A new method for identification of drowning-related out-of-hospital cardiac arrest (Danish Drowning Formula): A retrospective cohort study with 30-day follow-up

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Abstract

Background

Accurate, reliable, and sufficient data is required to reduce the burden of drowning by targeting preventive measures and improving treatment. Today’s drowning statistics are informed by various methods sometimes based on data sources with questionable reliability. These methods are likely responsible for a systematic and significant underreporting of drowning. This study’s aim was to assess the 30-day survival of patients with out-of-hospital cardiac arrest (OHCA) identified in the Danish Cardiac Arrest Registry (DCAR) after applying the Danish Drowning Formula.

Methods

This nationwide, cohort, registry-based study with 30-day follow-up used the Danish Drowning Formula to identify drowning-related OHCA with a resuscitation attempt from the DCAR from January 1st, 2016, through December 31st, 2021. The Danish Drowning Formula is a text-search algorithm constructed for this study based on trigger-words identified from the prehospital medical records of validated drowning cases. The primary outcome was 30-day survival from OHCA. Data were analyzed using multiple logistic regression.

Results

In total, 30,215 OHCA were registered in the DCAR. The Danish Drowning Formula identified 707 potential drowning related OHCA. Of these, 374 were non-drowning, and 16 were excluded because of irreversible death resulting in 317 (1%) patients with drowning related OHCA compared to 29,882 patients with OHCA from other causes. The 30-day survival for patients with drowning-related OHCA was higher compared to OHCA from other causes (33% vs 14%, p < 0.001). Adjusted OR for 30-day survival for drowning-related OHCA and other causes of OHCA was 2.3 [1.7–3.2], p < 0.001.

Conclusions

This study found higher 30-day survival among drowning-related OHCA compared to OHCA from other causes. This study proposed that a text-search algorithm (Danish Drowning Formula) could explore unstructured text fields to identify drowning persons. This method may present a low-resource solution to inform the drowning statistics in the future.

Registration:

This study was registered at ClinicalTrials.gov before analyses (NCT05323097).
Introduction

Drowning is defined by the World Health Organization (WHO) as “the process of experiencing respiratory impairment from submersion or immersion in liquid”. (1) The Global Burden of Disease Study in 2010 and 2017 reported a slight reduction in the incidence of drowning, (2,3) yet drowning continues to be a preventable (4,5) major cause of mortality in otherwise healthy persons. (6–8)

Accurate and sufficient data is necessary to support targeted preventive and treatment measures to reduce the burden of drowning, (9) which is of great public interest.

However, differences in drowning terminology and definitions (10–13) make up significant obstacles when trying to identify drowning persons. These obstacles also apply to and challenge the current Danish drowning statistics which is based on collecting death certificates using primary-cause International Classification of Diseases 10th Revision (ICD-10) codes. This method significantly underreports the true incidence of fatal and non-fatal drowning accidents as the codes are not sufficiently specific to drowning, (12,14,15) and it is time-consuming, as collecting death certificates and confirming cause of death may take years. (16) The available evidence on drowning-related out-of-hospital cardiac arrest (OHCA) to inform clinical practice guidelines for drowning is very limited. (17,18) A potential for improvement exists, which requires standardized identification of drowning accidents.

This study aims to identify drowning accidents in Denmark leading to OHCA by using a text-search algorithm to search the Danish Cardiac Arrest Registry (DCAR) and analyzing 30-day survival.

Methods

Study design

This study was a nationwide, retrospective, registry-based cohort study with a 30-day follow-up.

Setting

Denmark has approximately 5.9 million inhabitants. According to the latest DCAR report from 2021, the annual incidence of OHCA was 4,807, corresponding to 81 per 100,000 citizens, (19) overall 30-day survival rate was 13% (10 per 100,000 citizens), with a bystander cardiopulmonary resuscitation (CPR) rate of 79%. (20)

This study applied an advanced text-search algorithm (Danish Drowning Formula) within the DCAR from January 1st, 2016, through December 31st, 2021, to identify potential drowning patients.

