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RESEARCH

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The Danish Drowning Cohort: Utstein-style data from fatal and non-fatal drowning incidents in Denmark

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Abstract

Background Effective interventions to reduce drowning incidents require accurate and reliable data for scientific analysis. However, the lack of high-quality evidence and the variability in drowning terminology, definitions, and outcomes present significant challenges in assessing studies to inform drowning guidelines. Many drowning reports use inappropriate classifications for drowning incidents, which significantly contributes to the underreporting of drowning. In particular, non-fatal drowning incidents are underreported because many countries do not routinely collect this data.

The Danish Drowning Cohort The Danish Drowning Cohort was established in 2016 to facilitate research to improve preventative, rescue, and treatment interventions to reduce the incidence, mortality, and morbidity of drowning. The Danish Drowning Cohort contains nationwide data on all fatal and non-fatal drowning incidents treated by the Danish Emergency Medical Services. Data are extracted from the Danish prehospital electronic medical record using a text-search algorithm (Danish Drowning Formula) and a manual validation process. The WHO definition of drowning, supported by the clarification statement for non-fatal drowning, is used as the case definition to identify drowning. All drowning patients are included, including unwitnessed incidents, non-conveyed patients, patients declared dead prehospital, or patients with obvious clinical signs of irreversible death. This method allows syndromic surveillance and monitors a nationwide cohort of fatal and non-fatal drowning incidents in near-real time to inform future prevention strategies. The Danish Drowning Cohort complies with the Utstein style for drowning reporting guidelines. The 30-day mortality is obtained through the Civil Personal Register to differentiate between fatal and non-fatal drowning incidents. In addition to prehospital data, new data linkages with other Danish registries via the patient's civil registration number will enable the examination of various additional factors associated with drowning risk.

Conclusion The Danish Drowning Cohort contains nationwide prehospital data on all fatal and non-fatal drowning incidents treated by the Danish Emergency Medical Service. It is a basis for all research on drowning in Denmark and may improve preventative, rescue, and treatment interventions to reduce the incidence, mortality, and morbidity of drowning.

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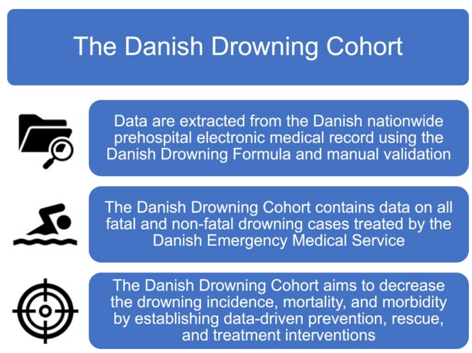
Keywords Danish drowning formula, Syndromic surveillance, Register, Database, Emergency medical services, Electronic medical records, Drowning

Plain Language Summary

The Danish Drowning Cohort includes data on fatal and non-fatal drowning incidents treated by the Emergency Medical Services from 2016 and onwards and serves as the foundation for drowning research in Denmark. Data are extracted from the Danish Prehospital Electronic Medical Record using the Danish Drowning Formula and manual validation. The research data can advance prevention, rescue, and treatment interventions, aiming to decrease drowning incidence, mortality, and morbidity. The research data follows the Utstein style for drowning reporting guidelines linked with 30-day survival.

Graphical Abstract



Introduction

Targeted preventative measures can avoid a large proportion of drowning incidents, and developing evidence-based rescue and treatment recommendations is a high priority to decrease mortality and morbidity following drowning [1, 2]. Effective preventative, rescue, and treatment interventions to reduce drowning incidents require accurate, reliable, and sufficient data to be scientifically analysed. However, the lack of high-quality evidence and the variability in drowning terminology, definitions, and outcomes pose significant challenges when assessing studies to inform drowning guidelines [1, 3, 4]. Most drowning reports use an inappropriate classification of drowning incidents, which significantly contributes to the under-reporting of drowning incidents [5, 6]. Especially non-fatal drowning incidents are under-reported, as many countries do not routinely collect this data [7].

A consensus-based advisory statement from the International Liaison Committee on Resuscitation recommending the Utstein style for drowning (USFD) was published in 2003 [8, 9]. The USFD was revised in 2015 based on a review of 14 studies [10–12]. However, many variables from the revised USFD are not routinely reported as they are unavailable [10]. Even in high-resource healthcare settings, the large amount of variables makes data collection time-consuming [13, 14].

