

Effect of Immediate Resuscitation on Children With Submersion Injury

Demetrios N. Kyriacou, MD, MPH*; Edgardo L. Arcinue, MD‡; Corinne Peek, MPH§; and
Jess F. Kraus, PhD, MPH||

ABSTRACT. *Study objective.* To determine the effect of immediate resuscitative efforts on the neurological outcome of children with submersion injury.

Design. A case-control study was designed to determine if immediate resuscitation by rescuers or bystanders reduces the frequency of severe neurological damage or death in children with a documented submersion event. Logistic regression was used to calculate an adjusted odds ratio.

Participants. The study group consisted of 166 children, aged zero to 14 years, having a submersion event during May 1984 through August 1992, and admitted through various emergency departments to Huntington Memorial Hospital in Pasadena, California.

Measurements and main results. All study subjects had an observed and documented episode of apnea at the time of submersion. Outcomes were evaluated on the basis of neurological impairment or death. Exposure was verified from historical accounts of postsubmersion events provided by family, friends, and/or paramedical personnel. The study factors included age and gender, duration of submersion, hypothermia, presence of apnea, resuscitative efforts, and clinical outcome. Children with a good outcome were 4.75 (adjusted odds ratio (OR)) times more likely to have a history of immediate resuscitation than children with poor outcome (95% confidence interval: $3.44 < OR < 6.06$, $P = .0001$). Various types of resuscitative efforts and potential confounding factors were also evaluated. CPR and mouth-to-mouth resuscitation were the most effective types for the prevention of death or severe anoxic encephalopathy.

Conclusion. Immediate resuscitation before the arrival of paramedical personnel is associated with a significantly better neurological outcome in children with submersion injury. *Pediatrics* 1994;94:137-142; drowning, resuscitation, submersion injury.

ABBREVIATIONS. CI, confidence interval; OR, odds ratio.

Aquatic submersion is a leading cause of injury morbidity and mortality in children. In the United States, drowning is second only to motor vehicle crash injuries as the most common cause of injury death in all children aged zero to 14 years.¹⁻³ In many states, submersion is the leading cause of injury death for children aged 1 to 5 years.^{2,3} In addition, morbidity from submersion occurs in 12% to 27% of survivors in the studies reviewed.⁴⁻¹⁰ Preschool-aged male children are at greatest risk of submersion injury and residential swimming pools the most common submersion site in this age group.²⁻¹⁰

The most important consequence of submersion injury is hypoxemia and its effect on the brain. Hypoxemia results from the shunting of blood through nonventilated alveoli of the lungs. Therefore, immediate restoration of effective pulmonary ventilation at the earliest opportunity is imperative. Since hypoxemia increases rapidly during apnea, even a few minutes of delay in commencing treatment may be critical to recovery of normal brain function.¹⁰⁻¹⁹

Paramedical personnel provide emergency resuscitation for submersion victims, but their arrival to the patient is often delayed. For example, in a study of pediatric submersion victims receiving prehospital care in King County, WA, the estimated elapsed time between the incident and the arrival of paramedical personnel was greater than 10 minutes in 91% of the victims (range of 7 to 64 minutes).²⁰

Unfortunately, the lack of CPR training of rescuers and bystanders often results in submersion victims waiting for the arrival of paramedical personnel before resuscitative efforts are initiated. Wintemute

From the *Olive View/UCLA Medical Center, Department of Emergency Medicine, Sylmar, California; †Huntington Memorial Hospital, Department of Pediatrics, Pasadena, California; ‡Southern California Injury Prevention Research Center, UCLA School of Public Health; and §Southern California Injury Prevention Research Center, UCLA School of Public Health. Presented at the Second World Conference on Injury Control, Atlanta, GA, May 1993.

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Reprint requests to (D.N.K.) Assistant Professor of Medicine, Department of Emergency Medicine, Olive View/UCLA Medical Center, 14445 Olive View Drive, Sylmar, CA 91342.

