction.

Patient Lying (Fig 30)

1. Kneel close to the side of the supine patient. Open the airway and turn head up.
2. Use hand position for and application of chest thrust as for applying external chest compression (heel of hand on lower half of sternum).
3. Exert four quick, downward thrusts that will compress the chest cavity.

Combined Use of Back Blows and Manual Thrusts. — Back blows produce an instant increase in pressure in the respiratory passages which may result in either partial or complete dislodgement of a foreign body. Manual thrusts produce a more sustained increase in pressure in the respiratory passages and may further assist in the dislodgement and movement of the foreign body. *The combination of these two techniques appears to be the most effective method of clearing upper airway obstruction* as opposed to isolated use of one technique. The only comparative data in medical literature show the combination of back blows and thrusts to be superior to either method used alone. It offers no support for the more effective sequence. Therefore, the sequence of manual thrusts followed by back blows could represent an acceptable alternative to the recommended sequence of back blows followed by thrusts.[99]

Finger Sweep (Fig 31). — If the presence of a foreign body is strongly suspected or can be seen in the mouth, it should be removed with the fingers. If it cannot be seen, the combination of back blows and manual thrusts may expel it, or it may be dislodged to a more accessible position for removal by the fingers.

It is difficult to remove foreign bodies from the airway with the fingers, and in most cases it is impossible to open the patient's mouth and insert the fingers for this purpose unless the person is unconscious. However, large foreign bodies can sometimes be dislodged and removed if they are at the level of or above the epiglottis.

Fig 31. — Finger sweep maneuver in unconscious victim of foreign body airway obstruction.

Guidelines for proper use of the finger sweep (Fig 31) technique follow:

1. With the head up, open the mouth by grasping both the tongue and mandible between the thumb and fingers and lifting (tongue-jaw lift). This action draws the tongue away from the posterior pharynx and a foreign body that may be lodged there. This alone may partially relieve the obstruction. If you are unable to open the mouth with the tongue-jaw lift technique, use the crossed-finger technique to open the airway. Open the mouth by crossing the finger and thumb and push the teeth apart.
2. Insert the index finger of the other hand down along the inside of the cheek and deeply into the throat to the base of the tongue. Use a hooking action to dislodge the foreign body and maneuver it into the mouth so it can be removed. It is sometimes necessary to use the index finger to push the foreign body against the opposite side of the throat to dislodge and lift it. Take care not to force the object deeper into the airway. If the foreign body comes within reach, grasp and remove it.

Devices. — The Kelly clamp and Magill forceps are recommended for use in relieving foreign body airway obstruction. Forceps should be used only with direct visualization of the foreign body. Either a laryngoscope or tongue blade and flashlight can be used to permit direct visualization.

Sequencing of Procedures for Relief of Foreign Body Airway Obstruction

The recommended sequence of procedures for emergency relief of airway obstruction varies according to (1) whether the emergency involves a conscious patient suspected of having a complete obstruction of the airway, a person who obviously was choking and being treated and who becomes unconscious, or the *unconscious* victim of an unwitnessed cause, and (2) the degree of training of the rescuer.

The sequence of procedures is effective if, after its application, the victim does at least one of the following: (1) resumes spontaneous breathing, (2) regains consciousness, (3) assumes normal skin color, or (4) expels the foreign body from the mouth or into the mouth where it can be seen. The procedures are ineffective if, after their application, the victim does not do at least one of the above. If, at any stage, a foreign body is seen in the mouth, attempt to remove it by finger sweeps.

As the patient becomes more hypoxic, the muscles will relax, and maneuvers that were previously ineffective may become effective. When the muscles relax or a foreign body is partially dislodged and the airway is partially open, slow, full, and forceful ventilation may keep a victim alive while bypassing the obstruction. If there is vomitus in the mouth or throat, turn the head and body to the side, wipe the material out quickly, and proceed with the sequence.

Conscious Choking Patient. — In the conscious victim of foreign body airway obstruction, immediate recognition and proper action are essential. If there is good air exchange with only partial obstruction and the patient is still able to speak or cough effectively, do not interfere with attempts to expel a foreign body.

