The Use of the Heimlich Maneuver in Near Drowning

Peter Rosen, Michael Stoto, and Jim Harley
Editors

Committee on the Treatment of Near-Drowning Victims

Division of Health Promotion and
Disease Prevention

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COMMITTEE ON THE TREATMENT OF NEAR-DROWNING VICTIMS

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Executive summary

The application of the Heimlich maneuver as the initial and perhaps only step for opening the airway in all near-drowning victims has been proposed by Henry Heimlich and Edward Patrick. This is contrary to current resuscitation guidelines for the treatment of near-drowning victims established by the Emergency Cardiac Care (ECC) Committee of the American Heart Association. To help resolve this difference, the Institute of Medicine (IOM) convened an expert committee to determine when the Heimlich maneuver should be used in the treatment of near-drowning victims, if at all. During its deliberations, the IOM Committee on the Treatment of Near-Drowning Victims met with Dr. Heimlich and his colleagues and considered literature reviews of clinical and basic research on drowning, scientific articles on pertinent pathophysiological states involving fluid in the airways, and its own clinical experience.

The committee concludes that, although the Heimlich maneuver is useful for the removal of aspirated solid foreign bodies, there is no evidence that death from drowning is frequently caused by aspiration of a solid foreign body that is not effectively treated by the current ECC recommendations. The committee further finds that the evidence is insufficient to support the proposition that the Heimlich maneuver is useful for the removal of aspirated liquid. Moreover, because there is no evidence to support Heimlich's hypothesis that substantial amounts of water are aspirated by near-drowning victims or that such aspirated liquid causes brain damage and death, the committee finds that the available evidence does not support routine use of the Heimlich maneuver in the care of near-drowning victims.

The committee also has a series of concerns about the routine use of the Heimlich maneuver for treatment of near drowning, because of: (a) the amount of time it would take to repeat this maneuver until the patient is no longer expelling water (as recommended by Heimlich) and how long this would delay the initiation of artificial ventilation; (b) possible complications of the Heimlich maneuver, especially if the near drowning is associated with a cervical fracture; and (c) the prospect of teaching rescue workers a different protocol than that which is taught at present for resuscitating victims of cardiopulmonary arrest from all causes other than near drowning.

The committee therefore concludes that given the present state of basic science and clinical knowledge about near drowning, the current ECC recommendations for establishment of the airway and ventilation should not be changed. These recommendations state that an abdominal thrust should be performed only after ventilation has been shown to be ineffective and then only to remove a solid foreign body.

Introduction

Drowning is the second leading cause of accidental death among children and young adults in the United States. In 1989, there were 4,600 accidental drowning deaths, 1,200 among children (0-14 years of age) and 900 among young adults (15-24 years of age).[1] Preventing death from drowning requires the establishment of adequate ventilation. Current resuscitation guidelines for the treatment of near-drowning victims established by the Emergency Cardiac Care (ECC) Committee of the American Heart Association (AHA) are focused on opening the airway and the early administration of artificial respiration for apnea.[2] The ECC recommends mouth-to-mouth respiration followed by efforts to open the airway, including abdominal thrusts, if the airway is obstructed.

The application of the Heimlich maneuver as the initial and perhaps only step for opening the airway in all near-drowning victims has been proposed by Henry Heimlich and Edward Patrick.[3,4,5,6,7,8] According to Heimlich, "Evacuation of water from the lungs by pulmonary compression should be the first step in resuscitating a drowning person. . . . The subdiaphragmatic pressure [Heimlich maneuver] should be performed and repeated until no water flows from the mouth. In the event that spontaneous respiration does not occur, standard resuscitative methods should then be used immediately."[5] The Heimlich-Patrick method for treating submersion victims is first to perform the Heimlich maneuver to remove fluid, followed by mouth-to-mouth resuscitation and chest compressions (CPR), if necessary.[8]

To help resolve these differences in recommendations regarding the treatment of drowning, in 1993 the Institute of Medicine (IOM) convened an expert committee to determine when the Heimlich maneuver should be used in the treatment of near-drowning victims, if at all.

Historical Background

Methods used for resuscitating drowning victims before the 1900s included back slapping, shaking, placing burning coals on the victim, insufflating tobacco smoke into the lungs and rectum, and burying the victim up to the neck in horse dung. The controversy concerning the role of manual compression with or without ventilation by lung insufflation in drowning resuscitation is quite old. In 1829, Leroy-d'Etiolles argued that insufflation should not be taught to laypeople because of the danger of overinflation of the lungs when given by untrained

people. He recommended that the thorax and abdomen be compressed in the supine position to simulate expiration followed by a period of relaxation to simulate inspiration.[9]

In the first half of the twentieth century, artificial manual respiration became the norm. In 1958, Safar compared the accepted Holger-Nielsen method of artificial manual respiration (extension of a prone victim's arms in inspiration and pressure on the scapulae in expiration) to mouth-to-mouth ventilation. The tidal volume exchanged with the manual method was less than the dead air space. Mouth-to-mouth respiration was much more effective.[10] Soon after Safar's study, mouth-to-mouth resuscitation became the standard technique for drowning resuscitation, and attempts to drain water from the lungs were no longer recommended.[8,11] The current ECC recommendations call for "immediate ventilation and rescue breathing," with use of the Heimlich maneuver only in cases in which "the rescuer suspects that foreign matter is obstructing the airway or the victim does not respond appropriately to mouth-to-mouth ventilation."[2]

Heimlich introduced the abdominal thrust technique for resuscitation of food-choking victims in 1974 and requested that anytime the maneuver was used, a report of the results be sent to him. By 1975, he had collected over 162 case reports. There were 5 unanticipated reports of the Heimlich maneuver being used to resuscitate near-drowning victims, and afterward Heimlich recommended that the technique be used for near-drowning victims.[12]

At the 1985 AHA National Conference on Standards for Cardiopulmonary Resuscitation and Emergency Cardiac Care, after extensive review and discussion of clinical, research, and anecdotal data related to the efficacy of the Heimlich maneuver, the procedure was recommended for use with drowning only if foreign body aspiration was suspected or if mouth-to-mouth ventilation was unsuccessful. The ECC Committee also recommended that further investigations be undertaken to determine the need for, timing, and risk of using subdiaphragmatic thrusts in the resuscitation of drowning patients.[13] In 1992, the ECC Committee reviewed these recommendations and left them unchanged, resulting in the guidelines summarized in the Introduction and Appendix F.[2]

For more than 40 years, the National Research Council has provided scientific advice to the American National Red Cross. In 1989, the Committee to Advise the American National Red Cross moved to the IOM Division of Health Promotion and Disease Prevention. In February 1991, the IOM released a brief report in response to a request from the Red Cross to address three specific aquatic issues: (1) wet versus dry lungs, (2) the Heimlich maneuver, and (3) in-water rescue breathing. The report concluded, among other things, that the Heimlich maneuver should not be used prior to executing the airway, breathing, and circulation (ABCs) assessment and correction measures on near-drowning victims. The report recommended that abdominal thrusts be performed only on

near-drowning victims on land, when the rescuer suspects airway obstruction after ABC measures have been attempted and proven unsuccessful.[14] After its completion, Heimlich challenged the report, and a review committee of the National Academy of Sciences suggested that the committee's study process was not adequately suited to the task. IOM President Kenneth I. Shine therefore decided that a new committee should be appointed to review this issue.