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et al found in 38% of childhood submersion deaths the child was retrieved from the water by a lay person (often a family member) who was unfamiliar with life-saving techniques. Resuscitation was delayed until the arrival of paramedical personnel or never begun at all.⁵

Although extensive clinical evidence suggests pediatric submersion victims receiving immediate resuscitation have a markedly better clinical outcome, there is little epidemiologic data concerning the effect of immediate resuscitation by rescuers or bystanders on neurological outcome. This study was undertaken to determine this effect.

METHODS

A case-control study was undertaken to test the hypothesis that immediate resuscitation reduces the frequency of neurological damage or death in children with submersion injury. A description of the study population, exposures, and outcomes are provided, followed by the measured effect of immediate resuscitation determined through a case-control approach.

Sources of Information

The study group consisted of 166 children, aged zero to 14 years, who had a submersion event which resulted in apnea or significant altered respiration (defined as incompatible with life) at the time of recovery. The subjects were admitted through various emergency departments to the Department of Pediatrics at Huntington Memorial Hospital in Pasadena, CA from May 1984 through August 1992. Subjects were selected through a computer search of the inpatient hospital medical files and identified by ICD-9 code.

A review of the medical charts provided information concerning the submersion event, presence of apnea, immediate resuscitative efforts, and clinical outcome. Other factors which might affect resuscitation and outcome (such as age, gender, race, duration of submersion, and hypothermia) were also examined for their roles as potentially confounding variables.

Setting

All the subjects sustained fresh water submersion in the San Gabriel Valley area of the County of Los Angeles. Given the geography and climate of the Los Angeles area, it is unlikely subjects were exposed to icy (<5°C) waters. There is, however, a mountainous region in the Angeles Crest National Forest north of the San Gabriel Valley which has snow in the upper altitudes during the winter months.

Definition of Cases and Controls (Outcome Variable)

The design of this study is simplified by the very distinct clinical outcomes of submersion injury victims. Previous studies have shown that submersion victims fall into four clinically distinct long-term outcome groups: neurologically normal survivors; survivors with mild anoxic encephalopathy; survivors with severe anoxic encephalopathy; and death.^{3,4,6,8-10,12,13,21,22} Severe anoxic encephalopathy is characterized by permanent vegetative state with no self-help skills and little or no meaningful interaction. Mild encephalopathy is characterized as ataxia and/or spasticity, but with normal or near normal cognitive functions.

Cases were defined as children having a "poor" outcome (severe anoxic encephalopathy or death) and controls were defined as subjects having a "good" outcome (neurologically normal or mild anoxic encephalopathy). Clinical classification was made at the time of discharge from the hospital. The distinct separation of clinical outcome groups reduced the possibility of misclassification. A similar classification has been used in a previous study examining predictors of outcome in pediatric submersion injuries.²⁰

Definition of Immediate Resuscitation (Predictor Variable)

Immediate resuscitation was defined as any action taken by rescuers or bystanders to restore respiration and revive the subject

upon immediate retrieval from the submersed position. This is in contrast to delayed resuscitation where the subject's treatment is initiated by paramedical personnel.

Resuscitative efforts were categorized into four groups (Groups I, II, III, and IV) based on the description of the actions and efforts provided in the patient's medical record. Group I patients received CPR or mouth-to-mouth resuscitation (CPR is defined as mouth-to-mouth resuscitation plus chest compressions). Group II patients received chest, back, and/or abdominal compressions, but not mouth-to-mouth ventilation. Group III patients received tactile stimulation and/or positioning of the body (for example, a patient was found submersed and apneic in a bath tub by her father, held in an inverted position, and repeatedly slapped on the back until she vomited and began spontaneous respirations). Group IV patients received no resuscitative action or effort; they were merely rescued from their submersed position and left to await the arrival of paramedical personnel.

Duration of Submersion

The time period of submersion, when provided, was usually given by family members or bystanders as an approximation or estimated range of time. This variable was categorized into four intervals that were most often used to describe this time period: less than 1 minute; 1 to 5 minutes; 5 to 10 minutes; and greater than 10 minutes.