The following sequence of maneuvers should be performed on the conscious patient:

1. Identify complete airway obstruction by asking the patient if he is able to speak.
2. Perform four back blows in rapid succession.
3. Perform four manual thrusts.
4. Repeat four back blows and four manual thrusts until they are effective or until unconsciousness ensues.

If the patient becomes unconscious, follow the sequence of maneuvers described below.

Choking Patient Who Becomes Unconscious. — The rescuer should call for help, open the airway, and attempt to ventilate the patient. If the ventilation attempt is unsuccessful, the rescuer should quickly perform the following measures:

1. Activate the EMS system if a second person is available.
2. Apply four back blows in rapid succession.

3. Apply four manual thrusts.
4. Apply the finger sweep. Dentures may need to be removed to improve the effectiveness of the finger sweep.
5. Open the airway and attempt to ventilate. If the patient cannot be ventilated:
6. Repeat steps 2, 3, 4, and 5 until successful or ACLS is available.

Unconscious Patient: Cause Unknown. — If the rescuer has found an unconscious victim, established unresponsiveness, called for help, opened the airway, diagnosed apnea, and attempted unsuccessfully to ventilate, the following sequence of maneuvers should be performed:

1. Reposition the head. Again attempt to ventilate. If unsuccessful and a second person is available, the EMS system should be activated.
2. Perform four back blows in rapid succession.
3. Perform four manual thrusts.
4. Perform finger sweep. Dentures may need to be removed to improve finger sweep.
5. Attempt to ventilate. If the patient cannot be ventilated:
6. Repeat steps 2, 3, 4, and 5 until successful or ACLS is available.

If successful in removing the foreign body, perform mouth-to-mouth ventilation or cardiopulmonary resuscitation if necessary. Even if the patient begins spontaneous ventilation, further examination is recommended.

Pediatric Resuscitation

Introduction

There are fewer opportunities for performing CPR on infants and children than in adults, and this is reflected by less objective data, experiential or research, in the literature. The American Heart Association Working Group on CPR and ECC in Infants and Children, in the absence of such data and with the help of advisors in many disciplines, has arrived at the following approach to CPR in infants and children. It is hoped that in the future the recommendations can be subjected to objective study and changes be made where necessary.

The number of children who require resuscitation, except in the newborn period, is small; for optimal results, therefore, each community should define the facility where such infants and children will receive care. It is recommended that (1) everyone trained in BLS should have competence in BLS for infants and children; (2) all hospitals having an obstetric service have personnel trained in ACLS for newborns and be part of a program that includes transport to a newborn intensive care unit; (3) all facilities having ACLS capability have personnel trained in those techniques for infants and children; (4) each such facility have an ongoing agreement with an identified institution where postresuscitative care for infants and children can be given in a pediatric intensive care unit under the supervision of trained personnel.

The basic principles of CPR are the same whether the victim is an infant, child, or adult. These principles include:

1. Establishing unresponsiveness or respiratory difficulty.
2. Calling for help.
3. Positioning the victim.
4. Airway: (a) Opening the airway; (b) Establishing apnea.
5. Breathing for the victim: (a) Rescue breathing; (b) Recognizing and managing the obstructed airway.
6. Circulation: (a) Establishing the presence or absence of pulse; (b) Activating the emergency medical services (EMS) system; (c) Applying external chest compression.

The differences in CPR in the infant and child are in priorities and techniques to allow for different underlying causes of the emergencies in infants and children and for variation in size.

Causes of Cardiopulmonary Arrest in Infants and Children

Cardiopulmonary arrest from primary cardiac causes and rhythm disturbances is rare in infants and children. In the majority of instances infants and children will have primary respiratory arrest with cardiac arrest as a result of the ensuing hypoxia. Great attention, therefore, must be paid to patency of the airway and adequacy of ventilation. In many instances further resuscitative attempts will prove unnecessary.