In response, the IOM Division of Health Promotion and Disease Prevention assembled a committee to review and evaluate the available scientific literature on the treatment of near-drowning victims. The charge to the committee was to determine when the Heimlich maneuver should be used in the treatment of near-drowning victims, if at all. The committee convened a workshop on November 20, 1993, at the Academy's Arnold and Mabel Beckman Center in Irvine, California, to address the appropriateness of immediately using the Heimlich maneuver on all near-drowning victims. The workshop consisted of several brief presentations followed by interactive discussions among participants and committee members (see the appendixes). Letters from other experts on resuscitation were solicited by IOM staff and made available to the committee and the workshop participants.

Methodology

To guide its deliberations, the committee considered the following four propositions:

1. Death from drowning is frequently caused by aspiration of a solid foreign body that is not effectively treated using the current ECC recommendations.

2. The Heimlich maneuver is useful for the removal of aspirated solid foreign bodies.

3. Death from drowning, when no foreign body is aspirated, is caused by aspiration of liquid that prevents ventilation and oxygenation.

4. The Heimlich maneuver is useful for the removal of aspirated liquid.

The committee used three types of information in reaching its conclusions: (1) literature reviews of clinical and basic research on drowning, (2) selected scientific articles on pertinent pathophysiological states involving fluid in the airways, and (3) the clinical experience of the panelists, workshop participants, and consultants.

The primary charge to the committee was to analyze the scientific and medical literature published on the Heimlich maneuver and its use in drowning resuscitation. Literature reviews were performed by workshop presenters as well as by the committee staff. A comprehensive literature search was performed using MEDLINE. The staff also examined the reference lists in articles that Heimlich and Patrick had published on the subject, as well as those in other scientific and review articles.

Results

The committee found no valid controlled clinical research studies that directly examined any of the four propositions. Indeed, very little information on the circumstances of drowning exists.[15] The available indirect data are discussed below in conjunction with the analysis of the four propositions.

Proposition 1

Death from drowning is frequently caused by aspiration of a solid foreign body that is not effectively treated using the current ECC recommendations.

Although mud, sand, and aquatic vegetation may be aspirated by someone drowning in natural fresh water or salt water,[16] the committee is not aware of evidence that such bodies frequently interfere with mouth-to-mouth ventilation.

Gordon and Terranova report the case of a 2-year-old boy who arrived at an emergency department pulseless and apneic after a cold-water near drowning.[17] He was given mouth-to-mouth respirations prior to arrival and vomited just outside of the emergency department. He was intubated but no air would pass through the tube with ventilation. The Heimlich maneuver was performed three times and a large piece of celery was expelled from the trachea. The child was then successfully ventilated. This case illustrates that near-drowning victims can have airways obstructed by solid objects after vomiting secondary to drowning.

Reporting on a series of ocean drownings in Australia, Manolios and Mackie noted a high incidence of both vomitus as well as seaweed and sand in the tracheas and bronchi of drowning victims, but the authors do not indicate whether these foreign bodies contributed to the deaths of these individuals.[18] Moreover, it is not easy to extrapolate data from this population of ocean swimmers to those who drown in swimming pools or calm water.

In Los Angeles County, where there are 130 to 135 drowning deaths per year, no evidence of obstructing foreign bodies was found in a 2-year period regardless of whether the victims had gone to a hospital emergency department

before being autopsied. (Sathyagiswaran, L. January 3, 1994. Memorandum to Michael Stoto.)

Conclusion The committee is aware of no scientific evidence of a substantial incidence of solid foreign body obstruction of the trachea or a main stem bronchus in drowning cases. Thus, based on a literature review and the clinical experience of the committee members and consultants, the committee finds no evidence to support Proposition 1, that death from drowning is frequently caused by aspiration of a solid foreign body that is not effectively treated using the current ECC recommendations.

Proposition 2

The Heimlich maneuver is useful for the removal of aspirated solid foreign bodies.

The committee did not review the literature or experimental evidence on the efficacy of the Heimlich maneuver in the removal of solid foreign bodies because it is outside of the scope of this investigation into near drowning. However, the committee members' clinical experience does indicate that the Heimlich maneuver is useful when treating choking victims, that is, when the aspirated body is large enough to block the passage of air into the lungs.

Heimlich was queried as to the incidence of complications of the maneuver and was asked if there was a higher risk of complications if the maneuver was performed on unconscious victims versus those who still had some ability to flex their abdominal musculature in response to the maneuver. He stated that the only complications of which he was aware were from an incorrect performance of the abdominal thrust, and that it was his conclusion that the maneuver was actually safer when used with unconscious victims.

Review of the literature revealed case reports of injuries due to abdominal thrusts, but there was no evidence to indicate whether or not such injuries resulted from incorrect performance of the maneuver, nor were there data concerning the relative danger of an abdominal thrust in unconscious versus conscious choking victims. Serious complications that have been noted when the Heimlich maneuver was used on choking victims include: (1) stomach rupture,[19] (2) aortic valve rupture,[20] (3) diaphragmatic rupture,[21] (4) esophageal rupture,[22] (5) jejunal rupture,[20] (6) mesenteric laceration,[23] (7) thrombosis of an aortic abdominal aneurysm,[24] (8) pneumomediastinum,[25] and (9) retinal detachment.[26] Six patients have been reported to have died from complications of this procedure.[19] Vomiting and abdominal tenderness are less serious complications of the procedure.[27] One potential complication that has not been reported is the manipulation of a cervical spine injury, a concomitant injury found in many near-drowning victims. If a cervical spine injury is suspected, it would be very difficult to perform the Heimlich maneuver safely, and turning the head to the side

(if thought to be necessary for the success of the maneuver) would greatly endanger the integrity of spinal cord function.

Conclusion The committee concludes that Proposition 2 is true, that is, that the Heimlich maneuver is useful for the removal of aspirated solid foreign bodies. There is concern, however, about the risks associated with using this procedure, especially on unconscious victims who might have cervical spine injuries.

Proposition 3

Death from drowning, when no foreign body is aspirated, is caused by aspiration of liquid that prevents ventilation and oxygenation.