Using electronic medical records is becoming increasingly common as they reduce resource utilization and improve the quality of care [15, 16]. Text-search algorithms to search the prehospital electronic medical record may provide new and improved ways of detecting drowning, as they can monitor drowning indicators (i.e. trigger words or constructs) similar to syndromic surveillance and create high-quality datasets to inform prevention strategies [17, 18].

The Danish Drowning Cohort reports prehospital data on fatal and non-fatal drowning patients treated by the Emergency Medical Services (EMS) in Denmark from 2016 and onwards. Drowning incidents are identified from the Danish prehospital electronic medical record using the Danish Drowning Formula and extensive manual validation. Data are extracted following the revised USFD [11, 12]. The Danish Drowning Cohort will facilitate research to improve preventative, rescue, and treatment interventions to reduce the burden of drowning.

This paper aims to describe the Danish Drowning Cohort, including the patient selection process and the reported variables.

Materials and methods

Setting

Denmark has approximately 5.9 million inhabitants [19]. Despite its small geographical area of 42,933 square kilometres, the country and its citizens are highly exposed to aquatic environments with 8,593 km coastline, 669 natural harbours, anchorages, marinas, and 251 public pools [20–22].

All Danish citizens are provided free and universal tax-supported health care by the Danish National Health Services [23]. The Danish prehospital EMS response is government-funded and divided into five regions, each with a regional Emergency Medical Dispatch Centre [24]. The Danish prehospital EMS response operates round-the-clock. It includes ambulances as the basic-level response, paramedic- or nurse-staffed cars as the intermediate-level response, and physician-staffed vehicles (mobile emergency care units) or helicopters (Helicopter Emergency Medical Services [HEMS]) as the advanced-level response [25, 26]. Since 2015, all Danish prehospital personnel have utilised the prehospital electronic medical record [25, 26]. Clinical data can be entered or directly transmitted from monitors into structured sections. Several unstructured text fields are available (e.g. a summary of the prehospital effort, treatment given prior to arrival, and previous diseases). However, data are not routinely collected or required to be entered here. Data from the prehospital electronic medical record is forwarded to in-hospital servers in real-time, providing prehospital information to the hospital staff receiving the patient.

All Danish citizens have a unique civil registration number in the Danish Civil Registration System [27]. Patients without a Danish civil registration number will receive a temporary number upon contact with the Danish health care system. In medical research, the civil registration number can be used for exact individual-level record linkage of all extensive Danish registries facilitating research [28]. Therefore, regularly updated data on 30-day survival can be collected from the Civil Personal Register and linked to the Danish Drowning Cohort [27].

Danish drowning formula

In 2023, the Danish Drowning Formula was developed as a text-search algorithm that searches the unstructured text fields of the prehospital electronic medical record to detect drowning-related out-of-hospital cardiac arrest registered in the Danish Cardiac Arrests Registry [29, 30]. The Danish Drowning Formula consists of 111 trigger words related to submersion injury and aquatic environments and is described previously [29].

Population

The study population included all fatal and non-fatal drowning patients treated by the EMS in Denmark from 2016 and onwards.

Case validation

The Danish Drowning Formula was initially used to detect all possible water-related incidents. To identify drowning-related records, a comprehensive validation of all records with potential drowning incidents was conducted (Fig. 1).

Nineteen trigger words and constructs from the Danish Drowning Formula were considered critical, i.e. high association with drowning (Fig. 1). These consisted of (1) variations of “drowning” and “near-drowning”, the latter still being used by some EMS personnel despite being incompatible with the current drowning definition, (2) variations of “found in water”, and (3) variations of “cardiopulmonary resuscitation” and “obvious clinical signs of irreversible death”. Critical words and constructs included in numbers one and two were already present in the Danish Drowning Formula. However, as critically ill or deceased drowning patients often have shorter medical records consisting of fewer words, we decided to manually validate all those records identified by the Danish Drowning Formula containing any critical words or constructs included in number three.

Records were separated into three groups: (1) records containing a critical trigger word, (2) records containing multiple non-critical trigger words, and (3) records containing a single non-critical trigger word (Fig. 1). If the records contained a critical trigger word or more than one non-critical trigger word, they were assumed to have a high probability of being drowning-related and were manually validated. For records containing a single non-critical trigger word, we identified text constructs containing the trigger word used in a context typically not associated with drowning (e.g. “*water* broke” as a sign of labour). If no drowning incidents were identified within 10% of the records containing the text construct, the text construct and related records were excluded.