The major events that may necessitate resuscitation are the following: (1) suffocation caused by foreign bodies, eg, toys, peanuts, plastic covers; (2) near drowning; (3) automobile or other accidents; (4) poisoning and drug overdose; (5) smoke inhalation; (6) sudden infant death syndrome (SIDS); (7) infection of the airway, ie, croup, epiglottitis.

The vast majority of emergency situations requiring CPR are preventable, and special attention must therefore be paid to producing an environment for the child that is safe and protective without suppressing the child's intellectual curiosity and need for exploration and discovery. Children should be taught respect for matches and fires and, if too young, should not be left unsupervised. Toys should be carefully examined for small parts which could be potentially aspirated before being given to toddlers whose mouths are favorite receptacles. Beads, small plastic toys, marbles, and peanuts must be kept away from infants and preschoolers. Children should be taught to sit while eating and not be allowed to eat while running and playing. When in automobiles, appropriate infant seats and seat belts should be worn; and when old enough, children should be taught water safety rules. Prevention of the cause leading to the need for CPR is infinitely superior to even the best performed resuscitation.

Size of the Infant or Child

Children differ in size from infancy through adolescence. For the purpose of CPR, we have called anyone younger than one year an infant and between one and eight years a child. Techniques appropriate to the adult may be applied to children older than eight years of age. It is recognized that there are large infants (younger than one year of age) who might be mistaken for a child (one to eight years) while at the other extreme a small adolescent might be mistaken for a child. These definitions should be taken as guidelines only. At the time of an emergency, one should not try to be too exact about age since a slight error one way or the other is not critical.

Establish Unresponsiveness or Respiratory Difficulty

An unconscious infant or child, like an adult, will not awaken or cry when shaken. The extremities will be limp. Therefore, gently tap or shake an infant or child to determine unconsciousness. If conscious, he will begin to move and cry.

A child who is not unconscious but is gasping and struggling to breathe may need to have the airway opened and, if necessary, have rescue breathing coordinated to breathing. As previously noted, the need for rescue breathing alone is more commonly required in infants and children than in adults.

Call Out for Help

If the patient does not respond to arousal attempts, call out for help from bystanders. (Even if no one is in sight, call out in the hope that someone will hear.)

Position the Patient

The circumstances in which the child victim is found will determine to some degree the care that must be exercised in positioning him. The likelihood of neck, spine, or bone injuries will be greater if the victim is found at the scene of an accident or at the base of a tree than if an infant is found in bed not breathing. If the infant or child is face down, he must be rolled over as a unit. One hand should always support the head and neck so that it does not roll or twist.

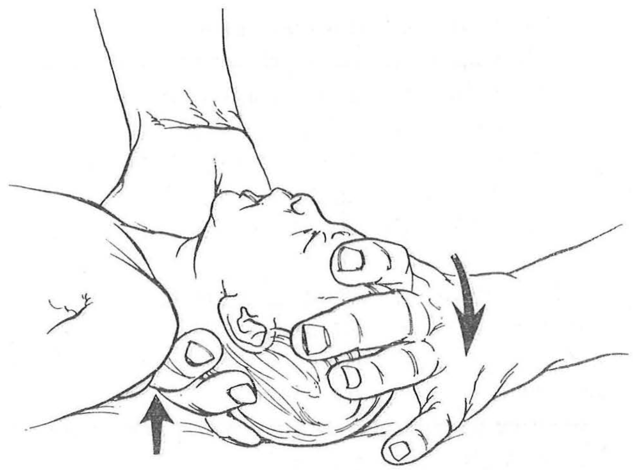

Fig 32. — Opening airway using head tilt-neck lift technique.

Fig 33. — Opening airway using head tilt-chin lift technique.