Much of the debate centers on the use of the Heimlich maneuver centers around the pathophysiology of drowning. Heimlich's view, which the committee considered, is summarized in his statement that "you cannot get air into the lungs until the water is out."[8] When a person drowning in water can no longer suppress inspiration, gasping occurs and water enters the mouth and pharynx. Exactly how much water enters the lungs is a matter of controversy. Heimlich and his colleagues state that it is a large amount, and that air cannot reach the alveoli because of airway obstruction with water. Others state that only a small amount of water enters and that it is rarely enough to impede ventilation.

Modell estimates that 85 percent of patients who survive near drowning aspirate 22 ml of water per kilogram of body weight *or less*.[28] This estimate is based on postmortem chloride measurements that were extrapolated from known changes in serum chloride levels in dogs who had 22 cc/kg of water placed in their lungs.[29] Heimlich cites this study to support the use of subdiaphragmatic thrusts, arguing that 100- to 150-lb individuals would have up to 1,000-1,500 ml of water in their lungs.[5] Modell wrote that Heimlich has misinterpreted his study.[30] He also stated that in the 118 drowning victims he studied, there were not significant amounts of water in the trachea, and that he is "convinced that significant blockage of the airway by free water is uncommon."[30] Modell also finds that it is unusual for near-drowning victims to have substantial changes in serum electrolyte concentrations.[31] He interprets this to mean that either only a small amount of fluid is aspirated or the fluid is rapidly redistributed.[32]

Harries wrote that it is unusual to aspirate more than 200 cc of fluid.[33] The clinical argument against a large amount of fluid being present in the airway is that the majority of near- drowning victims can be ventilated without evidence of airway obstruction.[34]

The sequence of events in drowning starts with breath-holding and panic, followed by a period of increasing air hunger and reflex inspiratory efforts that force the victim to swallow and inhale.[35] Peripheral airway resistance increases,

laryngospasm may occur, reflex pulmonary vasoconstriction leads to pulmonary hypertension, lung compliance decreases, fluid shifts across the alveolar myembrane, surfactant may be destroyed or altered, and pulmonary edema forms. Alteration or destruction of surfactant, if it occurs, leads to atelectasis, which in turn leads to intrapulmonary shunting. All of these changes lead to hypoxia, which is the cause of death and cerebral morbidity in almost all cases of submersion injury.[36] While it clearly would be advantageous to prevent these changes from occurring, no published studies demonstrate that removal of water from the lungs will stop this chain of events.

Physiological studies in animals provide a limited amount of information on drowning pathophysiology but must be viewed with some skepticism given the marked anatomical and physiological differences between small animals and humans. Emergency resuscitation of drowning victims requires adequate alveolar ventilation to restore normal blood oxygen levels rapidly;[10] therefore, a clear path from the mouth to the alveoli is a prerequisite for effective ventilation. Karpovich reported that fluid and foam obstruction of the airway did affect survival in rats,[37] but this has not been confirmed by Modell or in other postmortem observations in humans.

In 1909, Emerson showed that the application of positive airway pressure prevented death in experimentally induced pulmonary edema in rabbits.[38] Barach et al. later showed that positive airway pressure brought about dramatic alleviation of symptoms in patients with pulmonary edema.[39] Following the work of Ashbaugh et al. in 1969, continuous positive-pressure breathing became one of the principal methods of treating pulmonary edema in critically ill patients.[40]

A recent study by Tutuncu and colleagues of partial liquid ventilation with perfluorocarbon (PFC) in animals with acute respiratory failure is also relevant to Proposition 3. Tutuncu and colleagues began by producing acute respiratory failure in rabbits by repeated lung lavage with warm saline to achieve an arterial P_{O_2} below 100 mmHg.[41] After this, one group of rabbits had PFC (a liquid of high density, low surface tension, and high solubility for oxygen) added into the lungs in three consecutive doses of 6 ml/kg at 5-minute intervals through an endotracheal tube. This is an amount estimated to equal the rabbits' normal lung volume at functional residual capacity, and thus was a significant amount of liquid to be added to the lungs. The result of the addition of PFC to the lungs, in conjunction with continuous positive-pressure ventilation, was that respiratory distress was markedly improved. This study used two control groups of rabbits, one in which 18 ml/kg of normal saline was instilled through the endotracheal tube, and another in which no liquid was used. Although the authors wanted to show that it is not the liquid per se that caused the improvement, the important result with respect to the treatment of near drowning is that there were no significant differences between the two control groups. This indicates that despite a large difference between the two control groups in the amount of water in the

lungs, intermittent positive-pressure ventilation was essentially equally effective. These results are incompatible with Heimlich's idea that "you cannot get air into the lungs until the water is out."[8]

Conclusion Based on the literature cited, the committee concludes that there is likely to be some aspiration of water during drowning. Except for a small percentage of victims (less than 10 percent), water can be found in the trachea and bronchi of drowned victims.[28] There is, however, considerable debate as to how much water is aspirated. In no study has a significant electrolyte change been found, whether drowning has occurred in fresh or salt water. A review of the research literature, as well as the clinical literature, finds no evidence of absorption of seawater from ocean drownings, although there does appear to be movement of water into the bronchi to dilute the concentrated seawater that was aspirated.[28] The literature is not clear on whether this is merely an osmotic fluid shift or whether the victim had developed pulmonary edema from the combination of hypoxia and hypertonicity.

A substantial body of basic and clinical scientific literature, including the studies cited above, indicates that even when large amounts of water are present within the trachea and bronchi, it is possible to oxygenate patients. Although there is limited evidence in the clinical literature to demonstrate the effectiveness of positive-pressure ventilation and end-expiratory ventilation in near drowning, there is evidence that water does not obstruct ventilation.

Heimlich and his colleagues cite several case reports to indicate that ventilation could not occur until the water in a drowning victim's trachea and bronchi had been removed by abdominal thrusts (see the next section), but the details of those case reports are incomplete and a full interpretation of these cases is impossible.

The clinical and pathological experience of the committee members, as well as their review of the scientific literature, does not indicate a substantial incidence of fluid interfering with ventilation in near-drowning victims. Thus the committee finds that the available evidence is insufficient to support Proposition 3, that death from drowning, when no foreign body is aspirated, is caused by aspiration of liquid that prevents ventilation and oxygenation.

Proposition 4

The Heimlich maneuver is useful for the removal of aspirated liquid.

Very few research studies have been performed to examine the efficacy of using the Heimlich maneuver in the resuscitation of near-drowning victims, and no controlled studies have been done of either the Heimlich maneuver or other resuscitation methods.

Heimlich uses an analogy of a straw and a glass of water to explain why the Heimlich maneuver works to expel water.[5] The anatomy of the lungs and trachea are more complex than a rigid straw allows, thus this analogy does not seem to be appropriate.