The Danish Cardiac Arrest Registry

In 2016, the Danish Emergency Medical Services (EMS) introduced a nationwide electronic medical reporting system recording all consecutive cases of OHCA in which a resuscitative attempt was initiated. (21) With the application of a manual validation process, this electronic system is the cornerstone of the
DCAR and constitutes a solid base for identifying and verifying OHCA.(22) Furthermore, the DCAR is linked with the text fields from the electronic prehospital medical records in the Danish quality database for prehospital emergency medical services.(23) This system enables advanced text searching within all unstructured text fields in the DCAR for specific cases of OHCA(24) based on prespecified identifying trigger words.

**Identification of drowning-related OHCA**

During the manual validation of OHCA in the changeover period in 2016, 211 cases were labelled as potential drowning accidents. These cases were manually reviewed and validated as drowning if the person most likely had suffered cardiac arrest following submersion in liquid. Three reviewers (NB, TWJ, and MGH) manually reviewed the prehospital medical records of validated cases and identified trigger-words related to submersion injury. NB and SNFB combined these trigger-words by “OR” and build a text-search algorithm, which was used to search the unstructured text fields within the electronic prehospital medical records in the DCAR. The algorithm returned new medical records from the initial text search, which were manually reviewed and validated by three reviewers (NB, SAW, and TWJ) to identify new trigger-words to be added to the algorithm. This iterative process was repeated until no more drowning cases appeared, thereby improving the sensitivity of the algorithm. Subsequently, NB and SNFB added specific trigger-words to the existing algorithm by “NOT” to improve the specificity without decreasing sensitivity. The final text-search algorithm was named the Danish Drowning Formula.

**Participants**

All cases from the final search were manually reviewed by three reviewers (NB, SAW, and TWJ) for validation. Any discrepancies were solved by a senior investigator (HCC). Patients were eligible for inclusion if they had suffered OHCA while submerged or immersed in liquid in which a resuscitative attempt was initiated. Cases with clinical signs of irreversible death were excluded (decomposition, post-mortem lividity, and post-mortem rigidity) (Fig. 1). All Danish citizens have a unique identification number which is a personal identifier that enables accurate linkage between all Danish national registries. Follow-up was completed for all patients with a valid identification number to report 30-day survival.

**Variables**

The primary outcome was 30-day survival. The primary outcome was analyzed as univariable and as multivariable adjusted for age, sex, bystander-witnessed event, and initial rhythm. Bystander CPR was removed from the adjusted analysis due to multicollinearity with bystander-witnessed event. Secondary outcomes were annual incidence rates of drowning-related OHCA per 100,000 citizens, survival status at hospital admission, and geographical localization of drowning-related OHCA in Denmark.

**Data sources**

SNFB extracted data from the DCAR for all Danish OHCA from 2016–2021, including age, sex, date of occurrence, observation of occurrence, CPR performed by bystanders and EMS personnel, bystander use
of an automated external defibrillator (AED), GPS coordinates, EMS response time, initial rhythm analyzed by EMS, return of spontaneous circulation (ROSC) at any time prehospital, ROSC at hospital admission, 30-day, and 1-year survival. Data on liquid type, location type, activity type, and cause of drowning (intentional/unintentional) were manually extracted from the electronic prehospital medical records on validated drowning cases. The municipal population density was used to estimate population density at the OHCA site stratified as low, intermediate, and high density according to the EUROSTAT degree of urbanization system (DEGURBA).(25) The location type was categorized as following: 1) Bathtub, 2) Swimming pool, 3) Harbor, 4) Coastline, 5) Open ocean, 6) Lake, 7) Streams, 8) Other. The location type “Swimming pool” was used for all in- or outdoor structures designed to hold a body of standing water. The location type “Other” included drowning accidents in wells, manure stores, etc. Activity type described what the person was doing at the time of the incident and was categorized as following: 1) Swimming/bathing, 2) Boat activity, 3) Diving, 4) Recreational fishing, 5) Traffic, 6) Harbor activity, 7) Water sports. The activity type “Swimming/bathing” included all forms of playing, bathing, and swimming. The activity type “Boat activity” included activities on a boat in open water, such as oceans and lakes, including fishing from a boat. However, if the boat was in port, the activity was defined as “Harbor activity”. The activity type “Diving” was used for freediving and scuba diving. The activity type “Traffic” was used for accidents involving driving into the water using a bike or motorized vehicle. The activity type “Water sports” was used for accidents involving swim practice, kayaking, water polo, and surfing.

