Trends in Unintentional Drowning

The Role of Alcohol and Medical Care

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Context During the last few decades, mortality from drowning has decreased in the United States for unknown reasons. It has been hypothesized that this decline may be due to decreased use of alcohol in and around water or improved medical treatment after a submersion.

Objectives To estimate changes in unintentional mortality due to submersion, estimate trends in drownings attributable to alcohol use, and assess the role of medical care in these mortality trends.

Design A 21-year longitudinal study of case findings, from January 1, 1975, through December 31, 1995.

Setting and Participants All residents of King County, Washington, who died unintentionally from submersion and 284 persons hospitalized for submersion who survived.

Main Outcome Measures Changes in submersion-related mortality incidence over time, proportion of this mortality that could be attributed to alcohol use, changes over time in the case-fatality rate of treated patients, and estimate of deaths prevented in 1995 compared with projected estimates had there been no change in incidence since 1975.

Results There were 539 deaths due to drowning in King County during 21 years. Mortality rates during this period declined by 59% (95% confidence interval [CI], −70% to −46%). The incidence of death attributable to alcohol use decreased by 81% (95% CI, −91% to −57%); this could account for 51% of deaths prevented in 1995. Among 249 comatose patients who received prehospital care, 205 died; the odds of survival decreased 40% over 21 years ($P = .40$). Among 101 comatose patients who were hospitalized, 63 died; the odds of survival decreased 29% ($P = .75$). The incidence of survival of comatose hospital patients decreased by 29% from 1975 to 1995 (95% CI, −78% to +125%). We found no evidence that trends in medical treatment prevented any deaths due to drowning in 1995.

Conclusions Drowning incidence in King County, Washington, declined because of a decrease in severe submersion episodes rather than an increase in success of medical interventions. Our data support the theory that less use of alcohol around water prevents some deaths. About half of the decrease was unexplained.

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In 1995, 4350 deaths in the United States were attributed to unintentional drowning: 1.7 per 100 000 person-years.[1] Drowning was the fourth most common mechanism of unintentional injury death in 1995.[2] In the United States, mortality due to drowning has been declining,[2-6] but the reasons for this decline are not known. From 1971 through 1988, unintentional mortality due to non–boat-related submersion fell by about 5.5% per year among children aged 10 through 19 years.[5] The authors who reported these data speculated that declining mortality among older children might be related to reduced use of alcohol while in or around water or to reduced exposure to water due to migration of the population to more urban settings. On the other hand, *Healthy People 2000*, a report on US health objectives, raised the possibility that while submersion-related case-fatality rates may have decreased, submersion-related neurological damage may have become more common.[7] Other authors have suggested that aggressive care might increase the incidence of neurologically injured survivors.[8,9]

We collected information regarding submersion episodes over a 21-year period in part of Washington State. We analyzed these data to address 3 questions: (1) What were the trends in mortality? (2) What was the trend in deaths attributable to alcohol use? and (3) What role did medical treatment play in mortality trends?

See also p 2245 and Patient Page.

METHODS

We sought data regarding submersion episodes in King County, Washington, from January 1, 1975, through December 31, 1995. King County, which includes the city of Seattle, had 1 507 319 residents in 1990.[10] A data collection form with 346 fields was used to abstract information from the records of all 19 acute care hospitals in King County, the medical examiner, and the 2 emergency medical services agencies. Case finding was supplemented by using the records of all 13 acute care hospitals and the medical examiners in 2 adjacent counties, the computerized files of Washington State death certificates for

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all study years, and computerized files of state civilian hospital discharges from 1987 through 1996.

