EM Advances

Drowning: an overlooked cause of out-of-hospital cardiac arrest in Canada

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ABSTRACT

Introduction: Drowning is a major public health concern, yet little is known about the characteristics of drowning patients. The objectives of this study were to describe the demographic and clinical characteristics of out-of-hospital cardiac arrest (OHCA) attributed to drowning in Ontario and to compare the characteristics of OHCA attributed to drowning to those of presumed cardiac etiology.

Methods: A retrospective, observational study was carried out of consecutive OHCA patients of drowning etiology in Ontario between August 2006 and July 2011. Bivariate analysis was used to evaluate differences between drowning and presumed cardiac etiologies.

Results: A total of 31,763 OHCA patients were identified, and 132 (0.42%) were attributed to drowning. Emergency medical services treated 98 patients, whereas the remaining 34 met the criteria for legislative death. Overall, 5.1% of drowning patients survived to hospital discharge. When compared to patients of presumed cardiac etiology, drowning patients were younger and their arrest was more likely to be unwitnessed, present with a nonshockable initial rhythm, occur in a public location, and receive bystander cardiopulmonary resuscitation (CPR). A nonsignificant trend was noted for drowning cases to more frequently have a public access AED applied. There were no significant differences in the gender ratio or paramedic response times. Drowning patients were more likely to be transported to hospital but had a trend to be less likely to arrive with a return of spontaneous circulation. They were also more likely to be admitted to hospital but had no difference in survival to hospital discharge.

Conclusions: Significant differences exist between OHCA of drowning and presumed cardiac etiologies. Most drownings are unwitnessed, occur in public locations, and present with nonshockable initial rhythms, suggesting that treatment should focus on bystander CPR. Future initiatives should focus on strategies to improve supervision in targeted locations and greater emphasis on bystander-initiated CPR, both of which may reduce drowning mortality.

RÉSUMÉ

Introduction: Les noyades constituent un problème sérieux de santé publique, pourtant on connaît peu de choses sur les caractéristiques des personnes qui en sont victimes. L'étude avait pour objectifs de décrire les caractéristiques démographiques et cliniques des arrêts cardiaques extrahospitaliers (ACEH) attribuables aux noyades en Ontario et de comparer les caractéristiques des ACEH attribuables aux noyades avec celles d'origine probablement cardiaque.

Méthodes: Il s'agit d'une étude d'observation, rétrospective, menée chez des patients consécutifs, victimes d'un ACEH causé par noyade, en Ontario, d'août 2006 à juillet 2011. Une analyse bidimensionnelle a permis d'évaluer les différences entre les arrêts cardiaques attribuables aux noyades et ceux d'origine probablement cardiaque.

Résultats: Au total, 31 763 patients ayant subi un ACEH ont été repérés; sur ce nombre, 132 (0.42%) ont été victimes d'une noyade. Les services médicaux d'urgence ont traité 98 patients, et les 34 autres répondaient au critère légal de mort. Dans l'ensemble, 5.1% des noyés ont survécu jusqu'au moment du congé de l'hôpital. Les patients victimes de noyade étaient plus jeunes que les patients ayant subi un arrêt vasculaire d'origine probablement cardiaque, et les probabilités que l'arrêt cardiaque se soit produit en l'absence de témoins et dans un lieu public, qu'il y ait eu non-défibrillation du rythme initial et que des passants aient pratiqué la réanimation cardiorespiratoire (RCR) étaient plus élevées chez les premiers que chez les seconds. Une tendance non significative à une utilisation plus fréquente du défibrillateur

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externe automatique, à usage public a été relevée dans les cas de noyade. Par contre, il n'y avait pas de différences importantes quant à la proportion hommes-femmes ou au délai d'intervention des ambulanciers paramédicaux. Les patients victimes de noyade avaient plus de chances d'être transportés à l'hôpital, mais étaient moins susceptibles de connaître un rétablissement spontané de la circulation à l'arrivée. Ils avaient également plus de chances d'être hospitalisés, mais il n'y avait pas de différence en ce qui concerne la survie jusqu'au moment du congé de l'hôpital.