Statistical methods

Baseline characteristics are presented separately for drowning-related OHCA and other causes of OHCA and fatal and non-fatal drowning accidents. Categorical variables are presented as frequencies (counts and percentages) and compared using the chi-squared test. Numerical variables are presented as medians with interquartile ranges (IQR) due to non-normality (inspected using histograms and Q-Q plots) and compared using the Mann Whitney U test.

The primary outcome was analyzed using a multiple logistic regression model and presented as odds ratios (ORs) with 95% confidence intervals (CIs) adjusted for age, sex, bystander-witnessed event, and initial rhythm.

Annual incidence rates per 100,000 citizens were calculated and presented with 95% CIs. P-values < 0.05 were considered statistically significant. There was no imputation of missing data. All drowning-related OHCA were presented on a map of Denmark. All analyses were performed using R statistical software (version 4.2.2).(26)

Results

Study population
From January 1st, 2016, to December 31st, 2021, 30,215 cases of OHCA were attended by the Danish EMS. The authors used the Danish Drowning Formula to identify 707 cases, which were manually validated by three reviewers (NB, SAW and TWJ). Following manual validation, 16 cases were excluded due to clinical signs of irreversible death and 374 were identified as non-drowning (Fig. 1). As a result, 317 drowning-related OHCA and 29,882 OHCA from other causes were included in the analyses, equivalent to an incidence of 1% from all Danish OHCAs from 2016–2021. This corresponded to an annual incidence of 0.91 drowning-related OHCA per 100,000 citizens in the Danish population (95% CI, 0.8-1.0). A total of 83 (26%) of patients with drowning-related OHCA had missing identification numbers and were lost to follow-up. This group may also represent non-residents without a Danish identification number.

Most drowning patients with OHCA were male (72%). The median age of all drowning patients with OHCA was 58 [IQR: 38–73] years. Children less than 5 years accounted for 6%, and children and young adults from 5 years to less than 25 years accounted for 10%. Most drowning-related OHCA occurred during the summer months and public holidays from June to August (40%). There was no significant difference in the incidence of drowning-related OHCA according to the day of the week (Monday to Sunday). Drowning-related OHCA most frequently occurred during swimming/bathing (46%), and the most frequent locations were coastlines (28%), swimming pools (22%), and harbors (17%). Figure 2 presents a map of Denmark with all drowning-related OHCA from 2016–2021, showing the location of incidents.

**Drowning-related OHCA and other causes of OHCA**

Drowning-related OHCA more frequently occurred at a public location (87% vs 25%, p < 0.001), were more frequently witnessed by bystanders (70% vs 55%, p < 0.001), and received higher rates of bystander CPR (77% vs 70%, p = 0.017) compared to OHCA from other causes (Table 1). An initial shockable rhythm was less common in drowning-related OHCA compared to OHCA from other causes (9% vs 17%, p = 0.001).
### Table 1
Baseline characteristics of drowning-related OHCA compared to other causes in Denmark from 2016–2021