Analyses, except as noted, were limited to submersions that occurred within King County. To estimate population-based rates, we excluded submersions of persons who were visiting King County or patients referred to the county for hospital care. Denominators for rates were yearly estimates of county population by sex and age in 5-year groups (Office of Financial Management, Olympia, Wash, unpublished data [electronic files of Washington State population, 1980-1995]).[11] We used Stata statistical software for all analyses.[12]

Mortality Trends

We estimated the overall linear trend in mortality for the 21-year period, 1975-1995, using negative binomial regression.[13-16] Interactions were tested using the likelihood ratio test.[16] We used predicted counts from the regression models to estimate the number of deaths in 1995, given the observed data, and compared this with the expected number for 1995 had there been no change in incidence since 1975. Activity prior to drowning was grouped into 5 categories: (1) boating, including fishing from a boat; (2) swimming or diving; (3) occupant of a car that went into water; (4) fell into deep water from a dock or from shore or while wading; (5) bathing.

If within-county drownings declined, this might have occurred because residents went outside King County to engage in water-related activities. We therefore assessed the overall trend in submersion deaths of King County residents in areas outside King County.

The Role of Alcohol

A case-control study estimated that the relative risk (RR) of drowning was 31.8 (95% confidence interval [CI], 5.8-176) among persons with a blood alcohol level of 21.7 mmol/L or greater, and 4.6 (95% CI, 1.6-13.1) among those with a blood alcohol level greater than 0 but less than 21.7 mmol/L, compared with persons who had no alcohol in their blood.[17] We used these RRs and the standard formula for attributable fraction ([RR − 1]/RR),[18] to estimate the proportion of deaths among the exposed that could be attributed to alcohol: 97% of deaths were attributed to alcohol when the blood level was 21.7 mmol/L or greater, and 78% of deaths were attributed to alcohol when the level was between 0 and 21.7 mmol/L.

Measures of alcohol in the blood of drowning victims were obtained from emergency department, hospital, and medical examiner records. Blood alcohol levels may rise after death due to putrefaction, so we classified the level as unknown if the body was not recovered within 24 hours.[19] We categorized known blood alcohol levels into 3 groups: 0, greater than 0 but less than 21.7 mmol/L, and 21.7 mmol/L or greater.

Because blood alcohol information was often missing, we used a multiple-imputation method.[20,21] Deaths were classified by year and victim's age (15-49 years, $\geq$50 years), and within each stratum of year and age the missing values for blood alcohol category were imputed 20 times using an approximate Bayesian bootstrap method.[20]

Two methods were used to examine the role of alcohol. First, we multiplied each death by its attributable fraction to generate a count of deaths attributable to alcohol in each year. Then we used negative binomial regression to estimate the trend in mortality attributable to alcohol. Second, we used logistic regression to estimate any change in the proportion of deaths that could be attributed to alcohol. Deaths that involved alcohol were assigned to alcohol or not according to the attributable fractions; for example, if the victim's blood alcohol level was 21.7 mmol/L or greater, we counted this as 0.97 deaths due to alcohol and 0.03 deaths unrelated to alcohol.

We conducted these regression analyses in each imputed data set and averaged the log of the 20 rate ratios or odds ratios to calculate a point estimate. Variances, confidence limits, and significance levels were calculated using methods described by Rubin.[22]

The Role of Medical Care

For this part of the analysis, we included all persons who died, plus 284 additional persons who survived after prehospital, emergency department, or hospital care. We excluded 2 persons who were released to home after prehospital care and 60 who were released to home from an emergency department. None of these 62 persons were later hospitalized and none died.

Using published definitions,[23] we classified patient outcomes as death, vegetative state, severe disability, moderate disability, mild disability, or normal. Presubmersion function was classified using the same scale; survival with worse function after submersion was defined as a new neurological injury. For our analyses, we used 3 outcomes: death, survival with new neurological injury, and survival with no new neurological injury.

Medical care could improve survival in 2 ways. First, if medical treatment improved, outcomes might improve among those who received care. We estimated the linear change in the odds of survival, compared with death, using logistic regression. Previous studies have reported that after submersion, death is likely only among comatose victims.[24-26] Therefore, to control for the severity of treated cases, we restricted this analysis to comatose victims. Potential confounders examined were age (categorized as $<$5 years, 5-14 years, 15-49 years, or $\geq$50 years), sex, category of submersion site (open water, pool, or bathtub), pupillary response (none, reactive), and whether or not cardiopulmonary resuscitation was administered.