Conclusions: Il existe des différences importantes entre les ACEH attribuables à la noyade et ceux d'origine probablement cardiaque. Dans la plupart des cas de noyade, il n'y avait pas de témoins, l'accident s'était produit dans des lieux publics et il n'y avait pas eu de défibrillation du rythme initial, ce qui donne à penser que le traitement devrait être axé sur la RCR pratiquée par les passants. Il faudrait donc élaborer de futures stratégies visant à améliorer la supervision dans certains lieux et à mettre l'accent sur la RCR amorcée par les passants, deux mesures susceptibles de réduire la mortalité par noyade.

Keywords: cardiopulmonary resuscitation, emergency medical services, drowning, out-of-hospital cardiac arrest

Drowning is a major public health concern worldwide.[1] Although numerous definitions exist for what constitutes a drowning event or death,[2] guidelines for scientific reporting of drowning define drowning as "a process resulting in primary respiratory impairment from submersion/immersion in a liquid medium."[1] In 2002, an estimated 450,000 people drowned worldwide, accounting for 9% of all injury-related deaths.[3] An additional 1.3 million disability-adjusted life-years were lost as a result of premature death or disability after a drowning incident.[3] In spite of the fact that drowning incidents were on the decline between 1992 and 2004 in Canada, the number is on the rise again,[4] and drowning remains the fourth most common cause of unintentional injury deaths, behind motor vehicle crashes, falls, and poisonings.[5] The Lifesaving Society of Canada estimates that between 400 and 500 people (or 1.5 per 100,000) drown every year in Canada.[4] Drowning represents approximately 0.5 to 1.0% of all treated out-of-hospital cardiac arrests (OHCAs).[6,7] In Canada, the economic burden of water-related drowning deaths exceeded $10 billion dollars during a 10-year period.[5]

Little is known about the characteristics of drowning cardiac arrest episodes treated by emergency medical services (EMS) and how they compare to other types of cardiac arrest episodes in Canada. These characteristics may inform strategies to prevent drownings and improve resuscitation efforts. Most epidemiologic studies of drownings are derived from European countries that border oceans and report incidence and mortality statistics,[3,5,8–14] with little emphasis on the prehospital characteristics.[7,15] Deakin recently noted that significant gaps in the evidence surrounding drowning and resuscitation science exist and highlighted the need for further research into drownings and prehospital care.[16]

The objectives of this study were to describe the demographic and clinical characteristics of OHCA attributed to drowning in Ontario and to compare the characteristics of OHCA attributed to drowning to those of presumed cardiac etiology.

METHODS

Design

We conducted a retrospective observational study of consecutive cardiac arrests occurring between August 1, 2006, and July 31, 2011. Data were obtained from the Toronto site of the Resuscitation Outcomes Consortium (ROC) Epistry - Cardiac Arrest database, a population-based epidemiologic registry of OHCA attended by EMS personnel. The methods and design of this database have been described in detail elsewhere.[17] Data variables were developed and collected in accordance with the Utstein standard[18,19] and included patient demographics, call characteristics, pick-up locations, and prehospital interventions. Data were extracted from standardized provincial ambulance call reports by trained data abstractors. Electrocardiogram recordings were obtained directly from the defibrillator units, whereas emergency department (ED) outcomes and hospital discharge status were obtained from in-hospital records. The study was approved by the research ethics board at St. Michael's Hospital, Toronto.