Four observers (two physicians and two medical students) manually validated all remaining records in three steps. In the first validation process, each record was assessed by two independent reviewers. A physician and a medical student reviewed discrepancies in the second validation process. In the third validation process, a physician reviewed any ambiguous records with prehospital vital signs indicating respiratory impairment (increased respiratory rate and decreased peripheral arterial oxygen saturation).

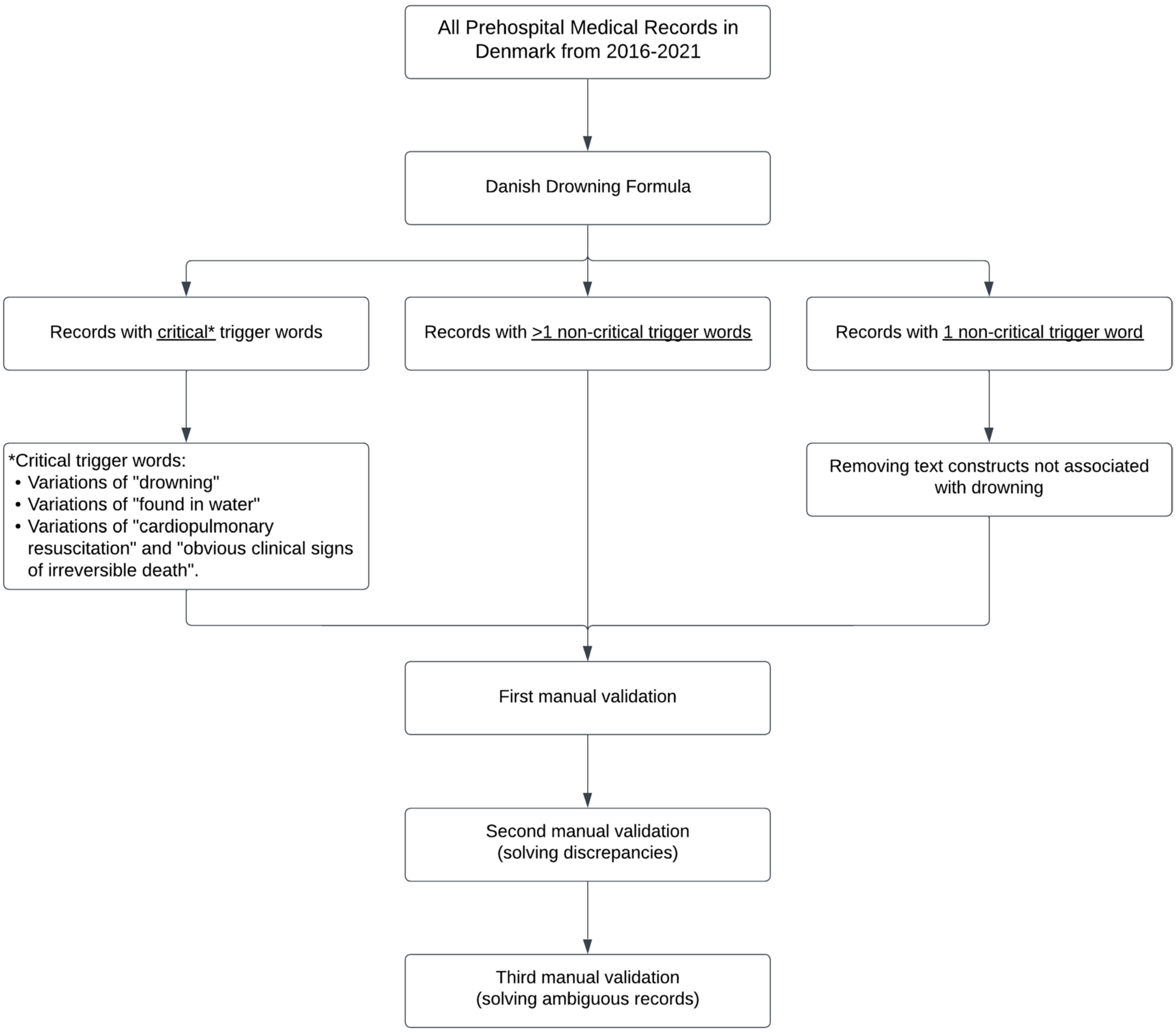


Fig. 1 Flowchart showing the process of manual validation of drowning incidents for the Danish drowning cohort from 2016–2021

We used 30-day mortality to differentiate between fatal and non-fatal drowning.