Second, even if treatment outcomes did not improve, overall mortality might decrease if, over time, comatose submersion victims were more likely to receive medical care.

Therefore, we estimated trends in the incidence rate of comatose patients who were treated. To assess the combined effects of any change in access to care and any change in outcome among those who received care, we estimated the change in the incidence rate of patients who were initially comatose and survived. We used 2 definitions of medical care: (1) prehospital care and (2) hospital admission. Mental status was classified when the patient was first seen by ambulance personnel, or when first admitted, respectively.

In addition, we estimated the change in incidence of survival with new neurological injury.

RESULTS

Mortality Trends

We identified 539 deaths (1.86/100 000 person-years) of King County residents due to unintentional submersion in King County. Most deaths occurred at the scene, without any medical treatment; only 12% occurred during hospitalization.

Mortality due to submersion declined by 59% during the 21-year period (TABLE 1). In 1995, an estimated 27.8 deaths were prevented by this decline in mortality, compared with what would have been expected had mortality remained unchanged since 1975. The incidence of death at the scene, without any medical care, declined by 77%; this subgroup accounted for 91% of the prevented deaths in 1995.

Categorized by age, 9% of drownings involved children aged 0 to 4 years (rate, 2.6/100 000 person-years), 9% of victims were aged 5 to 14 years (rate, 1.2), 24% were aged 15 to 24 years (rate, 2.9), 33% were aged 25 to 49 years (rate, 1.5), and 24% were 50 years of age or older (rate, 1.9). Mortality declined in every age group; the changes ranged from a 47% decrease among persons aged 50 years or older to an 84% decrease among children 5 to 14 years old. A test that the change in incidence differed by age group was not significant ($P = .28$)

Mortality due to drowning in open water decreased by 65%, deaths in pools fell by 48%, and deaths in a bathtub decreased by 9% (Table 1). Boat-related drowning declined by 74%. Drowning while swimming decreased by nearly two-thirds; the decrease was about half for occupants of cars and for those who fell into deep water. There was little change in the incidence of drowning while bathing.

There were 328 additional submersion deaths of a King County resident outside King County; 60% occurred within Washington State. The incidence of out-of-county fatal submersion decreased by 66% (95% CI, −78% to −46%).

Table 1. Number, Average Rates per 100 000 Person-Years, and Estimated Change in Rates for Unintentional Drowning, King County, Washington, 1975-1995*

Event	No. (Rate)	Overall Change, % (95% Confidence Interval)
All deaths	539 (1.86)	−59 (−70 to −46)
Any medical care		
Yes	217 (0.75)	+10 (−29 to +71)
No	294 (1.02)	−77 (−87 to −61)
Submersion site		
Open water	340 (1.18)	−65 (−78 to −44)
Pools	64 (0.22)	−48 (−77 to +16)
Bathtubs	97 (0.34)	−9 (−53 to +75)
Activity		
Boating	108 (0.37)	−74 (−88 to −45)
Swimming	105 (0.36)	−63 (−82 to −25)
In car	60 (0.21)	−55 (−81 to +4)
Fell in	112 (0.39)	−53 (−75 to −14)
Bathing	103 (0.36)	+7 (−44 to +103)

*Overall changes with 95% confidence intervals are linear trends over 21 years. Data are missing for some categories.