Setting and patient selection

The study catchment area includes eight regions in southern Ontario (Peel, Durham, Halton, Hamilton, Muskoka, Simcoe, Toronto, and York). Collectively, in these regions, over 5,000 paramedics and first responders provide tiered response emergency care and

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transport to a population of 8.8 million people in both urban and rural settings within a geographic area of 17,000 km^2. Defibrillator-equipped personnel from the fire department respond in parallel with primary care paramedics for the highest priority calls, including those for suspected cardiac arrest. Some regions also have advanced care paramedics. Primary care paramedics are capable of defibrillation and cardiopulmonary resuscitation (CPR), whereas advanced care paramedics are also capable of administering advanced life support (ALS) medications and performing advanced airway maneuvers.

All patients, regardless of age, with an OHCA prior to EMS arrival from either drowning or presumed cardiac etiology were included (referred to as the drowning group and the cardiac group, respectively). Cardiac arrest etiologies were determined by responding paramedics and/or data abstractors after reviewing available source documents, including EMS reports, police reports, fire department reports, and in-hospital records. All data abstractors were certified primary or advanced paramedics. Each data abstractor underwent an orientation and training process with one of the program's paramedic research assistants prior to abstracting cases. This process included abstracting sample cases with the trainer to ensure that the abstractor was familiar and confident with the data abstraction process. An extensive quality assurance program was used to verify the accuracy of the study data.[17] A cardiac arrest was deemed to be of presumed cardiac etiology if there was a documented history of symptoms consistent with such an etiology preceding the patient's collapse or if no other obvious causes, including trauma, drug overdose, asphyxia, and exsanguination, were documented in the past medical history or EMS clinical documentation.[17,19] Patients with OHCA attributed to obvious noncardiac causes or those presenting with characteristics that met the legislative criteria for a prehospital pronouncement of death (rigor mortis, lividity, decomposition, transection, or decapitation) were excluded. Treated cardiac arrests of presumed cardiac etiology were eligible for prehospital termination of resuscitation after paramedics consulted with an online medical director or base hospital physician based on a previously validated tool for any unwitnessed arrest, with no defibrillator shocks delivered and no return of spontaneous circulation.[20,21] The resuscitation of drowning OHCA patients was terminated only after direction from the online medical director or base hospital physician as OHCA attributed to drowning falls outside the termination of resuscitation protocol.

Analysis

Descriptive statistics were used to assess the distribution of Utstein characteristics.[18,19] Continuous variables were treated as normally distributed and reported as means with standard deviations. Categorical variables were reported as counts and percentages. Drowning arrests were compared to arrests of presumed cardiac etiology during the same time interval for the variables of interest. Bivariate analyses were performed to assess differences between the drowning and cardiac groups. A *t*-test was used for all continuous variables, and a χ^2 test was used for discrete or categorical variables. A Fisher exact test was used when 25% or more of the cells had expected counts less than 5. A χ^2 test was used to examine hourly and monthly variations in incidence. Statistical analysis was performed with *SAS* software version 9.1 (SAS Institute, Cary, NC).

RESULTS

Figure 1 provides a graphic illustration of the derivation of the study population. There were 31,763 OHCA patients during the study period. A total of 14,287 (45%) were excluded as they met the criteria for obvious death and were not treated by EMS. Of these, 34 (0.24%) were attributed to drowning. Among treated patients, 1,602 were excluded based on obvious etiology and an additional 1,683 were excluded because they were witnessed by EMS. The final study population included 14,093 cases of presumed cardiac etiology and 98 cases of drowning etiology. Overall, drowning cases represented 0.42% of all OHCA and 0.56% of treated patients.

Table 1 provides Utstein patient demographics for drowning and presumed cardiac etiologies. Patients of drowning etiology were younger (36.7 $\pm$ 23.4 v. 68.0 $\pm$ 18.1 years, $p < 0.001$), were more likely to have their arrest in a public location (61.2% v. 15.8%, $p < 0.001$), and had received bystander CPR (49.0% v. 36.2%, $p = 0.009$) but were less likely to have their arrest witnessed by a bystander (20.0% v. 42.9%, $p < 0.001$) and to present in an initial shockable rhythm (9.9% v. 22.5%, $p = 0.004$). A non–statistically significant trend was noted for drowning cases to more frequently have a