The Airway

Open the Airway. — Once it has been established that the infant or child is unconscious or is having serious difficulty breathing, the airway should be opened. An infant or child who is struggling to breathe but who is not cyanotic probably has an adequate airway and is best immediately transported by the rescuer to an ACLS facility. The infant or child who is apneic or is making respiratory efforts but is cyanotic should have the airway opened by the head tilt-neck lift technique or the head tilt-chin lift. The head tilt-neck lift technique is performed by placing one hand (or as many fingers as will fit comfortably) under the patient's neck and the other hand on the forehead (Fig 32). The neck is lifted slightly and the head pushed back with gentle pressure on the forehead. This extension of the head will usually be sufficient to move the tongue away so it does not obstruct the airway. In some situations the chin lift technique may be helpful in moving the tongue forward and away from the posterior pharyngeal wall. In this technique, extension of the head is maintained by pressure on the forehead. The tips of the fingers of the hand that had been under the neck are now used to lift the mandible near the chin forward (Fig 33). Care should be exercised that the mouth is not closed completely and that the fingers are not causing undue pressure on the soft tissue of the neck.

Establish Apnea. — As soon as the airway is opened and while it is maintained, the rescuer should immediately check to determine if the patient is breathing. The rescuer places his ear over the patient's mouth and nose and looks toward the patient's chest and abdomen. Breathing is confirmed by (1) seeing the chest and abdomen rise and fall, (2) feeling air from the mouth and nose, and (3) hearing air during exhalation.

It should be stressed that the airway may be obstructed despite respiratory efforts by the patient. Often, opening the airway is all the patient needs in order to breathe effectively. If the infant or child resumes breathing, the airway is simply maintained. If the patient is apneic, rescue breathing is applied. If after opening the airway the infant or child is gasping or struggling to catch his breath, a decision has to be made by the rescuer whether to apply rescue breathing. This decision can be made by looking for cyanosis of the lips. In absence of cyanosis the patient should be transported as rapidly as possible to an ACLS unit while patency of the airway is maintained. If cyanosis is present, rescue breathing is applied.

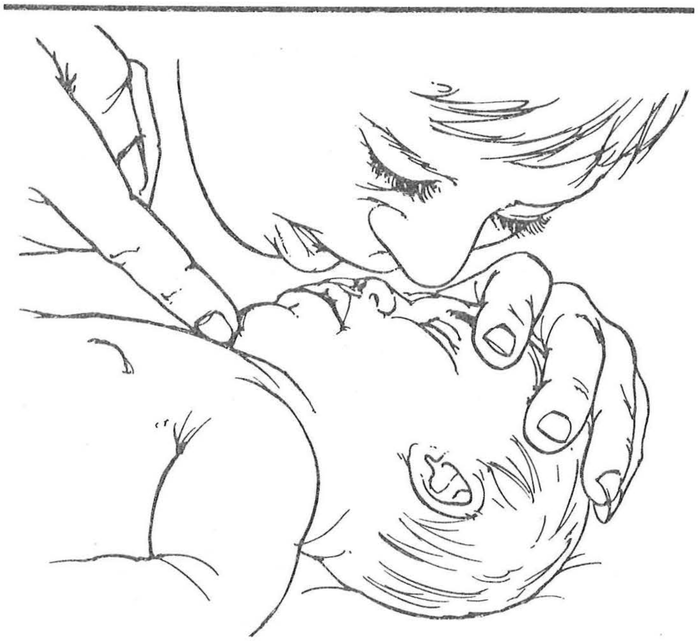

Fig 34. — Rescue breathing with airtight seal to include mouth and nose.

Breathing

Rescue Breathing. — This term refers to the ventilation of an apneic infant, child, or adult by a rescuer. If the patient is an infant, the rescuer must cover both the mouth and the nose and make a seal (Fig 34). If the child is large enough so that a tight seal cannot be made over both nose and mouth together, the nose is pinched as in the adult, and only the mouth of the child is covered as in ventilation of the adult patient.

When an airtight seal has been established — either mouth-to-nose and mouth, or mouth-to-mouth, four gentle breaths are delivered in rapid succession without allowing for full exhalation. These four quick breaths serve as a means of checking for airway obstruction as well as opening the alveoli. Due to small lung volumes, ventilation should be limited to the amount of air needed to cause the chest to rise. It should not, however, be forgotten that the smaller tracheobronchial tree provides a greater resistance to air flow requiring more inspiratory pressure than anticipated.