Table 2. Mortality Due to Unintentional Drowning, According to Blood Alcohol Level of the Victim and Time Period for 440 Persons Aged 15 Years or Older, King County, Washington*

	Blood Alcohol Level, mmol/L			
Time Period	0	>0 to <21.7	≥21.7	Missing
1975-1979	42 (1.7)	7 (0.3)	34 (1.4)	51 (2.0)
1980-1984	46 (1.9)	11 (0.4)	21 (0.8)	30 (1.2)
1985-1989	41 (1.9)	3 (0.1)	15 (0.7)	24 (1.1)
1990-1995	58 (1.5)	5 (0.1)	21 (0.6)	31 (0.8)

*Data are numbers (rates per 100 000 person-years).

The Role of Alcohol

Among fatal cases with blood alcohol measurements, none younger than 15 years had alcohol in their blood. Of the 440 persons aged 15 years or older who died, 10.7% had unknown alcohol values because the blood sample was drawn more than 24 hours after death, and 20.2% had unknown values for other reasons. There were 304 deaths with known values; 61.5% had no alcohol, 8.6% had values between 0 and 21.7 mmol/L, and 29.9% had values of 21.7 mmol/L or greater (TABLE 2).

The incidence of death attributable to alcohol decreased 81% (95% CI, −91% to −57%) for persons aged 15 years or older. About 14.2 deaths were prevented in 1995 by this change, 51% of all prevented deaths. The proportion of deaths of persons aged 15 years or older that were attributable to alcohol decreased over time, from 50% in 1975 to 22% in 1995 ($P = .005$ for a test for trend).

The Role of Medical Treatment

A total of 468 persons received emergency prehospital care. The proportion who died varied little over time (TABLE 3). Initially, 249 patients were comatose and 205 deaths occurred in this group (initial mental status was not known for 11 who died). The odds of survival was 40% less in 1995 compared with the odds of survival in 1975 ($P = .40$ for a test for trend); this estimate was adjusted for age and sex.

Among the 346 persons who were hospitalized (Table 3), 101 patients were comatose and 63 of these comatose patients died. After adjusting for age, sex, and pupillary response, the odds of survival was 29% less in 1995 compared with 1975 ($P = .75$ for a test for trend). No deaths occurred among patients who were alert or lethargic at the scene or in the hospital.

The incidence rate of prehospital care of comatose patients increased slightly from 1975 to 1995 (12%; 95% CI, −27% to +73%). The incidence of survival of comatose patients who received prehospital care declined by 37% (95% CI, −76% to +68%).

The incidence of hospital admission of comatose patients decreased by 1% (95% CI, −48% to +89%). The incidence of survival of hospital patients who were comatose decreased by 29% (95% CI, −78% to +125%). These changes did not result in any prevented deaths in 1995.

The incidence rate of survival with new neurological injury declined 47% (95% CI, −85% to +95%).

COMMENT

In a county in western Washington State, mortality due to drowning decreased by more than half from 1975 through 1995. Deaths attributable to alcohol decreased by 81%. Decreased mortality was not explained by any improvement in prehospital or hospital treatment.

Our estimates might be incorrect if we missed a large proportion of the victims, especially if records were missing in a systematic way over time. Deaths were probably ascertained in a fairly complete manner. Although computerized death certificate files may not identify all drowning deaths,[27] we used additional sources, including medical examiner logs, hospital records, and prehospital records. It is possible that we failed to identify some hospitalized cases, but we sought to minimize this problem by using multiple sources, including computerized hospital record systems, prehospital emergency medical services records, and computerized data that the hospitals sent to the Washington State Department of Health. Because King County includes referral centers for western Washington, patients whose submersion occurred in King County were unlikely to go outside the county for care; furthermore, we searched the hospital records in 2 adjoining counties.

We probably missed some patients who were seen by ambulance personnel or in an emergency department and then released to home. Of the 62 people who were known to have this disposition, none was subsequently hospitalized and none died. None of the 539 deaths were people who were released from care and subsequently died. Patients released to home, without hospital admission, were so mildly injured and so unlikely to die that they were not necessary to our analysis.