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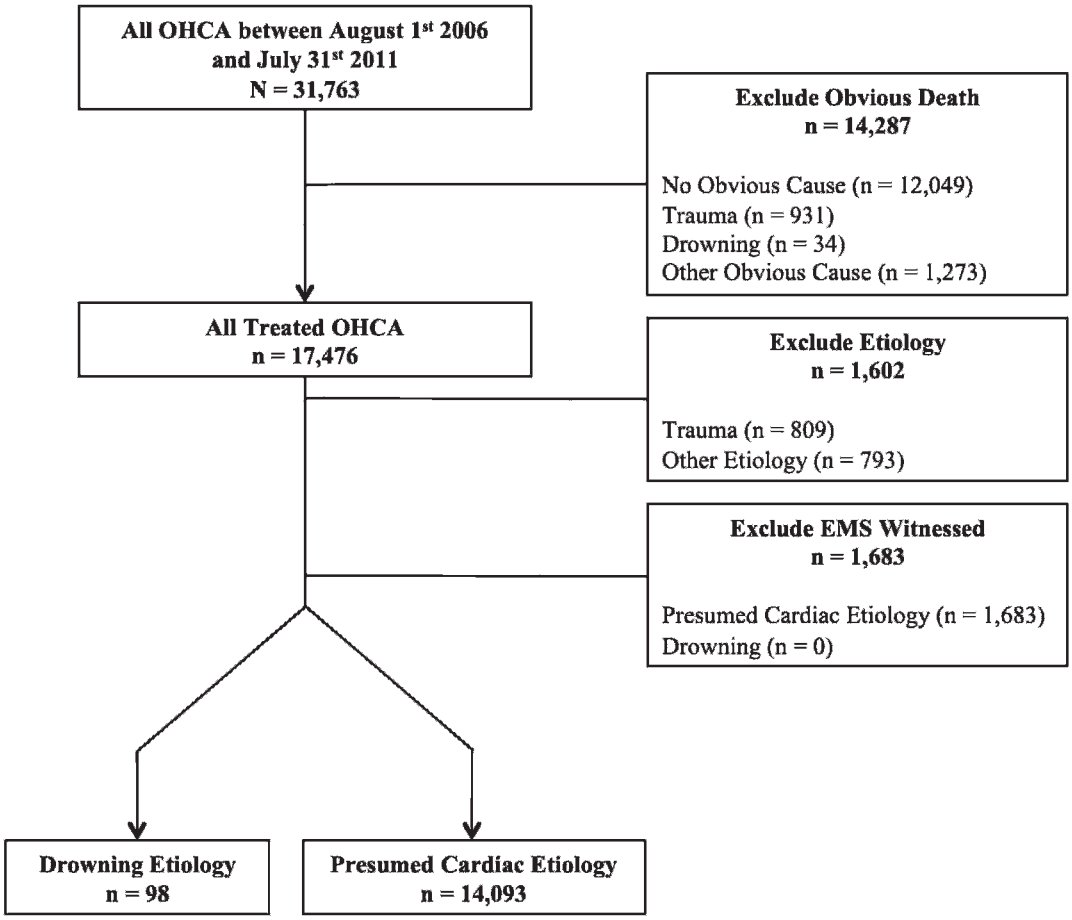

Figure 1. Flow diagram for inclusion and exclusion of patients. EMS = emergency medical services; OHCA = out-of-hospital cardiac arrest.