If air enters freely with the four breaths and the chest rises, the airway is clear and the rescuer proceeds with checking the pulse. If obstruction is encountered, patency of the airway must be checked. If after readjustments of head extension and chin lift, ventilation is not achieved, an obstruction must be suspected.

Gastric Distention

Artificial ventilation can cause gastric distention that, if excessive, can restrict rescue breathing by elevating the diaphragm and thus decreasing lung volume. The incidence of gastric distention can be minimized by limiting ventilation volumes to the point at which the chest rises thus avoiding exceeding the esophageal opening pressure. Attempts at relieving gastric distention by pressure on the abdomen should be avoided because of the danger of aspiration. Gastric decompression should be attempted only if the abdomen is so tense that ventilation is ineffective. In such a situation the infant or child's entire body is turned to the side before pressure is applied to the abdomen.

Airway Obstruction

It should be kept in mind that airway obstruction with secondary cardiac arrest is much more common in infants and children than cardiac arrest with secondary airway obstruction. Airway obstruction can be caused by a foreign body such as a toy, peanut, or other small objects or may be caused by infectious processes resulting in croup or epiglottitis. The differentiation between a foreign body and an infectious cause must be made prior to treatment. The signs of croup or epiglottitis are those of airway obstruction, and the underlying cause can only be suspected at the time of an emergency by the circumstances under which the event occurred. A child who has been ill with fever, a barking cough, and progressive airway obstruction needs transportation to the nearest ACLS facility, whereas a child, previously healthy, who chokes while eating peanuts or playing with small toys and has difficulty in breathing may need CPR and relief of the airway obstruction. Foreign bodies may cause partial or complete airway obstruction. With partial airway obstruction, the patient may be capable of either "good air exchange" or "poor air exchange." With good air exchange the patient can cough forcefully although wheezing may be present. The patient with good air exchange should be allowed and encouraged to persist with spontaneous coughing and breathing efforts. At this point the rescuer should not interfere with the patient's attempts to expel the foreign body but should monitor respiratory status.

Poor air exchange may be present initially, or good air exchange may progress to poor air exchange. Poor air exchange is characterized by an ineffective cough, high-pitched inspiratory noises, increased respiratory difficulty, and cyanosis. Partial obstruction with poor air exchange should be managed as a complete obstruction. Relief of foreign body airway obstruction is achieved through a combination of back blows and chest thrusts. Each blow or thrust should be delivered with the intent of relieving the foreign body airway obstruction. Abdominal thrusts are not recommended in infants and children because of their potential injury to the abdominal organs.

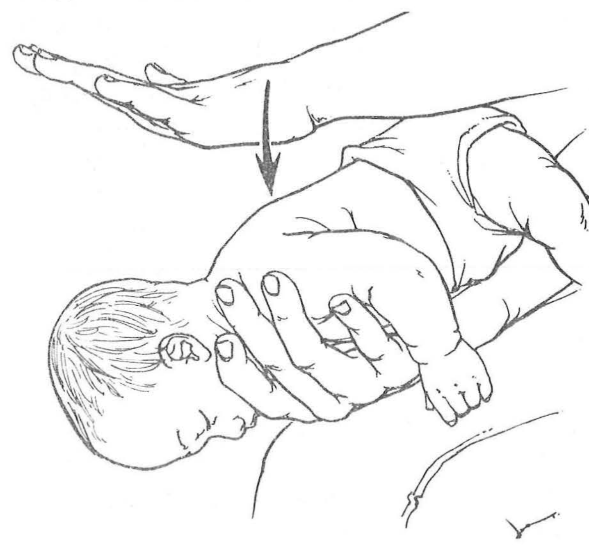

Fig 35. — Infant back blows for management of foreign body airway obstruction.