For the records that we had, information was very complete for many items: we had information regarding age, sex, and survival for all victims; final neurological status for 99%; initial mental status for 95%; drowning site for 96%; and predrowning activity for 93%. However, information regarding blood alcohol levels was missing for 31% of those who died and were aged 15 years or older. We used multiple imputation to avoid the biases associated with analyzing only records with complete information and produce statistics that formally accounted for the missing nature of some data.[21,22]

Mortality due to within-county submersions declined by 59%, similar to the 66% decline in out-of-county submersion mortality. Therefore, the overall trend in mortality that we found cannot be explained by a change in where King County residents drowned. However, we could not assess the role of alcohol or medical care in drownings outside King County.

Our finding that about one third of persons aged 15 years or older who drowned had alcohol in their blood was in general agreement with several other studies.[28] Alcohol might increase the risk of drowning through many mechanisms.[29] For example, intoxicated people might be more likely to boat or swim in dangerous circumstances, to fall into water, or be less able to get out of water compared with sober persons.

The hypothesis that decreased use of alcohol while in, on, or close to water contributed to the decrease in mortality was consistent with our findings; the incidence of deaths attributable to alcohol decreased, and the proportion of deaths that could be attributed to alcohol decreased. However, while some information about alcohol use among boaters and swimmers has been reported,[28-31] we are not aware of any studies that have measured changes in person-time spent around water while drinking alcohol.

Our analysis regarding alcohol relied on RR estimates from 1 case-control study of alcohol use and drowning.[17] The estimates from that study were roughly similar to those from studies of drinking and death due to a traffic crash.[32-35] However, additional esti-

Table 3. Patients With Unintentional Submersion Episodes Who Either Died, Suffered a New Neurological Injury, or Survived With No Change in Neurological Status, King County, Washington, 1975-1995

Time Period	Deaths, No. (%)	Neurological Injury, No. (%)	No Change in Neurological Status, No. (%)
		Prehospital Care	
1975-1979	42 (47)	8 (9)	39 (44)
1980-1984	45 (47)	4 (4)	46 (48)
1985-1989	53 (41)	6 (5)	70 (54)
1990-1995	76 (49)	7 (5)	71 (46)
		Hospital Care	
1975-1979	11 (17)	8 (13)	45 (70)
1980-1984	11 (16)	4 (6)	53 (78)
1985-1989	21 (20)	6 (6)	79 (75)
1990-1995	20 (19)	7 (6)	81 (75)

mates of the association between alcohol use and drowning would be desirable.

We found no evidence that decreased mortality could be attributed to better treatment or improved access to care. The case-fatality rate among comatose patients showed no improvement over time, and the incidence of survival after treatment among persons who were comatose did not increase. Others have expressed concern that aggressive treatment may have resulted in more survivors with new neurological injury.[7-9] We found that survival with neurological injury was uncommon, and the incidence of this outcome decreased in King County.

Migration of the population away from bodies of water has been suggested as a possible reason for decreasing mortality due to drowning.[5] This is not likely to explain the decrease that we found; while some migration within the county undoubtedly occurred, bodies of water are ubiquitous in King County and much of the population increase has been in suburban areas near lakes and rivers.

Improvements in safety may have prevented some drownings. In 1981 and 1986, King County ordinances were passed to improve the gates and fences around outdoor pools, and in 1981, the Seattle-King County Department of Health expanded pool inspections.[36] Lifeguards have become more common at pools and public beaches and their training has improved.[36] Observed use of life vests has increased in King County among boaters aged 15 years or older; prevalence was 14% in 1992, 25% in 1994, and 51% in 1997.[37-39] However, this increase in life vest use came too late to explain much of the decrease in mortality.

Drowning incidence in King County, Washington, declined chiefly because severe submersion episodes decreased. Some of the decrease may be explained by less use of alcohol around water. Medical care made no important contribution to this decrease. About half of the decrease was unexplained. Additional hypotheses include a decrease in time spent in water-related activities, such as wading, swimming, or boating and an increase in safe behaviors when in or near water.

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