Table 1. Utstein patient demographics for drowning and presumed cardiac etiologies

Variable	Drowning (*n* = 98)	Presumed cardiac (*n* = 14,093)	*p* value
Age (yr)	36.7 ± 23.4	68.0 ± 18.1	< 0.001
Male gender, *n* (%)	69/98 (70.4)	9,232/14,071 (65.6)	0.319
Bystander witnessed, *n* (%)	19/95 (20.0)	5,991/13,961 (42.9)	< 0.001
Shockable rhythm, *n* (%)	9/91 (9.9)	3,063/13,637 (22.5)	0.004
Public location, *n* (%)	60/98 (61.2)	2,227/14,055 (15.8)	< 0.001
Bystander CPR, *n* (%)	48/98 (49.0)	4,996/13,799 (36.2)	0.009
Bystander AED, *n* (%)	5/95 (5.3)	289/13,544 (2.1)	0.054
Response time (min)	6.9 ± 3.9	6.5 ± 3.3	0.282
Transport, *n* (%)	88/97 (90.7)	7,551/14,026 (53.8)	< 0.001
ROSC at ED arrival, *n* (%)	11/95 (11.6)	2,594/13,917 (18.6)	0.085
Hospital admission, *n* (%)	27/97 (27.8)	2,542/14,032 (18.1)	0.013
Survival, *n* (%)	5/98 (5.1)	826/14,093 (5.9)	0.75

AED = automated external defibrillator; CPR = cardiopulmonary resuscitation; ED = emergency department; ROSC = return of spontaneous circulation.
Shockable rhythms include ventricular fibrillation/ventricular tachycardia and any rhythm where a shock was delivered from a defibrillator.
Because of missing data for each variable, the denominator for each variable is different from the total number of drowning and presumed cardiac out-of-hospital cardiac arrest (OHCA).
Among drowning OHCA patients, information was missing for age (*n* = 2), bystander-witnessed status (*n* = 3), initial rhythm (*n* = 7), bystander AED (*n* = 3), emergency medical service (EMS) response time (*n* = 14), patient transported (*n* = 1), ROSC at ED arrival (*n* = 3), and survival to hospital admission (*n* = 1).
Among presumed cardiac OHCA patients, information was missing for age (*n* = 39), gender (*n* = 22), bystander-witnessed status (*n* = 132), initial rhythm (*n* = 456), pick-up location (*n* = 38), bystander CPR (*n* = 294), bystander AED (*n* = 549), EMS response time (*n* = 1,136), patient transported (*n* = 67), ROSC at ED arrival (*n* = 176), and survival to hospital admission (*n* = 61).

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public access automated external defibrillator (AED) applied (5.3% v. 2.1%, $p = 0.054$). There were no significant differences in male gender (70.4% v. 65.6%, $p = 0.32$) or EMS response time (6.9 ± 3.9 v. 6.5 ± 3.3 minutes, $p = 0.28$). Drowning patients were more likely to be transported to hospital (90.7% v. 53.8%, $p < 0.001$) but had a trend toward being less likely to have a return of spontaneous circulation at ED arrival (11.6% v. 18.6%, $p = 0.08$). Drowning patients were more likely to be admitted to hospital (27.8% v. 18.1%, $p = 0.01$); however, there was no difference in their rate of survival to hospital discharge (5.1% v. 5.9%, $p = 0.74$).

Table 2 provides the number and percentages of witnessed cardiac arrest cases categorized by location type. The majority of drowning cases were unwitnessed by a bystander; 86% of private and 75% of public drownings were unwitnessed compared to 61% and 38% of presumed cardiac OHCA in private and public settings, respectively. Table 3 provides the number and percentages of bystander CPR cases categorized by location type. Whereas OHCAs of presumed cardiac etiology received more bystander CPR in public settings compared to private settings (51.5% v. 33.3%, $p < 0.001$), drowning OHCA patients received more bystander CPR in private locations than in public locations (65.8% v. 38.3%, $p = 0.008$).