Ruben and Ruben studied the flow of water from the lungs in nine people soon after they died (of causes not related to drowning).[42] One liter of 1 percent saline was instilled through an endotracheal tube into the lungs. Forceful anterior chest and abdominal compressions were applied. The result was less than a 5 percent return of fluid. A second liter of fluid was instilled into the lungs and similar results were obtained. They conclude that "when more than a small amount of water flows from the mouth of a drowning patient, subjected to artificial respiration, it comes from the stomach." They also state that "mechanical efforts to drain the lungs are of no practical use; and trying to do so, before beginning artificial respiration, only means wasting valuable time."

Werner studied the effect of gravitational drainage and abdominal thrusts after seawater near drowning in dogs.[43] Three groups of five dogs were intubated and asphyxiated, and 30 cc/kg of artificial seawater was instilled into the lungs. The control group was drained in a horizontal position. The second group was drained by gravity with 30° of Trendelenburg. The third group was given four abdominal thrusts. After 1 minute more fluid had drained from the gravity and abdominal thrust groups, but there was no difference among the groups after 10 minutes. Furthermore, there was no difference in oxygenation or acidosis among the three groups.

Heimlich reported details of five cases in which the Heimlich maneuver was used to resuscitate near-drowning victims.[8] These were case reports by people who had responded to his request to tell of instances in which the Heimlich maneuver had been used. In two of the cases artificial respiration was not effective initially. After the Heimlich maneuver was used and water flowed from the mouth, the victim was able to be ventilated and survived. In no instance was there any determination of whether the water came from the lungs or the stomach.

Patrick reports a case of a 2-year-old boy who had been submerged for 20 minutes. He was given mouth-to-mouth resuscitation for 20 minutes.[44] He was then intubated but could not be ventilated. No breath sounds were heard with bagging. Patrick applied the Heimlich maneuver several times and substantial amounts of fluid came through the endotracheal tube. The victim was then able to be ventilated and survived to be discharged from the hospital. There was, however, significant brain damage, and he died about 4 months after the drowning episode.

Orlowski described the case of a 10-year-old submersion victim who vomited and aspirated the vomit after the Heimlich maneuver was performed.

The poor outcome in this patient was attributed to this complication (the boy died 7 years later).[27] Heimlich has argued that this was not a gastric aspiration because the pH of the fluid was 7.5, despite the fact that Orlowski stated that it looked and smelled like gastric contents.

Based on an analysis of submersion cases from Ohio, Indiana, Pennsylvania, and West Virginia reported to him during the spring and summer of 1993, Patrick reported to the committee that seven out of eight nonbreathing near-drowning victims without a pulse survived without complications after the Heimlich-Patrick method was used, whereas only two out of seven survived after only mouth-to-mouth ventilation was used. Although Patrick labeled this as a "prospective study," all of the data on these cases were gathered after Patrick was notified of each case. Patrick did not develop a consistent method of responding to the drowning episode or of determining the validity of the data presented. Anecdotal information obtained retrospectively is obviously fraught with tremendous limitations in terms of generalizing these observations. Thus these data are not equivalent to those from a randomized trial in which the populations treated with each maneuver can be assumed to be comparable.[45]

Furthermore, in the analysis he presented to the committee, Patrick did not consistently differentiate between cases with and without a detectable pulse at the time that resuscitation was begun, which *a priori* would be a strong confounding factor. Patrick also was not able to identify how many of the survivors on whom the Heimlich maneuver had been performed had also had initial mouth-to-mouth ventilation attempted, with performance of the abdominal thrust only after ventilation was found to be impossible (the current ECC recommendation).

It has been shown that the Heimlich maneuver causes vomiting, but so does mouth-to-mouth ventilation, and according to the Australian study, vomiting is common among drowning victims.[18]

Conclusion In summary, there is no experimental evidence that an abdominal thrust removes a substantial volume of aspirated fluid, and there is no evidence that near-drowning victims cannot be ventilated adequately without use of the Heimlich maneuver. The committee therefore concludes that the available data are insufficient to resolve whether or not Proposition 4, that the Heimlich maneuver is useful for the removal of aspirated liquid, is true.

Conclusions and Recommendations

The committee concludes that although the Heimlich maneuver is useful for the removal of aspirated solid foreign bodies, there is no evidence that death from drowning is frequently caused by aspiration of a solid foreign body that is

not effectively treated by the current ECC recommendations. The committee further finds that the evidence is insufficient to support the proposition that the Heimlich maneuver is useful for the removal of aspirated liquid. Moreover, because there is no evidence to support Heimlich's hypothesis that substantial amounts of water are aspirated by drowning victims and that such aspirated fluid causes brain damage and death, the committee finds that the available evidence does not support routine use of the Heimlich maneuver in the care of near-drowning victims.

The committee has a number of concerns about the changes Heimlich and colleagues have suggested for the present ECC guidelines for treatment of near drowning. First, whereas the correct performance of a single abdominal thrust need not be excessively time-consuming, it is not known how much time it would take to repeat this maneuver until the patient is no longer expelling water (as recommended by Heimlich), and how long this would delay the initiation of artificial ventilation. In drowning situations, even a short delay in restoration of breathing can cause brain damage and death. Furthermore, it is not clear to the committee that the Heimlich maneuver is as easily or quickly applied to an unconscious near-drowning victim as it is to a conscious choking person. Second, the committee is concerned that beginning resuscitation in all cases with an abdominal thrust would inhibit rescue workers from performing timely artificial ventilation because of the natural reluctance to perform mouth-to-mouth ventilation on a person who has vomited as a result of an abdominal thrust. While the incidence of vomiting is large in all near-drowning victims, as well as in patients receiving mouth-to-mouth ventilation, it is also significant in victims who have received an abdominal thrust. Third, there is concern about possible complications of the Heimlich maneuver, especially that the incidence of complications may be greater in unconscious victims. Fourth, injuries from cervical fractures are common in diving accidents and surf drownings, and turning a victim's head to avoid aspiration of vomitus prior to performing the abdominal thrust could greatly endanger the victim's life or spinal cord integrity. Heimlich has recommended omission of the head turn, but if this is not done, the committee cannot understand why the expelled liquid or solid foreign body would not be reaspirated. Fifth, the committee is also concerned about teaching rescue workers a different protocol than that which is taught at present for resuscitating victims of cardiopulmonary arrest from all causes other than near drowning. The committee feels that given the wide variety of workers who deliver cardiopulmonary resuscitation, it is important to have a simple, constant system that can be applied in any prehospital care situation. Complicating the simple system currently taught could, in the committee's judgment, lead to more harm than good--that is, more injuries and deaths than lives saved.

