Predicting outcome of drowning at the scene: A systematic review and meta-analyses

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ABSTRACT

OBJECTIVE: To identify factors available to rescuers at the scene of a drowning that predict favourable outcomes.

DESIGN: Systematic review and meta-analysis

DATA SOURCES: PubMed, Embase and Cochrane Library were searched (1979-2015) without restrictions on age, language or location and references lists of included articles.

STUDY SELECTION: Cohort and case-control studies reporting submersion duration, age, water temperature, salinity, emergency services response time and survival and/or neurological outcomes were eligible. Two reviewers independently screened articles for inclusion, extracted data, and assessed quality using GRADE. Variables for all factors, including time and temperature intervals, were categorized using the those used in the articles. Random effects meta-analyses, study heterogeneity and publication bias were evaluated.

RESULTS: Twenty-four cohort studies met the inclusion criteria.

The strongest predictor was submersion duration. Meta-analysis showed that favourable outcome was associated with shorter compared to longer submersion durations in all time cutoffs evaluated: < 5-6 minutes: risk ratio [RR] =2.90;(95% confidence interval [CI]: 1.73, 4.86); < 10-11 minutes: RR =5.11 (95% CI: 2.03, 12.82); < 15-25 minutes: RR = 26.92 (95% CI: 5.06, 143.3). Favourable outcomes were seen with shorter EMS response times (RR = 2.84 (95% CI: 1.08, 7.47) and salt water versus fresh water 1.16 (95% CI: 1.08, 1.24). No difference in outcome was seen with victim’s age, water temperatures, or witnessed versus unwitnessed drownings.

CONCLUSIONS:

Increasing submersion duration was associated with worse outcomes. Submersion durations <5 minutes were associated with favourable outcomes, while those >25 minutes were invariably fatal. This information may be useful to rescuers and EMS systems deciding when to perform a rescue versus a body recovery.

**INTRODUCTION**

The World Health Organization estimates 372,000 people die annually from drowning worldwide.1 The real number is probably 2 to 5 times higher. Rescuers save many lives, but some die in the attempt.2-6 Rescuers with a duty to respond, such as firefighters, policemen and lifeguards, are trained to decide if and how to perform a rescue and to consider the safety of a rescue.7 In some situations the risk of a rescue has to be weighed against the victim’s chance of survival. Many issues affect the decision, including the safety, training and physical condition of the rescuer, environmental conditions and available resources. In some situations, the decision needs to be made to change from a rescue to a body recovery. Such a decision may have legal consequences.8 Knowing what factors might predict a favorable outcome for a drowning victim could help inform a rescuer’s decision-making in such situations.

Many drowning studies have reported on outcomes of survival with or without qualifying neurologic outcomes, evaluating demographic, scene, medical and/or treatment factors as predictors of outcome. The methodology and quality of these studies vary widely and conclusions are occasionally contradictory. There are no comprehensive systematic reviews and meta-analyses of factors associated with drowning outcomes. This study’s objective was to systematically review existing literature and conduct  meta-analyses to determine what factors known to rescuers  (age of victim, emergency medical service (EMS) response time, duration of submersion, salinity of water, water temperature, and if the event was witnessed) are associated with favorable outcomes.

**METHODS:**

This review was based on the guidelines from the International Liaison Committee for Resuscitation (ILCOR) and Grading of Recommendations Assessment, Development and Evaluation (GRADE) Working Group, then registered on the ILCOR on-line Scientific Evidence Evaluation and Review System.9-11 Meta-analyses were then conducted.

**Eligibility**
PubMed, Embase and Cochrane Library were searched systematically for studies published between 1979-2015. (Supplementary File 1) Reference lists of included articles were hand searched for additional relevant studies. Eligible studies for the systematic review were cohort and case-control studies in all languages. Studies were selected for inclusion if they reported favorable and unfavorable outcomes of drowning victims for at least one of the following six factors: (i) victim’s age, (ii) whether the drowning event was witnessed, (iii) submersion duration, (iv) salinity of water (fresh versus salt), (v) water temperature, and (vi) the emergency medical service’s response time. If available data did not allow calculation of relative risk, authors were contacted for additional information. For studies from overlapping populations, the study with the largest sample that evaluated the most factors of interest was selected.