<table>
<thead>
<tr>
<th></th>
<th>OHCA non-drowning (n = 29,882)</th>
<th>OHCA drowning (n = 317)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years, median, [IQR]</td>
<td>73 [62–82]</td>
<td>58 [38–73]</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Missing</td>
<td>1,071</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>Sex, male, n (%)</td>
<td>18,410 (64)</td>
<td>175 (72)</td>
<td>0.008*</td>
</tr>
<tr>
<td>Missing</td>
<td>1,070</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Public location, n (%)</td>
<td>7,296 (25)</td>
<td>274 (87)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Missing</td>
<td>196</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Bystander-witnessed, n (%)</td>
<td>16,366 (55)</td>
<td>216 (69)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Missing</td>
<td>207</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Bystander CPR, n (%)</td>
<td>20,925 (70)</td>
<td>243 (77)</td>
<td>0.02*</td>
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<tr>
<td>Missing</td>
<td>136</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>CPR by EMS, n (%)</td>
<td>27,725 (94)</td>
<td>265 (84)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Missing</td>
<td>222</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Initial shockable rhythm, n (%)</td>
<td>4,748 (17)</td>
<td>28 (9)</td>
<td>0.001*</td>
</tr>
<tr>
<td>Missing</td>
<td>1,154</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Defibrillation by bystander, n (%)</td>
<td>2,534 (8)</td>
<td>27 (9)</td>
<td>1.00</td>
</tr>
<tr>
<td>Missing</td>
<td>301</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Defibrillation by EMS, n (%)</td>
<td>7,619 (26)</td>
<td>53 (17)</td>
<td>0.006*</td>
</tr>
<tr>
<td>Missing</td>
<td>251</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Response time, min, median [IQR]</td>
<td>7 [5–10]</td>
<td>8 [6–11]</td>
<td>0.001*</td>
</tr>
<tr>
<td>Missing</td>
<td>3,182</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>Season, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The 30-day survival for patients with drowning-related OHCA was greater compared to OHCA from other causes: 78 (33%) vs 4,001 (14%) (p < 0.001). Drowning-related OHCA more frequently had ROSC at hospital admission (38% vs 27%) and greater 1-year survival (32% vs 13%) compared to OHCA from other causes (p < 0.001).

The unadjusted OR with a 95% CI for 30-day survival following drowning-related OHCA was 3.1 [2.4–4.1] compared to OHCA from other causes (p < 0.001). The adjusted OR for 30-day survival following drowning-related OHCA was 2.3 [1.7–3.2] compared to OHCA from other causes (p < 0.001) (Fig. 3).

This study found greater 30-day survival for drowning-related OHCA occurring in swimming pools compared to OHCA from other causes occurring at other public locations with an OR of 11.6 [6.0-22.6], p < 0.001 (Fig. 4).

**Fatal vs non-fatal drowning-related OHCA**
Survivors from drowning-related OHCA were younger (median [IQR] age 33 [7–60] vs 67 [51–75] years, p < 0.001), more frequently bystander-witnessed (44% vs 27%, p = 0.01), more often received bystander CPR (96% vs 68%, p < 0.001), had a higher rate of initial shockable rhythm (19% vs 6%, p = 0.01), and were more likely to receive defibrillation by bystanders (17% vs 5%, p = 0.005) (Table 2). There was no significant association between population density and survival outcome following drowning-related OHCA.
### Table 2