The committee therefore concludes that given the present state of basic science and clinical knowledge about drowning, the current ECC recommendations for establishment of the airway and ventilation should not be changed. These

recommendations state that an abdominal thrust should be performed only after ventilation has been shown to be ineffective, and then only to remove a solid foreign body. Although there are no randomized trials of mouth-to-mouth resuscitation, the ECC recommendations are based on an extensive review of physiological, clinical, and anecdotal data, using established standards for scientific evidence.

The committee is concerned about the absence of valid data on the efficacy of the Heimlich maneuver in near-drowning cases. Obtaining such data would require prospective randomization in a defined population to ensure that the test groups are similarly sampled and, in particular, that no group has a higher incidence of victims lacking respirations or a pulse. Such as study should include the entire population at risk, not just cases chosen retrospectively after hearing about an episode. Given the lack of evidence for the effectiveness of the use of the Heimlich maneuver in near-drowning situations and ethical concerns about doing research without a person's or surrogate's informed consent, it is hard to imagine a research methodology for such a study that would or should be approved by a human studies committee.

However, while the effectiveness of the Heimlich maneuver in altering the clinical course in recovery of pulmonary functions after near drowning in humans is difficult to study in a controlled trial, its effectiveness can be studied in animals. The major characteristics of near drowning can be produced in anesthetized experimental animals, and even larger amounts of fresh water or seawater can be instilled into the airways than might be present in near drowning in humans. If the animal studies showed that the clinical course was improved and the recovery of pulmonary function was accelerated with the application of abdominal thrusts as proposed by Heimlich, a stronger case could be made for consideration of a change in the current ECC guidelines. A review of the literature reveals only one such study, which concluded that more fluid could be drained initially with abdominal thrusts, but that after 10 minutes the total amount of fluid drained was the same whether abdominal thrusts or gravity was used, and that the thrusts produced no significant effect on oxygenation over the 6 hours of study.[43] This one study, of course, is not definitive, but before current standards are changed, some supportive evidence of improvement as a result of using the modified procedures in animal experiments should be required.

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Appendix A

WORKSHOP AGENDA

INSTITUTE OF MEDICINE
Committee on the Treatment of Near-Drowning Victims
November 20, 1993

NAS Beckman Study Center
Irvine, California

10:00 a.m.	Welcome and Introductory Remarks *Peter Rosen, Chairman* *Michael Stoto, Director, Division of Health Promotion and Disease Prevention*
10:10 a.m.	Literature Review on Research Related to the Treatment of Near-Drowning Victims *Jim R. Harley, Children's Hospital and Health Center, San Diego*
10:30 a.m.	Rationale for Established Guidelines *Lawrence D. Newell, American National Red Cross* *Linda Quan, American Heart Association*
11:00 a.m	Use of Heimlich Maneuver on Near-Drowning Victims *Eric Spletzer, The Heimlich Institute Foundation* *Henry Heimlich, The Heimlich Institute Foundation* *Edward A. Patrick, The Patrick Institute*
12:30 p.m.	Questions and Answers

Appendix B

WORKSHOP PARTICIPANTS

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Appendix C

SUMMARY OF HENRY HEIMLICH'S PRESENTATION

Spletzer's review of all drowning reports from 1930 to 1993 found no study showing that mouth-to-mouth/cardiopulmonary resuscitation (m-to-m/CPR) increases survival for drowning victims without first draining water from the lungs. The Heimlich maneuver removes fluid and other foreign substances from the airway and alveoli in 10 to 15 seconds, which resuscitates drowning victims.[43,44]

Bystander CPR did not improve outcome in drowning, yet it doubled survival in ventricular fibrillation (cardiac arrest victims have no water in the lungs). In the presence of lifeguards, 42 percent of pediatric submersion victims in Seattle public swimming pools died. They use m-to-m/CPR only.[46,47]

American Heart Association (AHA) Guidelines, 1986 to 1993, recommend using the Heimlich maneuver for drowning to remove foreign matter from the airway and "if the victim does not respond appropriately to mouth-to-mouth ventilation." The American Red Cross instructs to use the Heimlich maneuver after the chest does not rise with two breaths. No instructions are given as to when to stop m-to-m if the chest rises, which can occur as water is pushed deeper into the airway. Paramedics often continue m-to-m/CPR for 25 minutes, even though there is neither response nor recovery; hypoxic brain damage results.

It takes 173 ml of fluid (a half cup) to fill and completely obstruct the tracheobronchial tree. Salt water is never absorbed. Fresh water is never absorbed from the tracheobronchial tree, and its absorption from the alveoli ceases after cardiac arrest. Consequently, absorption of water does not relieve hypoxia.

Laypersons are first on the scene in the vast majority of drownings. A minuscule fraction of 248,000,000 Americans are trained in CPR; 90 percent of those trained cannot perform m-to-m/CPR properly a year later. AHA instructions to use m-to-m/CPR, therefore, are of little practical value. The Heimlich maneuver is widely known. Children have learned the maneuver watching a 1-minute TV demonstration and have used it successfully. The maneuver is repeated, at most two to four times, until fluid is no longer expelled from the mouth, which takes 10 to 15 seconds.

Risk/benefit ratio: 87 percent of pulseless drowning victims survive with the Heimlich maneuver; 28 percent with m-to-m/CPR. M-to-m delays ventilation due to water in the lungs, increasing hypoxia deaths. CPR injuries caused death in 17 percent of cases, most done by physicians in hospitals. Heimlich maneuver injuries are rare. Eighty-six percent vomit with danger of aspiration after m-to-

m/CPR; 2.9 percent vomit with maneuvers. M-to-m raises fear of contagion.[18,45,46,48,49]

The Heimlich maneuver clears the airway as A of the ABC's:

1. Perform the Heimlich maneuver as the initial step in treating near-drowning victims until water no longer flows from the mouth. Two to four Maneuvers over a period of 10 to 15 seconds are sufficient. The maneuver can be performed standing in shallow water or with the victim in the supine position on the shore.

2. If recovery is not immediate, perform CPR, if necessary.

Appendix D

SUMMARY OF EDWARD PATRICK'S PRESENTATION

The Heimlich-Patrick method for treating submersion victims[8,45,46] is to first perform the Heimlich maneuver to remove fluid followed by mouth-to-mouth and chest compressions if necessary. Research supports three categories of submersion victims at the scene: those with cardiac output (a pulse) and respirationS who need neither mouth-to-mouth nor the Heimlich-Patrick method; those victims with a pulse having absorbed fresh water for whom mouth-to-mouth may deliver oxygen to the circulation; those without a pulse and thus water is in the respiratory tract, requiring the Heimlich-Patrick method.

In support of this hypothesis, Patrick and Hess presented 15 verified, serious freshwater submersions analyzed at the Patrick Institute. Analysis indicates that 7 out of 8 (87 percent) of nonbreathing submersion victims without a pulse survived without complications using the Heimlich-Patrick method while only 2 out of 7 (28 percent) survived without complications using mouth-to-mouth. One of the Heimlich-Patrick's was where mouth-to-mouth with chest compressions failed but a succeeding Heimlich maneuver was successful.