Studies were excluded if the study (i) design lacked a comparison group (e.g. case reports, case series) (ii) contained insufficient information to calculate a relative risk (RR) and the required data were unavailable after contacting the author(s) (iii) reported only highly selected patient treatment groups (e.g. those receiving invasive ventilation or extracorporeal membrane oxygenation, and (iv) was published as an abstract only or in conference proceedings. There were no age, setting or language restrictions.

**Factor Variables and Outcome Measures**

Age was categorized as child or adult using the age definitions in the studies identified. The following categories were used for water salinity: salt water for salt water and oceans versus fresh water for all other waters (fresh, lake, river, well, pond, stagnant); witnessed status: Yes or No; and EMS response time < or > 9 minutes as used in the studies reviewed. Time and temperature intervals were categorized using the intervals used in the articles. Submersion duration intervals were grouped as short (< or > 5-6 minutes), intermediate (< or > 10 minutes) or prolonged (< or >15-25 minutes). Water temperature intervals used in articles were also grouped as < or > 6-80C, and < or > 15-170C.

Critical outcomes were defined a priori as (i) good versus bad neurological outcome/death and (ii) survival versus death at either hospital discharge or one month or one year after hospital discharge as reported in each study**.** For the analyses, good neurologic outcome or survival was categorized as favourable outcomes. Bad neurologic outcome or death was categorized as poor outcomes.

**Data Extraction**

Two authors (LQ and JB) screened the studies by title and abstract for eligibility. GDP resolved disagreements. Reviewers (RL, JB, LQ) collected data: author, year of publication, study design, study population (including age group, data source (emergency department, hospital, drowning data base, other), factors studied, outcome definition and risk ratio. If a study provided data for survival/death as well as for good/bad outcome the study was categorized using only the good/bad outcomes.

**Quality Assessment**

Three authors (JB, LQ and PM) assessed the risk of bias for each study using the QUIPS tool for prognostic studies (study participation; study attrition; prognostic factor measurement; outcome measurement; and statistical analysis and reporting) For each outcome and factor variable, they, in accordance with GRADE, for each outcome and factor variable made an overall assessment of the quality of evidence based on risk of bias, inconsistency, indirectness, imprecision, publication bias, and possible rating up criteria.12-13

**Statistical Analysis**

Findings of included studies were pooled using RR. All analyses were conducted using random and fixed effect models; both models are presented in the forest plots (DerSimonian and Laird (D+L) = Random Effects, Mantel-Haenszel (M-H) = Fixed Effect); however, all interpretations were based on the random effects model estimates due to the observed heterogeneity of effects and plausibility. Studies with a zero cell were included by adding 0.5 to all cell counts to permit calculation of an effect measure and 95% confidence interval.14

Between-study heterogeneity was calculated using the *I2* statistic. Heterogeneity was deemed low if it was <25% and considerable if it was >75%. Three tests were conducted to assess publication bias: Funnel plots were created for visual assessment. When there were ≥7 studies, the Begg adjusted rank correlation test, a numerical analogue to the funnel plot and the Egger regression asymmetry test were conducted.15-16Analyses were conducted using STATA 12.

This study of published literature did not require Institutional Review Board approval.

**RESULTS**

The database search identified 1,542 unique papers of which 349 related to drowning. After reading the title, 127, after reading the abstract, 47, and after reading the full text, 24 papers were selected. (Supplementary File 2) All were cohort studies. Eight studies included multivariate analyses for some factors.

Description of each study’s author, year of publication, study location, study design, study population, sample size, factor definition, outcome definition, percent of poor outcome, and RR for each factor are listed in Table 1 A- I.

See Supplementary File 3 for the Risk assessment for each study. See Supplementary File 4 for the Quality assessment for prognostic factors.

**Age**

Twelve studies evaluated the role of age for the critical outcomes of good neurological outcome and survival among 3,975 victims.17-28 (Table 1-A)Quality of evidence was very low.