Hypothermia

Subjects were defined as hypothermic if they had an initial recorded temperature of 33°C or less in the emergency department or pediatric intensive care unit. No attempt was made to estimate water temperatures where the submersion events occurred.

Statistical Analyses

Statistical analyses were performed using Epi Info and SAS System microcomputer software statistical programs. Crude odds ratios were calculated to determine the relationships between immediate resuscitation and clinical neurological outcome. Chi-square analyses were conducted to estimate the strength of the relationships.

Additional analyses, including analyses of variances, were performed to evaluate potential confounding factors which might distort the outcome measure following immediate resuscitative efforts. A logistic regression model was developed to control for potential confounding factors and calculate an adjusted odds ratio.

RESULTS

Of the 166 study subjects, 105 (63.3%) were males and 61 (36.7%) were females. The age range was 6 to 154 months, with a mean of 35.6 months and a median of 26 months. Eighty-seven percent were under the age of 5 years (Table 1). The majority of submersion events occurred in private residential swimming

TABLE 1. Study Population Demographic Characteristics, Total Study Group 166

	Controls N = 136	Cases N = 30	Total
Age (years)			
<1	8 (5.9%)	2 (6.7%)	10 (6.0%)
1 to 4	109 (80.1%)	26 (86.7%)	135 (81.3%)
5 to 9	13 (9.6%)	2 (6.7%)	15 (9.0%)
9 to 14	6 (4.4%)	0 (0.0%)	6 (3.6%)
Gender			
Male	91 (66.9%)	14 (46.7%)	105 (63.3%)
Female	45 (33.1%)	16 (53.3%)	61 (36.7%)
Race			
White	69 (50.7%)	14 (46.7%)	83 (50.0%)
Asian	21 (15.4%)	8 (26.7%)	29 (17.5%)
Hispanic	22 (16.2%)	6 (20.0%)	28 (16.9%)
Black	24 (17.6%)	2 (6.7%)	26 (15.7%)

pools, followed by bath tubs, spas, and public pools, with only a few cases occurring in buckets, rivers, lakes, or ponds (Table 2). The subject's mother was the most frequent rescuer, and was also the most frequent provider of immediate resuscitation (Table 3).

One hundred and twenty-four (74.7%) subjects had completely normal neurological outcome, 12 (7.2%) subjects had mild anoxic encephalopathy, eight (4.8%) subjects had severe anoxic encephalopathy, and 22 (13.3%) subjects died prior to discharge from the hospital. Thirty-three children arrived in the emergency department in cardiopulmonary arrest. Of these, 29 had a poor clinical outcome; 21 died and eight had severe anoxic encephalopathy. Only four children with cardiopulmonary arrest in the emergency department survived with a good clinical outcome; all four with mild anoxic encephalopathy, one improving to normal prior to discharge from the hospital.

One hundred and forty-eight (89.2%) children received some type of immediate resuscitative intervention: 125 (75.3%) received CPR or mouth-to-mouth resuscitation (Group I), 13 (7.8%) received chest, back, and/or abdominal compressions (Group II), and 10 (6.0%) received only tactile stimulation or positioning (Group III). Eighteen (10.8%) children received no resuscitative intervention (Group IV).

Overall, any type of immediate resuscitation displayed a significant association with good clinical outcome (Table 4, crude odds ratio = 4.58, 95% confidence interval (CI): 1.45 < OR < 14.45, $P = .0021$). The different types of immediate resuscitation, when compared to no immediate resuscitation, were also contrasted with outcome (Table 5). The clinical outcome of children receiving CPR or mouth-to-mouth resuscitation (Group I) was significantly better than children receiving no resuscitation (Group IV). Groups II and III, however, were not large enough to be statistically different from Group IV. In addition, Group III had no "poor" outcomes, making calculation of an odds ratio for this group untenable.