#### Fatal vs non-fatal (30-day survival) drowning with OHCA in Denmark from 2016–2021

<table>
<thead>
<tr>
<th></th>
<th>Fatal drowning (n = 156)</th>
<th>Non-fatal drowning (n = 78)</th>
<th>Follow-up missing (n = 83)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, years, median, [IQR]</strong></td>
<td>66.5 [50.8–75.2]</td>
<td>33 [7.0–59.5]</td>
<td>42 [29.5–63.5]</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td><strong>Missing</strong></td>
<td>0</td>
<td>0</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td><strong>Sex, male, n (%)</strong></td>
<td>124 (80)</td>
<td>49 (63)</td>
<td>2</td>
<td>0.003*</td>
</tr>
<tr>
<td><strong>Missing</strong></td>
<td>0</td>
<td>0</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td><strong>Public location, n (%)</strong></td>
<td>131 (84)</td>
<td>67 (88)</td>
<td>76 (93)</td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Missing</strong></td>
<td>0</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>Population density at OHCA site, n (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>Low</td>
<td>42 (27)</td>
<td>23 (30)</td>
<td>28 (34)</td>
<td></td>
</tr>
<tr>
<td>Intermediate</td>
<td>35 (22)</td>
<td>15 (19)</td>
<td>11 (13)</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>12 (8)</td>
<td>14 (18)</td>
<td>13 (16)</td>
<td></td>
</tr>
<tr>
<td><strong>Missing</strong></td>
<td>67 (43)</td>
<td>26 (33)</td>
<td>31 (37)</td>
<td></td>
</tr>
<tr>
<td><strong>Location type, n (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bathtub</td>
<td>16 (10)</td>
<td>0 (0)</td>
<td>1 (1)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Swimming pool</td>
<td>15 (10)</td>
<td>42 (54)</td>
<td>13 (16)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Harbor</td>
<td>34 (22)</td>
<td>6 (8)</td>
<td>13 (16)</td>
<td>0.04*</td>
</tr>
<tr>
<td>Coastline</td>
<td>38 (24)</td>
<td>18 (23)</td>
<td>33 (40)</td>
<td>0.02*</td>
</tr>
<tr>
<td>Open ocean</td>
<td>8 (5)</td>
<td>1 (1)</td>
<td>8 (10)</td>
<td>0.06</td>
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<tr>
<td>Lake</td>
<td>21 (14)</td>
<td>4 (5)</td>
<td>4 (5)</td>
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</tr>
<tr>
<td>Streams</td>
<td>13 (8)</td>
<td>2 (3)</td>
<td>3 (4)</td>
<td>0.13</td>
</tr>
<tr>
<td>Other</td>
<td>6 (4)</td>
<td>2 (3)</td>
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<td>5 (3)</td>
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<td>7 (8)</td>
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<tr>
<td><strong>Liquid type, n (%)</strong></td>
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<tr>
<td>Fresh water</td>
<td>54 (35)</td>
<td>10 (13)</td>
<td>11 (13)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td></td>
<td>Fatal drowning (n = 156)</td>
<td>Non-fatal drowning (n = 78)</td>
<td>Follow-up missing (n = 83)</td>
<td>p-value</td>
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<tr>
<td>----------------</td>
<td>--------------------------</td>
<td>-----------------------------</td>
<td>---------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Salt water</td>
<td>87 (56)</td>
<td>27 (35)</td>
<td>58 (70)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Chlorinated water</td>
<td>10 (6)</td>
<td>38 (49)</td>
<td>8 (10)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Other</td>
<td>1 (1)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0.60</td>
</tr>
<tr>
<td>Missing</td>
<td>4 (3)</td>
<td>3 (4)</td>
<td>6 (7)</td>
<td></td>
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<tr>
<td>Activity type, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swimming/bathing</td>
<td>65 (42)</td>
<td>49 (63)</td>
<td>32 (39)</td>
<td>0.003*</td>
</tr>
<tr>