Meta-analysis showed no significant difference in outcome between age groups of individuals <3-6 years versus>3-6 years: RR 1.20 (95% CI: 0.87, 1.67). There was considerable between-study heterogeneity (*I2*= 94.7% (95% CI: 92.4, 96.3)) and no significant publication bias (Begg: 0.58, Egger: 0.08). (Supplementary File 5) (Figure 1)

**EMS Response Time**

Two studies addressed the critical outcome of survival among 377 victims who had received resuscitation by EMS, excluding victims who had had successful bystander resuscitation or were declared dead without EMS involvement.29-30 (Table 1-B) Quality of evidence was downgraded to low. One study adjusted for age, sex, location, witnessed, bystander CPR, shockable rhythm, EMS response time, but did not include submersion duration, a key predictor in other studies.30

Meta-analysis showed a response time of <9 minutes, compared to ≥9 minutes, was associated with favourable outcomes: RR 2.84 (95% CI: 1.08, 7.47). There was low between-study heterogeneity (*I2*= 0.0% (95% CI: 0.0, 0.0)) but insufficient numbers of studies to assess publication bias by funnel plot, Begg, or Egger test. (Figure 2)

**Salinity (Fresh vs. Salt Water)**

Seven studies involving 2,163 drowning victims were identified. 19,22,26,27,30-32 (Table 1-C) For the critical outcome of intact neurologic survival, four studies evaluated salinity.19,22,27,32 Quality of evidence was very low. For the critical outcome of survival, three studies were identified.26,30,31 Quality of evidence was very low. In the one study using multivariate analysis, adjusting for age, sex, location, witnessed, bystander CPR, shockable rhythm, and EMS response time, salt water was associated with a bad outcome.30

Meta-analysis found that drowning in salt water, compared to fresh water, was associated with favourable outcomes: RR 1.16 (95% CI: 1.08, 1.24). There was low between study heterogeneity (*I2*= 4.7% (95% CI: 0.0, 72.2)), and no significant publication bias (Begg = 0.88, Egger = 0.49). (Supplementary File 6) (Figure 3)

**Submersion Duration**

Eighteen studies evaluated a total of 2,587 victims with estimated submersion durations.17-20,22,23,25-27,31,33-40 All studies reported higher percentages of good outcomes among victims with shorter submersion durations. A dose response gradient was noted with worse outcomes associated with longer submersion durations. (Table 1-D, E, F)

In two studies using multivariate analyses(one included age, sex, water temperature and blood alcohol, the other, age, water temperature, submersion duration), submersion duration was the major factor associated with outcome.27,3 In a third study, multivariate analysis adjusting for age, sex, hypothermia, submersion duration, immediate resuscitation was most predictive of favourable outcome.20

Short submersion intervals (<5-6 minutes)

Fifteen studies met inclusion criteria for short submersion. 18-20,22,23,25-27,33-35,36,40 (Table 1D) For the critical outcome of intact neurological survival, 10 studies were identified involving 1,445 victims and were of low quality evidence.18-20,22,25,27,33,35,36 For the critical outcome of survival, five studies comprising 252 victims were identified and with low quality evidence.23,26,31,34,40

Meta-analysis showed submersion durations ≤5-6 minutes, compared to >5-6 minutes, were associated with favourable outcomes: RR 2.90 (95% CI: 1.73, 4.86). (Figure 4a) There was considerable between study heterogeneity (*I2*= 92.6% (95% CI: 89.5, 94.8)), and no significant publication bias (Begg = 0.18, Egger = 0.69). (Supplementary File 7)

Intermediate submersion intervals (<10-11 minutes)

For the critical outcome of intact neurological survival, eight studies involving 1,380 victims were identified.20,22,27,33,35,36,38,39 Quality of evidence was low. For the critical outcome of survival, four studies of very low quality, comprising 229 victims were identified.26,31,37,40 (Table 1-E)

Meta-analysis showed submersion durations ≤10 minutes versus >10 minutes were associated with favourable outcomes: RR 5.11 (95% CI: 2.03, 12.82). (Figure 4b)