An analysis of duration of submersion versus clinical outcome revealed a very significant association

TABLE 2. Location of Submersion Event

Private pool	121 (72.9%)
Bath tub	20 (12.0%)
Spa	13 (7.8%)
Public pool	7 (4.2%)
Bucket	3 (1.8%)
River/lake/pond	2 (1.2%)

TABLE 3. Rescuer and Immediate Resuscitation Provider

	Rescuer	Provider
Mother	48 (29.5%)	46 (27.7%)
Father	29 (17.5%)	28 (16.9%)
Grandparent/ aunt/uncle	25 (15.1%)	27 (16.3%)
Neighbor/friend	20 (12.0%)	22 (13.3%)
Sibling/cousin	9 (5.4%)	0 (0.0%)
Lifeguard/paramedic	7 (4.2%)	5 (3.0%)
Caretaker/sitter	6 (3.6%)	4 (2.4%)
Unknown or no resuscitation	22 (13.3%)	34 (20.5%)

TABLE 4. Immediate Resuscitation and Clinical Outcome

	Clinical Outcome		Total
	Good	Poor	
Any resuscitation (Groups I-III)	126 (85.1%)	22 (14.9%)	148
No resuscitation (Group IV)	10 (55.6%)	8 (44.4%)	18
Total	136 (81.9%)	30 (18.1%)	166

Chi square = 9.48; $P = 0.0021$; crude odds ratio = 4.58 (1.45 < OR < 14.45).

between these two variables. Longer submersion periods were clearly related to poor outcomes (Table 6, $P < .0001$). However, there was no apparent association between the duration of submersion and the initiation of immediate resuscitative efforts ($P = .37$).

Hypothermia was strongly associated with poor clinical outcome (Table 7, $P < .0001$). This variable, however, was also strongly associated with duration of submersion (Table 8, $P < .0001$).

The mean age for good outcome was 37.4 months (median = 27 months), and the mean age for poor outcome was 27.1 months (median = 21 months). This difference was not statistically significant ($P = .64$). In addition, there was no statistical age difference between the two outcome subgroups and the initiation of immediate resuscitation ($P = .32$).

Although male subjects had a better overall clinical outcome versus female subjects (OR = 2.31, 95% CI: 0.97 < OR < 5.55, $P = .04$), there was no association between the subjects' gender and the initiation of resuscitation ($P = .84$).

No independent association existed between final clinical outcome and race, location, rescuer, or provider. Seven patients had pre-existing neurological disorders, including, Down Syndrome, cerebral palsy, autism, and seizure disorder. All of these patients had good clinical outcomes and returned to their normal premorbid neurological level of function after the submersion event.

By using a logistic regression statistical model to control for age, gender, duration of submersion, and hypothermia, children with good outcomes were 4.75 (adjusted OR) times more likely to have a history of immediate resuscitation than children with poor outcomes (95% CI: 3.44 < OR < 6.06, $P = .0001$).

DISCUSSION

In the late 1950s, a series of comparative studies established the superiority of the mouth-to-mouth technique of artificial respiration over manual methods. These studies showed that mouth-to-mouth resuscitation, as a form of intermittent positive pressure breathing, could easily provide a ventilatory tidal volume of 1000 to 2000 ml. This was two to three times the maximum measured tidal volume of 400 to 700 ml provided by manual techniques, which often were unable to provide any measurable inspiration.²³⁻²⁸ For over 30 years, mouth-to-mouth resuscitation has been the standard first aid artificial respiration treatment for asphyxiated children and adults, particularly useful in submersion victims. The purpose of artificial respiration is to restore

TABLE 5. Type of Immediate Resuscitation and Clinical Outcome

	Clinical Outcome		Total	OR	CI	P value
	Good	Poor				
Group I	108 (86.4%)	17 (13.6%)	125	5.08	(1.56 < CI < 16.64)	0.0013
Group II	8 (61.2%)	5 (38.5%)	13	1.28	(0.24 < CI < 7.02)	0.7390
Group III	10 (100.0%)	0 (0.0%)	10	N/A	N/A	
Group IV	10 (55.6%)	8 (44.4%)	18	N/A	N/A	
Total	136 (81.9%)	30 (18.1%)	166			

effective pulmonary ventilation and reverse the physiologic effects of hypoxemia and acidemia on susceptible end organs.