Inclusion and exclusion criteria

The WHO definition of drowning, supported by the clarification statement for non-fatal drowning, was used as the case definition to identify drowning (target condition) during the three steps of manual validation [31, 32]. Drowning was defined by the WHO in 2002 as "*the process of experiencing respiratory impairment from submersion or immersion in liquid*" [32]. Submersion indicated that the victim's entire body, including the airway, was below the surface of the liquid. Immersion indicated that the head was above the water, whereas the rest of the body was immersed [33, 34]. However, for drowning to occur, water must be aspirated [8, 9]. If the person died because of drowning, this was termed a fatal drowning, but if the process of respiratory impairment was stopped before death, this was termed a non-fatal drowning [31]. Patients were categorised as non-drowning if it was unclear that the incident involved submersion or immersion or if the patient did not experience respiratory impairment. If it was unclear if the patient had experienced respiratory impairment immediately after the drowning process was stopped, we selected the option that best reflected the respondent's description of the respiratory impairment, relying on the description from the respondent and vital signs and used the best judgment according to the "Clarification and Categorisation of Non-fatal Drowning" [31]. The Danish Drowning Cohort contains all drowning patients treated by the EMS, including unwitnessed incidents, non-conveyed patients, patients declared dead prehospital, or patients with obvious clinical signs of irreversible death (decomposition, postmortem lividity, postmortem rigidity).

Variables and data collection

Table 1 contains all the Danish Drowning Cohort variables, including the variable name and definition, collection method, and how the data are coded in the Danish Drowning Cohort. Blank fields indicate unknown/missing values. Variables are collected as outlined in the USFD based on the availability in the Danish prehospital electronic medical record. A complete overview of USFD variables compared to the available variables in the Danish Drowning Cohort is provided in Supplementary Table S1.

Statistical analysis

The performance metrics of the Danish Drowning Formula were statistically evaluated by calculating sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). These metrics were calculated from the numbers of true positives (TP; i.e. the record was drowning, and it was detected as drowning by the Danish Drowning Formula), false positives (FP; i.e. the record was not drowning, but it was detected as drowning), true negatives (TN; i.e. the record was a non-drowning and it was detected as a non-drowning), and false negatives (FN; i.e. the record was a non-drowning but it was detected as drowning). Sensitivity [TP / (TP + FN)] and specificity [TN / (FP + TN)] were calculated to show the performance of the Danish Drowning Formula as a drowning identification tool. PPV [TP / (TP + FP)] and NPV [TN / (FN + TN)] were calculated to show the Danish Drowning Formula test result. There was no imputation of missing data. All analyses were performed using R statistical software (version 4.2.2) [35].

Results

Figure 2 provides an inclusion flowchart. The Danish Drowning Formula identified 65,771 records from 3,471,681 unique prehospital medical records in the Danish prehospital electronic medical record containing one or more trigger words from January 1st, 2016, to December 31st, 2021. In total, 1,227 records were identified as drowning patients treated by the Danish EMS from 2016 to 2021, corresponding to an annual incidence of approximately 205 patients per year and an annual incidence rate of 3.5 per 100,000 persons.

Table 2 shows the performance metrics of the Danish Drowning Formula as a drowning identification tool when applied to the Danish prehospital electronic medical record on unrestricted terms. The sensitivity was 100%, the specificity was 98%, the PPV was 1.87%, and the NPV was 100%. The sensitivity and NPV of 100% were based on the assumption that using a text-search algorithm with comprehensive search criteria (e.g. the Danish Drowning Formula) followed by extensive manual validation was the gold standard for drowning identification.

Of 1,227 drowning records, 817 (66.6%) records contained one or more critical trigger words, 338 (27.5%) records contained multiple non-critical trigger words, and 72 (5.9%) records contained a single non-critical trigger word (Table 3). Overall, the drowning rate increased by the number of trigger words from the Danish Drowning Formula identified in the prehospital electronic medical record (Table 3). Most drowning records contained less than four trigger words, and 200 records (16.3%) contained only one trigger word. Therefore, it would not be possible to establish a cut-off based on the number of trigger words in the prehospital electronic medical record.