If the patient is an infant, he is straddled over the rescuer's arm with the head lower than the trunk (Fig 35). The head must be supported with a hand around the jaw and chest. For additional support it is

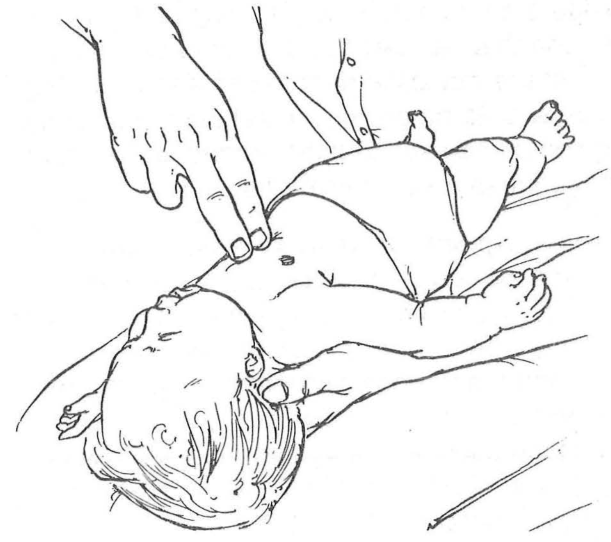

Fig 36. — Infant chest thrust for management of foreign body airway obstruction.

advisable for the rescuer to rest the forearm on his thigh. Four back blows are rapidly delivered with the heel of the hand between the infant's scapulae. Care must be exercised since much less force needs to be exerted than in the adult. Immediately after delivering the back blows, the rescuer places his free hand on the infant's back so that the patient is sandwiched between the two hands, one supporting the neck, jaw, and chest, while the other is in a position to support the back and head. While continuing to provide support to the head and neck, the patient is turned and placed on the thigh with the head lower than the trunk, and four chest thrusts are delivered in rapid succession in the same manner as external chest compressions are performed in the infant (Fig 36).

Fig 37. — Child back blows for managment of foreign body airway obstruction.

If the patient is a child too large to straddle the rescuer's forearm, the rescuer kneels on the floor and drapes the patient across the thighs keeping the head lower than the trunk (Fig 37). The four back blows can be delivered with somewhat greater force than that used for the infant.

With the head and back supported, the child is rolled over onto the floor and is now in position for the four chest thrusts. These are applied in the same manner as external chest compression is applied for the child (Fig 38).

Fig 38. — External chest compression hand position for child.

Blind finger sweeps are to be avoided in infants and children since the foreign body can easily be pushed back and cause further obstruction. In the unconscious patient, immediately after the chest thrusts, the tongue and lower jaw are lifted forward and the mouth opened. This is done by placing the thumb in the patient's mouth over the tongue with the other fingers wrapped around the mandible. If the foreign body is visualized, it may be removed with a finger.

If apnea persists after this maneuver, the airway should again be opened and a seal made over the mouth or the mouth-nose of the patient and an attempt made to deliver four breaths. If the chest does not rise and the obstruction persists, its relief must again be sought via the above technique.

Circulation

Check Pulse. — Once the airway has been opened and four breaths delivered, it must be determined whether only apnea is present or cardiac arrest has also occurred. Cardiac arrest is diagnosed by the absence of a pulse in an apneic unconscious patient. The pulse in a child can be detected over the carotid artery in a manner similar to that described for the adult. The palpation of a pulse in an infant is more of a problem. Unfortunately, the very short and at times fat neck of an infant makes the carotid pulse difficult to feel. Precordial activity represents an impulse rather than a pulse and has been found not to be reliable. Some infants with good cardiac activity may have a quiet precordium leading to the erroneous impression that chest compression is indicated. Because of this difficulty, it is recommended that in infants the brachial pulse be checked midway between the elbow and the shoulder (Fig 39).

Fig 39. — Palpation of brachial pulse in infant.

When there is a pulse but apnea, rescue breathing must continue. Ventilation should be *gentle,* just enough to make the chest rise, and if the infant or child is struggling for breath, ventilation should be coordinated with the patient's respiratory effort.