This study demonstrates the beneficial effect of immediate resuscitation artificial respiration for submersion victims. Although CPR or mouth-to-mouth resuscitation (Group I) were found to be superior to thoracic or abdominal compression techniques (Group II), these methods were more effective than no resuscitative intervention at all (Group IV). All patients receiving tactile stimulation or positioning (Group III) demonstrated good clinical outcomes. However, this sample size was very small and most of these children had short (less than 5 minutes) submersion periods. Overall, the increase in good outcome among children with a history of immediate resuscitation is driven predominantly by Group I, because Groups II and III have too few subjects to be statistically predictive.

Few epidemiologic studies exist concerning the effects of immediate resuscitation prior to the arrival of paramedical personnel. Quan et al, in a study of 135 pediatric submersion victims, found that cardiopulmonary resuscitation by bystanders was not associated with improved outcome.²⁰ In another study, Frates examined prognostic predictive factors of 42 warm water pediatric submersion victims and found that an estimated delay in cardiopulmonary resuscitation of greater than 15 minutes was not a significant factor in the clinical outcome.²⁹ Neither of these studies, however, clearly defined the type or timing of the resuscitation. In contrast, Orłowski's study reviewing the prognostic factors in pediatric drownings and near-drownings concluded that the early institution of resuscitative efforts (defined as less than 10 minutes after rescue from submersion) was "the single most important factor influencing survival."³⁰

In comparison with adults, multiple studies evaluating bystander CPR have shown a beneficial effect of similar magnitude on the survival of adult cardiac arrest victims.³¹⁻³⁵ Moreover, bystander CPR resulted in significantly less neurologic impairment in these adult patients.^{36,37}

Another variable associated with clinical outcome is duration of submersion. Prolonged submersion is strongly associated with poor outcome. However, since most submersion events were not witnessed, actual reported time periods of submersion were estimates at best. Often, these estimates were based on the time period since the child was lost to attention. In addition, estimates of elapsed time during frantic search and rescue efforts by family and friends were subject to recall bias.

TABLE 6. Duration of Submersion and Clinical Outcome

	Clinical Outcome		Total
	Good	Poor	
<1 minute	26 (100.0%)	0 (0.0%)	26
1 to <5 minutes	59 (92.2%)	5 (7.8%)	64
5 to <10 minutes	21 (61.8%)	13 (38.2%)	34
10+ minutes	3 (37.5%)	5 (62.5%)	8
Total	109 (82.6%)	23 (17.4%)	132

Chi square = 31.13; *P* < 0.00001.

TABLE 7. Hypothermia and Clinical Outcome

	Clinical Outcome		Total
	Good	Poor	
Hypothermic	11 (40.7%)	16 (59.3%)	27
Nonhypothermic	125 (89.9%)	14 (10.1%)	139
Total	136 (81.9%)	30 (18.1%)	166

Chi square = 36.94; *P* < 0.00001; odds ratio = 12.99 (4.59 < OR < 37.57).

Although accurate determination of the duration of submersion is difficult, the strength of the association between prolonged submersion and poor clinical outcome suggest that, at some period of time, death or severe anoxic encephalopathy is inevitable. This conclusion is consistent with clinical evidence relating duration of anoxia with degree of neurologic injury in both children and adults.

Hypothermia was also associated with poor clinical outcome. This factor, however, is closely related to the duration of submersion. The protective effect of icy (<5°C) water on pediatric victims with prolonged (greater than 30 minutes) submersion is well documented.^{12-14,38-40} Since all submersion events in this study took place in the temperate climate of Southern California, where icy water is not common, the environmental conditions needed to induce rapid protective hypothermia were not likely. Therefore, hypothermia in this study group was predominantly the result of prolonged submersion in nonicy waters.