Manolios and Mackie[18] support the hypothesis: mouth-to-mouth survivals when breathing and pulse present = 90/96 (94 percent), when breathing absent and pulse present = 46/47 (98 percent), while when breathing and pulse absent = 26/119 (22 percent). Quan[47] also supports the hypothesis: with mouth-to-mouth without a pulse, survival is 8/38 (21 percent). Biggart and Bohn[50] support the hypothesis: quality survival without any treatment when there is a pulse and spontaneous respiration = 14/14 (100 percent), while with mouth-to-mouth for no pulse or respiration = 4/27 (15 percent).

Further evidence that unabsorbed fluid in the lungs causes hypoxia is provided by: Karpovich,[37] Halmagyi,[51] Safar,[10] the 1961 Stavanger symposium,[52] Swann and Karpovich,[53] Gordon and Raymond,[54] Haimson,[55] Fuller,[56,57,58] Holden,[59] Copeland,[60,61] Ohmann et al.,[62] Biggart and Bohn,[50] Gee,[63] and Giartsen.[64]

Evidence the Heimlich-Patrick method removes water blocking the airway is provided by Patrick[44] using a planned protocol, Rubin and Rubin,[42] and Werner et al.[43] During the turmoil of saving a victim of a serious submersion, it is difficult for the first responders to measure a pulse. The Heimlich-Patrick method safely resolves the problem.

Analysis of verified submersions using Statistical Pattern Recognition (with a feature list consisting of over 50 variables) must continue--estimating outcome probabilities in terms of selected sets of independent variables.

Appendix E

SUMMARY OF ERIC SPLETZER'S PRESENTATION

In 90 percent of drownings, the penultimate event is an inhalative gasp flooding the lungs with fluid. Eight-five percent of drowning victims aspirate up to 10 ml of fluid per pound of bodyweight (1.5 L in a 150-lb adult); 15 percent aspirate more.[32] It takes 173 ml of fluid to completely fill and block the adult tracheobronchial tree.[65]

The nature of the aspirated fluid determines its fate. Salt water is not absorbed and draws fluid into the lungs;[66,67] fresh water is rapidly absorbed into the bloodstream from the alveoli until cardiovascular circulation ceases. Fluid absorption from the alveoli does not remove fluid from the trachea, bronchi, or bronchioles.

Hypoxia, the reason for drowning death, is caused by a combination of reflex terminal airway closure, changes in pulmonary surfactant activity, and/or blockage of the air passages. Of these causes of hypoxia, only airway blockage can be treated in the field.

Emergency resuscitation of the drowning victim requires adequate alveolar ventilation to rapidly restore normal blood oxygen levels;[10] therefore, a clear path from the mouth to the alveoli is a prerequisite for effective ventilation.

Karpovich[37] reported that the sole difference between rats that survived drowning, and those that died, was that the airways of nonsurvivors were always blocked with fluid and foam. Experimentally, intermittent positive-pressure breathing (mouth-to-mouth) has been shown to reoxygenate only after drainage of the lungs.[67,68,69,70]

The only rapid, efficient methods of removing fluid from the lungs are endotracheal suctioning, Trendelenburg gravity drainage with endotracheal intubation, and the Heimlich maneuver. The latter two methods have been shown to remove alveolar fluid.[43,44] Patrick showed that the Heimlich maneuver expels lung fluid that could not be removed by endotracheal suctioning. Both suctioning and gravity drainage require endotracheal intubation; for rescuers to use these techniques, special equipment and advanced training are needed. The Heimlich maneuver (which takes 10 to 15 seconds to expel intrapulmonary fluids) is available to anyone, even lay rescuers, with minimal training (1 minute). Complications of the Heimlich maneuver are infrequent and usually due to improper application of the technique.

The sole basis for current "no drainage" recommendations is a 1962 study which showed postural drainage is ineffective for removing fluid from the lungs.[42] Subsequent development of new drainage methods, shown experimentally to be efficacious, obviate "no drainage" recommendations. Solid foreign body airway obstruction is readily recognized and treated. Fluid obstruction does not preclude chest movement during attempted ventilation, but still prevents oxygenation. To avoid unwarranted delay in providing effective ventilation, expulsion of water from the lungs, using the Heimlich maneuver, should be the first step in drowning resuscitation.

Appendix F

GUIDELINES FOR CARDIOPULMONARY RESUSCITATION AND EMERGENCY CARDIAC CARE (AMERICAN HEART ASSOCIATION)

Near Drowning

The most important consequence of prolonged underwater submersion without ventilation is hypoxemia. The duration of hypoxia is the critical factor in determining the victim's outcome. Therefore, restoration of ventilation and perfusion should be accomplished as rapidly as possible.

Basic Life Support Rescue from the Water

When attempting to rescue a near-drowning victim, the rescuer should get to the victim as quickly as possible, preferably with some conveyance (boat, raft, surfboard, or flotation device). The rescuer must always be aware of personal safety in attempting a rescue and should exercise caution to minimize danger.

Rescue Breathing

Initial treatment of the near-drowning victim consists of rescue breathing with the mouth-to-mouth technique. Rescue breathing should be started as soon as the victim's airway can be opened and protected and the rescuer's safety can be ensured. This is usually when the victim is in shallow water or out of the water.

Appliances (such as a snorkel for the mouth-to-snorkel technique or buoyancy aids) may permit specially trained rescuers to perform rescue breathing in deep water. However, rescue breathing should not be delayed for lack of such equipment if it can otherwise be provided safely. Untrained rescuers should not attempt to use such adjuncts.

In a diving accident, neck injury should be suspected. The victim's neck should be supported in a neutral position (without flexion or extension), and the victim should be floated supine on a back support before being removed from the water. If the victim must be turned, the head, neck, chest, and body should be aligned, supported, and turned as a unit to the horizontal, supine position. If artificial respiration is required, rescue breathing should be provided with the head maintained in a neutral position; that is, jaw thrust without head tilt or chin lift without head tilt should be used.