There was considerable between study heterogeneity (*I2*= 87.3% (95% CI: 79.7, 92.1) and no significant publication bias (Begg = 0.34, Egger = 0.29). (Supplementary File 8)

Prolonged submersion intervals (<15-25 minutes)

For the critical outcome of intact neurological survival three studies involving 1,086 victims were identified. Studies were of low quality evidence.22,27,35 (Supplementary Table 1)

For the critical outcome of survival, one study involving 41 victims was identified.34 Quality of evidence was very low. Favourable outcomes were absent or rare. (Table 1-F)

Meta-analysis showed that submersion durations ≤15-25 minutes versus submersion durations >15-25 minutes were associated with good outcomes: RR 26.92 (95% CI: 5.06, 143.30). (Figure 4c) There was moderate between study heterogeneity (*I2*= 54.1% (95% CI: 0.0, 84.8)). There were insufficient numbers of studies to assess publication bias by funnel plot, Begg or Egger tests.

**Water Temperature**

Water temperature < or >6-8°C

Two studies evaluated water temperatures < or >6-8°C, involving 1254 victims for the critical outcome of intact neurologic survival.27,29 (Table 1-G) Quality of evidence was very low.

In the meta-analysis, water temperatures of <6-8°C versus ≥6-8°C did not significantly differ in outcomes: RR1.47 (95% CI: 0.31, 8.08). (Table 1-G) There was substantial between-study heterogeneity (*I2*= 91.1% (95% CI: 68.6, 97.5). There were insufficient numbers of studies to assess publication bias by funnel plot, Begg, or Egger test. (Figure 5a)

Water temperature < or > 15-17°C

Two studies evaluated water temperatures < or >15-17°C, involving 1,335 victims.27, 29 (Table 1-H) Quality was low. One study used a critical outcome of intact neurologic survival; the other study used survival. In both studies, water temperatures were not associated with outcome.

In the meta-analysis, water temperature of <15-17°C versus ≥15-17°C was associated with poor outcomes: RR 0.76 (95% CI: 0.61, 0.95) (26,28). There was low between-study heterogeneity (*I2*= 0.0% (95% CI: 0.0, 0.0)). There were insufficient numbers of studies to assess publication bias by funnel plot, Begg or Egger test. (Figure 5b)

**Witnessed Status**
Four studies involving 2,140 drowning victims met inclusion criteria.24, 28-30 (Table 1-I)All were of EMS cardiac arrest registries which routinely recorded “witnessed Yes or No” for cardiac arrest. For the critical outcome of intact neurologic survival, one study was identified, evaluating 1,737 victims.24 Quality of evidence was moderate. For the critical outcome of survival, three studies involving a total of 403 victims were identified.28-30 Quality of evidence was very low.

In the meta-analysis, witnessed and unwitnessed victims did not significantly differ in outcomes: RR 2.31 (95% CI: 0.67, 7.89). There was considerable between study heterogeneity (*I2*= 86.0% (95% CI: 65.8, 94.3)). There were insufficient numbers of studies to assess publication bias by funnel plot, Begg or Egger tests. (Figure 6)

**DISCUSSION**

In this meta-analysis of six factors that might be known to a rescuer at a drowning scene, the most robust predictor was submersion duration. The consistency and strength of this predictor refute the commonly held belief that submersion duration is unreliable because it is usually estimated. Shorter submersion durations in all time categories evaluated were associated with more favorable outcomes compared to longer submersion durations. The size of the effect of this predictor was quantified when the different time intervals were compared. A dose response for submersion duration was demonstrated with the strongest association with poor outcomes observed for prolonged submersion (RR 26.92), followed by intermediate (RR 5.11) and short (RR 2.90) intervals. Importantly, rates of survival or good neurologic outcomes for victims submerged in the longer time periods were probably overestimated since most victims were in hospital or EMS studies which excluded victims who had died at the scene or in the emergency department. This predictor has biologic plausibility since it is the most direct measure of the anoxic injury that is drowning. It should be added to the core data variables listed in the 2003 Drowning Utstein recommended guidelines for uniform reporting of data for drowning resuscitation.41