The smaller the child, the more rapid is the natural respiratory rate, so ventilation should be according to the following rates: (1) Infant — breathe once every 3 seconds or 20 times per minute; (2) Child — breathe once every 4 seconds or 15 times per minute.

Activate EMS System. — If the rescuer is not alone, one person should call the emergency telephone number to activate the EMS system. The shorter the time interval between cardiac arrest and initiation of BLS and ACLS, the greater the likelihood of survival of the cardiac arrest victim. If the rescuer is alone, CPR should be performed for approximately one minute and then, if a telephone is immediately available, help summoned. If no telephone is available, the only option is for the rescuer to continue CPR.

External Chest Compression. — If the patient's pulse is not palpable, then a combination of ventilation and chest compression is indicated. It is in the technique of external chest compression that differences between infants, children, and adults become most apparent. The differences are related to the position of the heart within the chest, the small size of the chest, and the faster heart rate of the infant and child as compared with that of the adult.

The heart in the infant and child is situated higher in the chest than it is in the adult. The proper area of compression in the *infant* is the midsternum (Fig 40). If an imaginary line is drawn between the nipples, the proper area of compression is the midportion of this line. A *child's* heart is lower than an infant's but not as low as an adult's. Using the technique as described for the adult, the notch where the ribs join in the center of the chest is located with the middle finger. The area just above the index finger is the appropriate area of compression in the *child* (Fig 38).

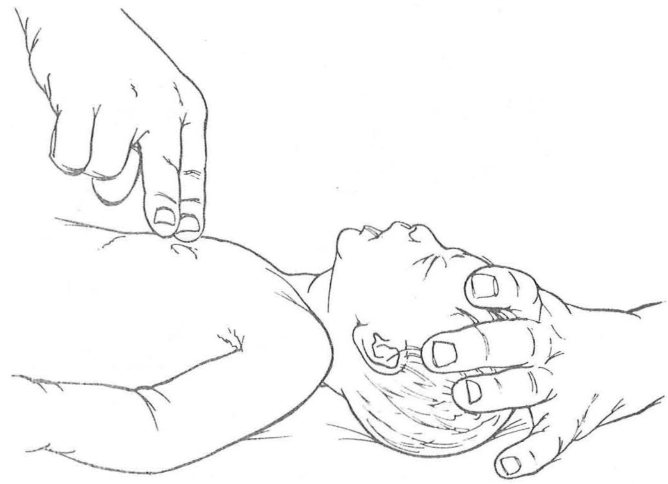

Fig 40. — External chest compression finger position for infant.

The chest of an infant or child is smaller and more pliable than that of an adult. Two hands are not necessary for proper compression. In an *infant* two or three fingers are adequate. With the fingers on the midsternum (between the nipples) the sternum is compressed ½ to 1 in (1.3 to 2.5 cm). The patient should lie on a hard surface for the rescuer to achieve best results. In the *child* more force will be required. If the infant or child is large enough so that the sternum will not easily compress with three fingers, the heel of one hand will be needed. Only the heel of the hand should be used; the fingers must be kept off the chest. If the patient is large enough to require the heel of the hand for compression, the depth should be increased to 1 to 1½ in (2.5 to 3.8 cm).

Fig 41. — External chest compression and rescue breathing performed in 5:1 ratio by single rescuer.

Because of the inherently faster heart rate in infants and children, the compression rate must also be faster as follows: (1) Infants — 100 compressions per minute; (2) Children — 80 compressions per minute.

External chest compression must always be accompanied by rescue breathing, and the two must be coordinated. The ratio of compressions to respirations is 5:1, both for single and for two rescuers. In infants and small children a backward tilt of the head lifts the back. A firm support beneath the back is therefore required for external chest compression and can be provided by the rescuer slipping one hand beneath the child's back while using the other hand to compress the chest. A folded blanket or other adjunct can also be used beneath the back to provide support. This helps to maintain head tilt and an open airway. Head tilt can also be maintained by utilizing the hand not performing compressions. When only a single rescuer is present, after each fifth compression a breath is interposed without stopping compressions (Fig 41). A brief pause is acceptable if necessary.