Locations varied between drowning and presumed cardiac etiologies ($p < 0.001$). Drownings occurred most often in houses (28 of 98; 28.6%) and sporting or recreational facilities (11 of 98; 11.2%), whereas cases of presumed cardiac etiology more often occurred in houses (8,372 of 14,055; 59.6%) and apartment buildings or condominiums (2,578 of 14,055; 18.3%). Both groups had significant monthly variations in frequency ($p < 0.001$). Drownings were most common in July (33.7%) and August (22.5%), whereas arrests of presumed cardiac etiology were more common in December (9.74%) and January (9.67%). Hourly incidence varied significantly across all blocks for both etiologies ($p < 0.001$). EMS/911 calls for drowning cardiac arrests were most frequent between 12:00–15:59 (26.5%) and 16:00–19:59 (28.6%), whereas arrests of presumed cardiac etiology were more common between 08:00–11:59 (22.6%) and 16:00–19:59 (19.4%).

DISCUSSION

This is the first study to evaluate the prehospital characteristics of drowning patients with cardiac arrest in a Canadian population. We found that drowning patients were younger, more likely to have an unwitnessed cardiac arrest, and more likely to have an initial nonshockable rhythm. Two European studies

Table 2. Witnessed cardiac arrest by location type

	Witnessed cardiac arrest	
Location type	Drowning etiology, *n* (%)	Presumed cardiac etiology, *n* (%)
Private		
Apartment/condominium building	1/8 (12.5)	976/2,556 (38.2)
Nursing home	1/1 (100)	313/853 (36.7)
House/townhouse	3/28 (10.7)	4/13 (30.8)
Farm	0/0 (0)	3,324/8,301 (40.0)
All private locations	5/37 (13.5)	4,617/11,723 (39.4)
Public		
Academic institution	1/2 (50.0)	29/42 (69.1)
Hotel	2/3 (66.7)	24/53 (45.3)
Shopping complex/mall	0/0 (0)	146/197 (74.1)
Recreation facility	1/5 (20.0)	107/135 (79.3)
Street/highway/road	1/7 (14.3)	448/813 (55.1)
Sports field/fairground/park	0/4 (0)	46/64 (71.9)
Water/boat	5/25 (25)	6/11 (54.6)
Other	4/12 (33.3)	555/892 (62.2)
All public locations	14/58 (24.1)	1,361/2,207 (61.7)

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Table 3. Bystander CPR by location type

	Bystander CPR	
Location type	Drowning etiology, *n* (%)	Presumed cardiac etiology, *n* (%)
Private		
Apartment/condominium building	4/8 (50.0)	786/2,513 (31.3)
Nursing home	2/2 (100)	456/844 (54.0)
House/townhouse	19/28 (67.9)	2,609/8,214 (31.8)
Farm	0/0 (0)	5/13 (38.5)
All private locations	25/38 (65.8)	3,856/11,584 (33.3)
Public		
Academic institution	1/2 (50.0)	26/42 (61.9)
Hotel	1/3 (33.3)	21/52 (40.4)
Shopping complex/mall	0/0 (0)	98/196 (50.0)
Recreation facility	3/5 (60.0)	86/135 (63.7)
Street/highway/road	2/7 (28.8)	317/805 (39.4)
Sports field/fairground/park	0/4 (0)	40/64 (62.5)
Water/boat	10/27 (37.0)	6/11 (54.6)
Other	6/12 (50.0)	532/881 (60.4)
All public locations	23/60 (38.3)	1,126/2,186 (51.5)

CPR = cardiopulmonary resuscitation.

showed similar results and observed fewer nonshockable initial rhythms and longer EMS response times in the drowning group.[7,15] They also found that drowning patients had higher survival to hospital admission[7,15] and higher discharge rates,[15] although there was no difference in 1-month survival.[7]

Compared to cardiac etiology OHCA patients, drowning patients in Ontario were more often transported to hospital, which is most likely attributable to the fact that drownings are excluded from the application of termination of resuscitation guidelines.[20,21] Drowning patients were more often admitted to hospital alive compared to cardiac OHCA patients, although there was no difference in survival to hospital discharge. This increase in short-term survival could be explained by the relatively public nature of drownings, which predominantly occur outside or in a shared space and are thus more likely to attract a crowd response. Paramedics are less likely to call for pronouncement and more likely to transport in these situations. However, the risks of transporting drowning patients compared to the long-term survival benefits are not clear.