<td>Boat activity</td>
<td>10 (6)</td>
<td>2 (3)</td>
<td>7 (8)</td>
<td>0.28</td>
</tr>
<tr>
<td>Diving</td>
<td>6 (4)</td>
<td>7 (9)</td>
<td>2 (2)</td>
<td>0.11</td>
</tr>
<tr>
<td>Recreational fishing</td>
<td>4 (3)</td>
<td>1 (1)</td>
<td>4 (5)</td>
<td>0.39</td>
</tr>
<tr>
<td>Traffic</td>
<td>11 (7)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0.003*</td>
</tr>
<tr>
<td>Harbor activity</td>
<td>5 (3)</td>
<td>2 (3)</td>
<td>3 (4)</td>
<td>0.93</td>
</tr>
<tr>
<td>Water sports</td>
<td>3 (2)</td>
<td>5 (6)</td>
<td>4 (5)</td>
<td>0.20</td>
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<tr>
<td>Missing</td>
<td>52 (33)</td>
<td>12 (15)</td>
<td>31 (37)</td>
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<tr>
<td>Cause, n (%)</td>
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<tr>
<td>Unintentional</td>
<td>110 (71)</td>
<td>75 (97)</td>
<td>53 (64)</td>
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</tr>
<tr>
<td>Intentional</td>
<td>8 (5)</td>
<td>1 (1)</td>
<td>2 (2)</td>
<td>0.26</td>
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<td>Missing</td>
<td>38 (24)</td>
<td>2 (3)</td>
<td>28 (34)</td>
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<tr>
<td>Bystander-witnessed, n (%)</td>
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<td>33 (44)</td>
<td>21 (26)</td>
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<td>Missing</td>
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<td>3</td>
<td>1</td>
<td></td>
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<tr>
<td>CPR by bystander, n (%)</td>
<td>107 (69)</td>
<td>75 (96)</td>
<td>61 (74)</td>
<td>&lt; 0.001*</td>
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<td>0</td>
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<td></td>
</tr>
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<td>Initial shockable rhythm, n (%)</td>
<td>9 (6)</td>
<td>12 (19)</td>
<td>7 (9)</td>
<td>0.01*</td>
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<tr>
<td>Missing</td>
<td>3</td>
<td>13</td>
<td>3</td>
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<tr>
<td>Defibrillation by bystander, n (%)</td>
<td>7 (5)</td>
<td>13 (17)</td>
<td>7 (9)</td>
<td>0.005*</td>
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<tr>
<td></td>
<td>Fatal drowning (n = 156)</td>
<td>Non-fatal drowning (n = 78)</td>
<td>Follow-up missing (n = 83)</td>
<td>p-value</td>
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<td>---------------------------</td>
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</tr>
<tr>
<td>Missing</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Defibrillation by EMS, n (%)</td>
<td>23 (15)</td>
<td>11 (15)</td>
<td>19 (24)</td>
<td>0.20</td>
</tr>
<tr>
<td>Missing</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Response time, min, median [IQR]</td>
<td>8 [6–12]</td>
<td>7 [4.2–10.8]</td>
<td>8.5 [6.0-11.5]</td>
<td>0.04*</td>
</tr>
<tr>
<td>Missing</td>
<td>14</td>
<td>8</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Season, n (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter (Dec.-Feb)</td>
<td>34 (22)</td>
<td>8 (10)</td>
<td>12 (15)</td>
<td>0.01*</td>
</tr>
<tr>
<td>Spring (Mar.-May)</td>
<td>28 (18)</td>
<td>26 (33)</td>
<td>15 (18)</td>
<td>0.07</td>
</tr>
<tr>
<td>Summer (Jun.-Aug.)</td>
<td>57 (37)</td>
<td>35 (45)</td>
<td>35 (42)</td>
<td>0.02*</td>
</tr>
<tr>
<td>Autumn (Sep.-Nov.)</td>
<td>37 (24)</td>
<td>9 (12)</td>
<td>21 (25)</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Legend: All analyses are unadjusted. * = statistically significant. Abbreviations: IQR = Interquartile range; EMS = Emergency Medical Service; CPR = cardiopulmonary resuscitation; min = minutes. Missing data are excluded from the denominator.