One child in this study may have benefitted from the rapid hypothermic effect of icy water. This patient had a documented 35-minute submersion event in a river in the Angeles Crest mountain region of Los Angeles during the month of April. The patient received immediate CPR by the rescuer and survived with only mild ataxia at the time of discharge from the hospital. The patient's initial core temperature was 82°F. Considering the length of this submersion event, it is quite possible that this patient was protected by the rapid hypothermic effect.

TABLE 8. Duration of Submersion and Hypothermia

	Hypothermic	Nonhypothermic	Total
<1 minute	0 (0.0%)	26 (100.0%)	26
1 to <5 minutes	9 (14.1%)	55 (85.9%)	64
5 to <10 minutes	9 (26.5%)	25 (73.5%)	34
10+ minutes	6 (75.0%)	2 (25.0%)	8
Total	24 (18.2%)	108 (81.8%)	132

Chi square = 25.44; $P = 0.00001$.

Potential sources of bias in this study were the omission of two subgroups of submersion subjects from the study sample. The first subgroup consisted of subjects who sustained a mild submersion event and were discharged from the emergency department in good condition without admission to the hospital. The omission of this subgroup of submersion victims may have introduced a degree of uncertainty into our estimate of the beneficial effect of immediate resuscitation. However, because of possible neurological and pulmonary complications, almost all patients with significant submersion injury treated in emergency departments are admitted to the hospital for close observation for at least a brief time period.⁹⁻¹⁹ Therefore this omitted subgroup, however large, would not likely influence our evaluation of the effect of immediate resuscitation on significant submersion injury victims.

The second subgroup involves submersion victims that died in the emergency department prior to hospital admission. Speculation on the effect of exclusion of this subgroup of submersion victims is difficult. The failure to initiate resuscitation could result in a higher likelihood of death prior to hospital admission resulting in exclusion of this subgroup from the study sample. This bias effect could result in a lower odds ratio.

Additionally, it is possible that some of the patients initially survived their submersion event because of immediate resuscitation, but later died or suffered severe anoxic encephalopathy. The increased awareness and use of effective resuscitative techniques during the past three decades has resulted in a shifting morbidity, with fewer deaths from drowning but increased numbers of survivors with anoxic encephalopathy. The effect of this shift in morbidity is an increase in the likelihood of patients who received immediate resuscitation (but still have a poor outcome) being included in the study sample. This could also cause a decrease in the calculated odds ratio.

Clinical outcome following significant submersion injury is a result of multiple factors. The detrimental effect of hypoxemia on the brain is well established. The measured effect of immediate versus delayed resuscitation has yet to be accurately determined. This effect is dependent on numerous variables which are difficult to account for in a retrospective study. Many potential confounders were not evaluated because of the lack of information concerning these variables in the patients' medical records. For example, information regarding the level of basic life support training of the providers was not generally documented, and therefore this variable was not

evaluated. In addition, paramedic response times were not available for evaluation.

A well designed prospective study would provide information on many potentially confounding variables and would include the omitted subgroups of submersion victims. Combined with the logistic regression model developed in this retrospective study, this would eliminate many biases and produce a more accurate assessment of the effect of immediate resuscitation.

CONCLUSION

Submersion injury is a leading cause of childhood death in the United States. Immediate resuscitation prior to the arrival of paramedical personnel is associated with a better neurological outcome in patients hospitalized with submersion injury. Prolonged submersion is associated with poor neurological outcome. The decisions to initiate resuscitative efforts, and the type of resuscitative efforts to administer, are not influenced by the subject's age, gender, or duration of submersion.

This study suggests that many victims of submersion injury can have improved clinical outcomes with simple, rapid, and effective artificial respiration which should be taught to all parents, siblings, and caretakers of children. As with most retrospective studies, many potential sources of bias exist. A prospective study designed to eliminate these biases would further elucidate the protective effect of immediate resuscitation of children with submersion injury.

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DISASTER IS ONLY ONE INTERVAL AWAY

At first there is only one lily pad in the pond, but the next day it doubles, and thereafter each of its descendants doubles. The pond is completely full with lily pads in 30 days. When is the pond exactly half full with lily pads? Answer: On the 29th day.

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Submitted by Student