Both previous studies[7,15] were carried out in European ocean-bordering countries with few internal bodies of water. Although Canada has over 200,000 km of ocean shoreline, most of Canada's 891,000 km^2 of water is composed of lakes and rivers, much of which is populated with cottages and leisure homes. This may account for the large proportion of Canadian OHCAs attributed to drowning that occur in public locations associated with open water and boating.[22] We found that the next most common locations for drowning in Canada were private homes and townhouses, attributable to those Canadians who have access to backyard and neighbourhood pools.

Shockable initial cardiac arrest rhythms were less common in the drowning group, which is consistent with the frequently unwitnessed nature of the event and unknown downtime. Our data suggest that the relative importance of CPR training may be greater than the need for rapid access to an AED as most patients do not immediately require defibrillation. Although more drowning patients receive bystander CPR, lay rescuers should still make every effort to minimize resuscitation delays, which have been associated with worse outcomes.[7,15,23–26] Lay rescuers should follow the 2010 American Heart Association guidelines for CPR and emergency cardiovascular care focusing on early, good-quality chest compressions and rescue breaths for drowning patients.[27]

The majority of all drowning cases were unwitnessed, which suggests that a primary mechanism for drowning may be a lack of supervision. Previous literature on this topic has reported an association between inadequate supervision of swimmers and fatal drowning incidents[8,26,28,29] and found that drowning accidents were less likely with proper lifeguard supervision.[30,31] Our data suggest that unwitnessed

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drownings occur predominantly in recreational facilities, apartment and condominium buildings, homes, sport fields, fairgrounds, and parks. Future public health initiatives, policies, or legislative changes should target these high-risk areas given the preventable nature of these deaths.

Bystanders are more likely to perform CPR on a drowning patient compared to OHCAs of presumed cardiac etiology. Although the ROC Epistry - Cardiac Arrest data set[17] does not collect data regarding bystander behaviours or perceptions, this increased rate of bystander CPR may be related to increased bystander recognition. Although bystanders often fail to recognize an arrest without an obvious cause,[32] a drowning may be more easily identified.[7] This bystander tendency to help in drownings may also be explained by the fact that many Canadians first learn about CPR in swimming classes; therefore, they more easily make the association between drowning and CPR and thus may be more likely to perform CPR when faced with a drowning patient.

Although public settings are often staffed by CPR-trained personnel such as lifeguards and security staff, our data indicate that drowning patients are more likely to receive bystander CPR in private than in public locations. This may be due to less hesitation on the part of family members or neighbours to commence CPR on drowning patients. Public policy and education should not only focus on CPR training for lay rescuers but also advocate that those individuals trained in CPR act in an emergency and for interventions, such as dispatch-coached CPR instructions for bystanders who call 911. Novel technologies, such as crowd-sourcing digital applications that alert potential trained bystanders to a nearby situation, may increase the likelihood that trained rescuers will initiate CPR before EMS arrives.

LIMITATIONS

The ROC Epistry - Cardiac Arrest database does not collect all the Utstein elements that are uniquely captured for drowning, such as whether or not the submersion event was witnessed or if the patient was unconscious when removed from water.[1] Previous studies have found that some drowning events may be preceded by a medical emergency, such as seizures or pre-existing conditions such as diabetes, heart disease, and psychiatric conditions.[14] Information on these medical emergencies or pre-existing conditions is not collected in the ROC Epistry - Cardiac Arrest database.

CONCLUSIONS

Significant differences exist between OHCA of drowning and presumed cardiac etiologies. Most drownings are unwitnessed, occur in public locations, and present with nonshockable initial rhythms, suggesting that treatment should focus on bystander CPR. Future initiatives should focus on strategies to improve supervision in targeted locations and greater emphasis on bystander-initiated CPR, both of which may reduce drowning mortality.

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