**Limitations**

The method used in this study has certain limitations. First, this method cannot fully differentiate between OHCA caused by drowning and OHCA caused by cardiac or other conditions while the patient was in the water. Linkage with the patients' unique identification number may enable future access to their death certificates to specify the actual cause of death. Second, drowning accidents with signs of irreversible death were excluded from the DCAR as they did not involve attempts at resuscitation. There might be a small proportion of cases registered in the DCAR with signs of irreversible death even after manual validation. However, we were not able to systematically exclude these. Third, drowning accidents in the open ocean where the patient or the body is retrieved by military Search and Rescue helicopters are limited as these are not routinely included in the prehospital medical records. Fourth, drowning patients will not show in the statistics if the body is not recovered. Fifth, information regarding supervision, activity before drowning, use of a life jacket, exact submersion time, and the patient's ability to swim will always be a limitation in drowning research.

**Discussion**

This study found greater 30-day survival for drowning-related OHCA compared to OHCA from other causes.
Methods compared to the existing literature

The current Danish drowning statistics identify drowning from the Danish cause of death register by searching for relevant diagnosis codes in the ICD-10 related to drowning.(28) The search results are combined with other data sources to create a triangulation method and improve data quality (e.g., reports on rescue missions, year-round media monitoring, police reports, social media, and reports from lifesaving clubs).(15,29) Other studies have used multiple and complex criteria for data extraction,(16) and some have used a correction factor to report an estimate of the true incidence of drowning accidents. (15) These methods have several limitations compared to text-search algorithms (such as the Danish Drowning Formula). First, collecting death certificates and confirming the cause of death may take several years.(16) Second, drowning studies using primary-cause ICD codes significantly underreport the true incidence of fatal and non-fatal drowning accidents as the codes are not sufficiently specific. (12,14,15) Third, the complexity and heterogeneity of the different methods complicate between-study comparisons. Fourth, accessing and linking data from various sources is time-consuming. Fifth, the reliability of some data sources is questionable and increases the risk of missing data. In summary, the various methods are likely responsible for a systematic and significant underreporting of drowning accidents. The Danish drowning statistics reported 102 drowning accidents in Denmark in 2020, including patients found in the water with no actual cause of death disclosed.(28) According to the statistics, 54 (53%) resulted in fatal drowning in 2020. We expect the Danish Drowning Formula to identify significantly more drowning cases once applied to the entire Danish quality database for prehospital EMS consisting of all “112 patient contacts”.(23)

According to Danish Index for Emergency Care, an ambulance will be dispatched in case of drowning. (30,31) Assuming that EMS will be contacted in the majority of cases with drowning, the use of text-search algorithms (such as the Danish Drowning Formula) to search the electronic medical records represents a paradigm shift with three main benefits: First, it could enhance the ability to identify fatal and non-fatal drowning accidents in the future accurately. Second, it could provide real-time data. Third, by linking each patient’s unique identification number with the comprehensive Danish registries, it could be possible to track the complete medical history and outcomes of each patient, including in-hospital information.(21) The use of text-search algorithms to search the electronic prehospital medical records could provide a cost-effective solution towards fully understanding and quantifying the overall impact of drowning. The use of text-search algorithms may provide high-quality data that could be used in monitoring preventative interventions accurately in real-time (e.g., impact from targeted campaigns in high-risk groups, increased signage in high-risk locations, allocation of lifeguards).

Results compared to the existing literature

Patients’ demographic information and the seasonal distribution of drowning corresponded to other studies.(29,32–36) This study reported an incidence of 1% drowning-related OHCA out of all OHCA, similar to that in Sweden. (37) This study confirmed a greater 30-day survival following drowning-related OHCA compared to OHCA from other causes found in other studies.(37–39)
The association of a bystander-witnessed event on improved survival from drowning is well-known. Submersion exceeding 10 minutes and lack of CPR at the scene is known to be associated with poor outcome, but early rescue and treatment with CPR, including oxygenation and ventilation, may reverse the hypoxic cause of cardiac arrest. Therefore, EMS personnel and bystanders, including parents or trained rescuers (e.g., trained lifeguards), play a critical role in the initial rescue attempts and treatment to improve outcome.