Immediate ventilation and rescue breathing should be initiated if the submersion victim is not breathing. Management of the airway and ventilation of the submersion victim are similar to those of any victim in cardiopulmonary arrest. There is no need to clear the airway of aspirated water. However, rescuers may need to remove debris, gastric contents, or other foreign materials using standard techniques for obstructed airways. Usual airway management with adjuncts, such as bag-mask ventilation and intubation, can be accomplished in the near-drowning victim.[5,48] At most only a modest amount of water is aspirated by the majority of both freshwater and seawater drowning victims, and it is rapidly absorbed from the lungs into the circulation.[29] Furthermore, 10 percent to 12 percent of victims do not aspirate at all because of laryngospasm or breath-holding.[29,30] An attempt to remove water from the breathing passages by any means other than suction is usually unnecessary and apt to be dangerous because it may eject gastric contents and cause aspiration.[30]

A Heimlich maneuver delays initiation of ventilation and breathing. Its value is not proven scientifically and is supported only by anecdotal evidence, and its risk-benefit ratio is untested. Therefore, a Heimlich maneuver should be used only if the rescuer suspects that foreign matter is obstructing the airway or if the victim does not respond appropriately to mouth-to-mouth ventilation. Then, if necessary, CPR should be reinstituted after the Heimlich maneuver has been performed.[5,6,44] The Heimlich maneuver is performed on the near-drowning victim as described in the treatment of foreign-body airway obstruction (unconscious supine), except that in near drowning the victim's head should be turned sideways unless cervical trauma is suspected.

Chest Compressions

Chest compressions should not be attempted in the water unless the rescuer has had special training in techniques in in-water CPR, because the brain is not perfused effectively unless the victim is maintained in the horizontal position and the back is supported. It is usually not possible to keep the victim's body horizontal and the head above water in position for rescue breathing.

After removal from the water, the victim must be immediately assessed for adequacy of circulation. The pulse may be difficult to appreciate in a near-drowning victim because of peripheral vasoconstriction and a low cardiac output. If a pulse cannot be felt, chest compressions should be started at once.

Advanced Cardiac Life Support

The near-drowning victim in cardiac arrest should be given advanced cardiac life support (ACLS) including intubation without delay. Every submersion victim, even one who requires only minimal resuscitation and regains consciousness at the scene, should be transferred to a medical facility for follow-up care. It is imperative that the monitoring of life support measures be administered if it is available in the transport vehicle, since pulmonary injury may develop up to several hours after submersion. Although survival is unlikely in victims who have undergone prolonged submersion and require prolonged resuscitation,[5] successful resuscitation with full neurological recovery has occurred in near-drowning victims with prolonged submersion in extremely cold water.[71,72,73] Since it is often difficult for rescuers to obtain an accurate time of submersion, attempts at resuscitation should be initiated by rescuers at the scene unless there is obvious physical evidence of death (such as putrefaction, dependent lividity, or rigor mortis). The victim should be transported with continued CPR to an emergency facility where a physician can decide whether to continue resuscitation. Aggressive attempts at resuscitation in the hospital should be continued for the victim of cold water submersion.

References

1. National Safety Council. Accident Facts. Washington, DC. 1990.

2. American Heart Association. Standards and guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiac care (ECC): special resuscitation situations. JAMA 1992;26:2242-50.

3. Heimlich HJ. A life-saving maneuver to prevent food-choking. JAMA 1975;234:398-416.

4. Heimlich HJ, Hoffmann KA, Canestri FR. Food-choking and drowning deaths prevented by external subdiaphragmatic compression. Ann Thorac Surg 1975;20:188-95.

5. Heimlich HJ. Subdiaphragmatic pressure to expel water from the lungs of drowning persons. Ann Emerg Med 1981;10:476-80.

6. Heimlich HJ. The Heimlich maneuver: first treatment for drowning victims. Emerg Med Serv 1981;10:58-60.

7. Heimlich HJ, Uhley MH. The Heimlich maneuver. Clin Symp 1979;31:1-32.

8. Heimlich HJ, Patrick EA. Using the Heimlich maneuver to save near-drowning victims. Postgrad Med J 1988;84:62-73.

9. Leroy-D'Etoilles J. Recherches sur l'asphyxie. J Physiol Exp Pathol 1827;8:97.

10. Safar P, Escarraga LA, Elam JO. A comparison of mouth-to-mouth and mouth-to-airway methods of artificial respiration with the chest-pressure arm-lift methods. N Engl J Med 1958;258:671.

11. Redding JS. Drowning and near drowning: can the victim be saved? Postgrad Med J 1983;74:85-97.

12. Heimlich HJ. Pop goes the cafe coronary. Emerg Med 1974;6:154-5.

13. American Heart Association. Standards and guidelines for cardiopulmonary resuscitation (CPR) and emergency cardiac care (ECC): special resuscitation situations. JAMA 1986;255:2929.

14. Institute of Medicine. A review of wet vs. dry lungs, the Heimlich maneuver, and in-water rescue breathing. Washington, DC: National Academy Press. 1991.

15. Brenner RA, Smith GS, Overpeck MD. Divergent trends in childhood drowning rates, 1971 through 1988. JAMA 1994;271:1606-8.

16. Ornato, JP. The resuscitation of near-drowning victims [review]. JAMA 1986;258:512-3.

17. Gordon BD, Terranova GJ. Heimlich maneuver in cold-water drowning. Conn Med 1981;45:775-6.

18. Manolios N, Mackie I. Drowning and near-drowning on Australian beaches patrolled by life-savers: a 10-year study, 1973-1983. Med J Aust 1988;148:165-71.

19. Van der Ham AC, Lange JF. Traumatic rupture of the stomach after Heimlich maneuver. J Emerg Med 1990;8:713-5.

20. Razaboni RM, Brathwaiten CE, Dwyer WA. Ruptured jejunum following Heimlich maneuver. J Emerg Med 1986;4:95-8.

21. Chapman JH, Menapace FJ, Howell RR. Ruptured aortic valve cusp: a complication of the Heimlich maneuver. Ann Emerg Med 1983;12:446-8.

22. Meredith MJ, Liebowitz R. Rupture of the esophagus caused by the Heimlich maneuver. Ann Emerg Med 1986;15:106-7.

23. Valero V. Mesenteric laceration complicating a Heimlich maneuver. Ann Emerg Med 1986;15:105-6.

24. Roehm EF, Twiest MW, Williams RC. Abdominal aortic thrombosis in association with an attempted Heimlich maneuver. JAMA 1983;249:1186-7.

25. Fink JA, Klein RL. Complications of the Heimlich maneuver. J Emerg Med 1989;7:486-7.

26. Redding JS. The choking controversy: critique of evidence on the Heimlich maneuver. Crit Care Med 1979;7:475-9.

27. Orlowski JP. Vomiting as a complication of the Heimlich maneuver. JAMA 1987;258:512-3.

28. Modell JH. Drowning. N Engl J Med 1993;4:253-6.

29. Modell JH, Davis JH. Electrolyte changes in human drowning victims. Anesthesiology 1969;30:414-20.

30. Modell JH. Is the Heimlich maneuver appropriate as first treatment for drowning? Emerg Med Serv 1981;10:63-6.

31. Modell JH, Graves SA, Ketover J. Clinical course of 91 consecutive near-drowning victims. Chest 1976;70:231-8.

32. Modell JH. Ventilation/perfusion changes during mechanical ventilation. Dis Chest 1969;55:447-51.

33. Harries MG. Drowning in man. Crit Care Med 1981;9:407-8.

34. Quan L. Drowning issues in resuscitation. Ann Emerg Med 1993;22:366-9.

35. Knopp RK. Near-Drowning. In: Rosen P, et al., eds. Emergency medicine: concepts and clinical practice. 3rd ed. St. Louis: Mosby Year Book, 1992:1013-9.