Additionally, several factors commonly believed to be predictors were not predictors in this evaluation. Primary among these was victim’s age. Rescue and resuscitation providers have long believed that young children have better outcomes than older children or adults who drown.42-44 This belief may have several bases: the greater level of supervision of young children provides for earlier recognition of drowning, easier retrieval, and therefore shorter submersion durations; the greater likelihood of the pediatric heart to respond to scene resuscitation; and the lack of hospital follow up wherein the child dies of brain death several days after the event; the emotional aspects of resuscitating a child. Our study was, however, unable to show a definitive difference in favourable outcomes between young children and adults. The lack of evidence for age as a predictor suggests the need to address the more aggressive approach to young children that has permeated the beliefs of rescuers.

Another widely held belief, that cold water provides neurologic protection, was not supported. Physiological evidence, a cohort study, a collection of 26 case reports, and a mass-casualty boating incident are the supporting evidence for the protective effect of ice-cold water.43,45,46 Case reports of survivors that seemed to defy the effects of submersion anoxia often fail to provide full neurologic evaluation, follow up, and assessment of the actual period of submersion, water temperature and a denominator that would allow assessment of the chance of good outcome.

EMS response time was an objective measurable predictor that performed well on multivariate and meta-analyses. EMS response time, like submersion duration, most likely reflects a time period of ongoing anoxia. However, the percent of favourable outcomes for those with < and >9 minute response times overlapped, making definitive recommendations difficult. Other EMS systems’ experience and the relationship of this predictor and submersion duration need evaluation.

In this review, a witnessed event was not associated with more favorable outcomes despite a presumably shorter period of anoxia. The studies reporting witnessed arrest, however, were designed to report primarily cardiac arrests, where the moment of arrest could be observed. In contrast, the drowning arrest usually happens while the victim is submerged. How EMS providers interpreted this parameter for their cardiac arrest registries is unclear. Thus, this parameter is ambiguous for drowning evaluation. The question needing evaluation is whether a witnessed drowning event predicts outcome.

The identified predictors may assist the rescuer’s decision about taking the next step in the series of four steps that constitute safe rescue of a drowning victim. The dangerous setting in which drownings occur make rescuer safety a guiding principle. The universal steps in water rescue are “Reach, Throw, Row, Go”. Rescuers should start by reaching for the victim with an object, such as a paddle or branch. If this fails, rescuers should throw a flotation device such as a throw bag or personal flotation device to the victim. If needed, rescuers can proceed to take a boat to the victim. As a last resort and recommended only for those trained in water rescue, rescuers can enter the water to rescue the victim. Each step adds greater risk to the rescuer. Thus, a risk benefit assessment could be used at each step.

One of the main lessons of this review is that the usefulness of the predictors is predicated on good design and analyses. The overall quality of evidence to support the prognostic factors for the critical outcomes was low to very low. Few studies (8 of 24) utilized multivariate analyses. Yet only an adjusted model can identify the independent factors from the confounders and identify the strongest predictors. The clinical usefulness of these predictors in life/death decision-making should be predicated on multivariate analyses.

A major strength of this study was to summarize studies that used various study designs, definitions of factors, and outcomes from various countries. In all of the analyses for which funnel plots, Begg and Eggers tests were completed, no significant publication bias was identified. We were able to include all potentially relevant peer-reviewed studies including non-English investigations.

Despite our ability to pool various effect estimates, limitations existed. The inclusion criteria required for the meta-analysis excluded a few peer-reviewed studies that evaluated age and submersion duration but used continuous variables or failed to provide data. The resulting number of studies for EMS response time, submersion duration, witnessed event, and water temperature was too low to analyze for publication bias using funnel plots, Begg, or Eggers tests. Additionally, several of the analyses showed considerable heterogeneity (i.e., water temperature, witnessed drowning, intermediate submersion duration, short submersion duration, age). As such, pooled effect estimates in these smaller categories need to be interpreted with caution.