**Perspectives**

This study demonstrates the use of a text-search algorithm (the Danish Drowning Formula) to systematically identify drowning accidents with OHCA from the DCAR. The method described in this study may be used to develop similar drowning algorithms in local language to systematically identify drowning cases in other OHCA registries. This study is the first step to establishing a Danish drowning database with consistent, high-quality data that may improve our understanding of the drowning process in the future. The Danish Drowning Formula has the potential to identify the majority of fatal and non-fatal drowning accidents once we apply it to all cases registered in the Danish quality database for prehospital EMS. This will provide important information on the reliability of the Danish Drowning Formula compared to the current Danish drowning statistics. Identification of drowning persons and linkage between Denmark’s extensive registries may improve uniform data reporting from drowning in the “Utstein style”. Accurate, reliable, and sufficient data is necessary before specific educative, preventative, rescue, and treatment strategies can be suggested to reduce drowning-related OHCA in Denmark.

**Conclusions**

This study proposes a text-search algorithm (Danish Drowning Formula) to identify drowning accidents from unstructured text fields in the electronic medical records. In the Danish Cardiac Arrest Registry, 30-day survival was higher after drowning-related OHCA compared to OHCA from other causes. This method may present a low-resource solution to the future identification of fatal and non-fatal drowning accidents.

**List Of Abbreviations**

AED
Automated External Defibrillator.
CI
Confidence Interval.
CPR
Cardiopulmonary Resuscitation.
DCAR
Danish Cardiac Arrest Registry.
DEGURBA
Degree of Urbanization System.
EMS
Emergency Medical Service.

GPS
Global Positioning System.

ICD
International Classification of Diseases.

IQR
Interquartile Range.

min
minutes.

OHCA
Out of Hospital Cardiac Arrest.

OR
Odds Ratio.

ROSC
Return of Spontaneous Circulation.

WHO
World Health Organization.

Declarations

Ethics approval

According to Danish law, registry-based studies do not need approval by a Research Ethics Committee (journal number EMN-2022-02630). The Committee on Health Research Ethics in the Region of Southern Denmark waived the need for informed consent, given the retrospective nature of the study. The Danish Data Protection Agency approved data management and processing (REG-033-2022). The Regional Council in the Region of Southern Denmark granted access to medical records (ID-number: EMN-2022-05034). The study was conducted per protocol and statistical analysis plan and pre-registered at ClinicalTrials.gov (NCT05323097). The study is reported according to the "Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)" guidelines for observational studies. (53)

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests
The authors declare no conflict of interest.

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**Authors’ contributions**

NB, SNFB, JS, and HCC participated in the study conception and design. NB, SAW, and TWJ were involved in the acquisition of data. All authors contributed to the analysis and interpretation of data. NB drafted the manuscript. All authors were involved in critically revising the manuscript for important intellectual content. All authors read and approved the final manuscript. NB takes responsibility for the paper as a whole.

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**References**


Figures
Figure 1

STROBE inclusion flow chart.

Legend: * = Identified through an electronic database search.

Figure 2

Map of drowning-related OHCA in Denmark from 2016-2021.

Legend: Drowning-related OHCA cases are evenly distributed across Denmark. Black dots = drowning-related OHCA in Denmark.
Figure 3

Forest plot of 30-day survival for drowning vs non-drowning OHCA in Denmark from 2016-2021.

Legend: The primary outcome was analyzed using multiple logistic regression models. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs) adjusted for age, sex, bystander-witnessed event, and initial rhythm. * = statistically significant.
Figure 4

Forest plot of 30-day survival for drowning locations in Denmark from 2016-2021.

Legend: 30-day survival adjusted for the drowning location was analyzed using a multiple logistic regression model. The location “bathtub” and “other” were removed as the samples were too small to analyze. Results are presented as odds ratios (ORs) with 95% confidence intervals (CIs). * = statistically significant.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- STROBEchecklist.docx