36. Pearn J. Drowning. In: Smith. The critically ill child: diagnosis and management. 3rd ed. Philadelphia: WB Saunders, 1985:129-56.

37. Karpovich PV. Water in the lungs of drowned animals. Arch Pathol 1933;15:828-33.

38. Emerson H. Artificial respiration in the treatment of edema of the lungs: a suggestion based on animal experimentation. Arch Int Med 1909;3:368-71.

39. Barach AL, Martin J, Eckman M. Positive-pressure respiration and its application to the treatment of acute pulmonary edema. Ann Int Med 1938;12:784-96.

40. Ashbaugh DG, Petty TL, Bigelow DB, Harris TM. Continuous positive-pressure breathing (CPPB) in adult respiratory disease syndrome. J Thorac Cardiovasc Surg 1969;57:31-41.

41. Tutuncu A, Faithfull S, Lachmann B. Comparison of ventilatory support with intratracheal perfluorocarbon administration and conventional mechanical ventilation in animals with acute respiratory failure. Am Rev Respir Dis 1993;148:785-92.

42. Ruben A, Ruben H. Artificial respiration: flow of water from the lung and the stomach. Lancet 1962;1:780-1.

43. Werner JZ, Safar P, Bircher NG, Stezoski W, Scanlon M, Stewart RD. No improvement in pulmonary status by gravity drainage or abdominal thrusts after sea water near drowning in dogs. Anesthesiology 1982;57(Suppl 3A):A81. Abstract.

44. Patrick EA. A case report: the Heimlich maneuver. Emerg Med 1981;13:45-7.

45. Patrick EA, Hess, PM. Individualized outcome analysis of treating submersion victims with mouth-to-mouth vs the Heimlich Patrick method. Unpublished. 1993.

46. Quan L, Gore EJ, Wentz K, Allen J, Novack AH. Ten-year study of pediatric drownings and near-drownings in King County, Washington: lessons in injury prevention. Pediatrics 1989;6:1035-40.

47. Quan L, Wentz KR, Gore EJ, Copass MK. Outcome and predictors of outcome in pediatric submersion victims receiving prehospital care in King County, Washington. Pediatrics 1990;4:586-93.

48. Enarson DA, Gracey DR. Complications of cardiopulmonary resuscitation. Heart Lung 1976;5:805-6.

49. Paaske F, Hart Hanson JP, Kondahl G, Olsen J. Complications of closed chest cardiac massage in forensic autopsy material. Dan Med Bull 1968;15:225-30.

50. Biggart MJ, Bohn DJ. Effect of hypothermia and cardiac arrest on outcome of near-drowning accidents in children. J Pediatr 1990;117:179-83.

51. Halmagyi DFJ, Colebatch HJH. Ventilation and circulation after fluid aspiration. J Appl Physiol 1961;16:35-40.

52. Symposium on Ventilatory and Circulatory Resuscitation. Concluding discussion: Wednesday, August 23, 1961. Acta Anaesthesiol Scand (Suppl) 1961;9:156-68.

53. Swann HE Jr, Karpovich PV, Dill DB. Ineffectiveness of artificial respiration in rats after drowning. J Appl Physiol 1953;5:429-31.

54. Gordon AS, Raymond F, Ivy AC. Drowning phenomena in various species. Fed Proc 1954;13:58.

55. Haimson N. A suggested modification in treatment of apparent drowning of SCUBA divers [letter]. Med J Aust 1973;1:83.

56. Fuller RH. Drowning and the postimmersion syndrome: clinicopathologic study. Mil Med 1963;128:22-36.

57. Fuller RH. The clinical pathology of human near-drowning. Proc R Soc Med 1963;56:33-8.

58. Fuller RH. The clinical pathology of human near-drowning. Proc R Soc of Med 1963;56:33-8.

59. Holden JA, Lumpkin JR, Richards MS. Vital records in the development of injury control research. Ann Emerg Med 1989;18:286-92.

60. Copeland AR. An assessment of lung weights in drowning. Am J Forensic Med Pathol 1985;6:301-4.

61. Copeland AR. Homicidal drowning. 1986. Forensic Sci Int 1986;13:247-52.

62. Ohmann C, Dick W, Lotz P, Ludes A, Schindewolf KH, Bowdler I. An experimental study of respiratory reanimation of piglets following standardized near-drowning in fresh or salt-water. Resuscitation 1981;9:297-306.

63. Gee DJ. Drowning. In: Polson CJ, Gee DJ, Knight B., eds. The essentials of forensic medicine. Oxford: Pergamon, 1985:421-48.

64. Giartsen JC. Drowning. In: Tedeschi CG, Eckert WG, Tedeschi LG, eds. Forensic medicine. Philadelphia: Saunders, 1977:1317-32.

65. International Commission on Radiological Protection. 1975: Group on Reference Man. Respiratory system. In: Report of the Task Groups on Reference Man: a report prepared by a task group of Committee 2 of the International Commission on Radiological Protection. New York: Pergamon, 1975:151-73.

66. Redding JS, Voight GC, Safar P. Treatment of sea-water aspiration. J Appl Physiol 1960;15:1113-6.

67. Modell JH, Calderwood HW, Ruiz BC, Downs JB, Chapman R. Effects of ventilatory patterns on arterial oxygenation after near-drowning in sea water. Anesthesiology 1974;40:376-384.

68. Redding JS, Cozine RA. Restoration of circulation after fresh water drowning. J Appl Physiol 1961;16:1071-1074.

69. Redding J, Voigt GC, Safar P. Drowning treated with intermittent positive pressure breathing. J Appl Physiol 1960;15:849-54.

70. Redding JS, Cozine RA, Voigt GC, Safar P. Resuscitation from drowning. JAMA 1961;178:1136-9.

71. Southwick FS, Dalglish PH Jr. Recovery after prolonged asystolic cardiac arrest in profound hypothermia: a case report and literature review. JAMA 1980;243:1250-3.

72. Siebke H, Rod T, Breivik H, Lind B. Survival after 40 minutes' submersion without cerebral sequelae. Lancet 1975;1:1275-7.

73. Bolte RG, Black PG, Bowers RS, Thorne JK, Corneli HM. The use of extracorporeal rewarming in a child submerged for 66 minutes. JAMA 1988;260:377-9.