Secondly, most of the studies involved hospital or EMS care, excluding large populations of victims who died at the scene (with or without EMS care). In addition, favourable outcomes included good neurologic outcomes as well as survival. Yet in most drowning studies that evaluated survivors’ neurologic status, most survivors have severe neurologic sequelae, not favourable outcomes. If the studies reporting only survival outcomes had determined neurologic outcomes instead, favourable outcomes would be less. Thus, between biased case selection and varying outcome measures, the RRs of favourable outcomes of studies in this review are probably overestimated.

The majority of the studies evaluated drowning victims who received medical care prior to the 2000 international resuscitation guidelines; this raises the concern that patient outcomes may not apply to present drownings due to changes in medical care. The impact of subsequent changes to resuscitation guidelines on survival from drowning events is uncertain, but the quality of evidence was downgraded for indirectness if a large number of these studies were included in the analysis.

Predictors need to be used in the context of the drowning incident which includes the setting, rescuer’s abilities, EMS system’s capabilities, available equipment, and experience. The consensus process of the ILCOR scientific review provided discussion and concern about the implications of the use of the predictors, inadequate evidence to drive absolute guidelines for their use, and clinical applicability.47 For instance, drowning in salt water was associated with better outcomes, but its risk ratio was low, the studies’ findings were not consistent, and clinical applicability of the predictor seems limited. On the other hand, the sigmoid-shaped relationship of submersion period with poor outcomes (0-10 minutes: unlikely; 10-25 minutes rapidly increasing, >25 minutes extremely likely) has significant implications for drowning prevention and speed of rescue when drowning occurs. The multivariate analyses and results of the meta-analyses did not provide evidence that age, water temperature, or salinity should modulate this advice. However, another time-based resuscitation factor, EMS response time, was predictive in the meta-analysis and an independent predictor in two multivariate analyses that unfortunately did not include submersion duration. The relationship between these two time-related factors merits further evaluation.

**CONCLUSIONS**

In this systematic review and meta-analysis of scene factors known prior to rescue, only submersion duration was a robust and independent outcome predictor. Shorter submersion durations were associated with better outcomes; submersion durations <10 minutes still predicted high rates of good outcomes; submersion durations >25 minutes were associated with dismal good outcome rates. This information may be useful to rescuers, responding systems and agencies in the setting where decisions to rescue and care for a drowning victim pose risk of death to the rescuer and very high costs to the responding system. They may contribute to the decision when to attempt a rescue versus a body retrieval. Better quality studies are needed to fully determine what are other useful predictors for the victims, rescuers, fire and EMS services, and the agencies that provide and pay for them.

**CONFLICTS OF INTEREST**

None of the authors had financial or personal relationships with other people or organisations that could inappropriately bias their work.

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**DISCLAIMER FOR C2015:**

This review includes information on resuscitation questions developed through the C2015 Consensus on Science and Treatment Recommendations process, managed by the International Liaison Committee on Resuscitation (www.ilcor.org/seers). The questions were developed by ILCOR Task Forces, using strict conflict of interest guidelines. In general, each question was assigned to two experts to complete a detailed structured review of the literature, and complete a detailed evidence evaluation. Evidence evaluations are discussed at ILCOR meetings to reach consensus and will be published in 2015 as the Consensus on Science and Treatment Recommendations (CoSTR). The conclusions published in the final ILCOR CoSTR consensus document may differ from the conclusions of this review because the CoSTR consensus will reflect input from other evidence evaluation review authors and discussants at the conference, and will take into consideration implementation and feasibility issues as well as new relevant research.

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**Tables and Figures**

Table 1 A-H. Studies with data on the association between each factor and favourable vs. poor outcome

Figure 1-Forest plot Age

Figure 2- Forest plot EMS response time

Figure 3- Forest plot salinity

Figure 4 a,b,c- Forest Plot submersion duration short, intermediate, prolonged

Figure 5 a,b-Forest plot water temperature </>6-8 C, </>17 C

Figure 6 – Forest plot witnessed

**Supplementary Files**
1-Search strategy

2- Prisma flow chart

3-Risk assessment

4-Quality assessment

5-Funnel plot Age

6-Funnel plot Salinity

7-Funnel plot short submersion duration

8-Funnel plot intermediate submersion duration