Discussion

Summary of results

The Danish Drowning Cohort is a new database under establishment containing nationwide prehospital data on all fatal and non-fatal drowning incidents treated by the Danish EMS from 2016 and onwards. Using the Danish Drowning Formula to detect fatal and non-fatal drowning incidents by searching the prehospital electronic medical record followed by extensive manual validation shows satisfying results. The Danish Drowning Cohort can monitor drowning incidents and facilitate research by providing detailed information on the exact geographical locations, time of incident, and patient characteristics (ClinicalTrials.gov: NCT06312202). These data can be used to improve preventative, rescue, and treatment interventions aimed at reducing the incidence, mortality, and morbidity of drowning. In the future, data from the Danish Drowning Cohort may be combined with other data sources of similar quality to contribute to an International Drowning Registry, as Thom et al. suggested, to facilitate multicenter and multinational sharing of drowning data [14].

Methods compared to the existing literature

Similar to other drowning reports from Sweden, Australia, and Canada, the past Danish drowning statistics identified drowning by searching the Danish Register

Table 1 Variables in the Danish Drowning Cohort year 2024

Variable name [Variable coding] (Extraction method)	Definition of variable	Data coding
Patient information		
Identifier [cpr_nummer] (PEMR)	The patient's civil registration number is unique and is used in Denmark as an identification number for all Danish citizens. It consists of 10 digits reflecting the birth date. The civil registration number is used for data collection and linkage with other registries, not reporting. Extracted from [CPR_nummer] in the PEMR	Integer
Prehospital description [free_text_field] (PEMR)	The prehospital description contains the EMS professional's case description	Free_text_field.
Sex [koen_cpr] (PEMR)	Sex. Extracted from [Koen] in the PEMR	Categorical, dichotomous. Male; Female
Age [alder] (PEMR)	Age in years at the drowning incident. Extracted from [Alder] in the PEMR	Integer. Age in years
Incident date [dato] (PEMR)	Date of the drowning incident. Manually validated from [incidentcreatedtime / AMKModtagetDateTime] in the PEMR	Date. YYYY-MM-DD
Incident time [tid] (PEMR)	Time of the drowning incident. Manually validated from [incidentcreatedtime / AMKModtagetDateTime] in the PEMR	Time. hh: mm
Activity [aktivitet] (manual validation)	Activity at the time of the incident. "Swimming/bathing" included all forms of playing, bathing, and swimming. "Boating activity" included activities on a boat in open water, including fishing from a boat. However, if the boat was in port, the activity was defined as "Harbour activity". "Diving" was used for free or scuba diving. "Water sports" was used for incidents involving swim practice, kayaking, water polo, surfing, etc. Manually validated from [free_text_field] in the PEMR	Categorical, nominal. Swimming/bathing; Diving; Recreational fishing; Operating vehicle; Water sports (specify); Attempted suicide; Walking; Biking; Boating; Rescuing; Urinating
Suspected alcohol or drug intoxication [alcohol_drug]	Alcohol and drug intoxication include suspicion of intake by any indications such as alcohol odour, empty bottles, self-reported intake, etc	Categorical, dichotomous. No; Yes
Precipitating event [forudgaaende] (manual validation)	Precipitating events with a possible causal relation to the drowning incident. "Unaware of surroundings" was used for patients falling unintentionally into the water where no other precipitating event could be selected. "Cold water immersion" was used for winter bathing specifically. Manually validated from [free_text_field] in the PEMR	Categorical, nominal. Jumping; Psychologically impaired; Suspected medical cause; Submerged vehicle; Flood, Panic attack/Hyperventilation; Breath holding; Man overboard; Capsized; Pushed into water or other type of violence; Walking on ice; Unaware of surroundings; Cold water immersion; Waterslide; Other (specify)
Scene information		
Water temperature [vand_tp] (Danish Meteorological Institute)	Icy or non-icy water. Manually validated based on incident coordinates linked with data from the Danish Meteorological Institute.	Categorical, dichotomous. Non-icy; Icy

Table 1 (continued)

Variable name [Variable coding] (Extraction method)	Definition of variable	Data coding
Witnessed drowning [bevidnet_drukning] (manual validation)	Witnessed drowning incident (did someone see the person going underwater?). Manually validated from [Givetaf / free_text_field] in the PEMR.	Categorical, nominal. Unwitnessed; Witnessed by a bystander; Witnessed by a lifeguard; Witnessed by police or EMS
Rescuer [redningsperson] (manual validation)	Rescuer characteristics (who rescued the patient?). Manually validated from [free_text_field] in the PEMR.	Categorical, nominal. Self-rescue; Member of the public; Professional; Unknown
Highest level of EMS unit [ems_type] (PEMR)	Highest level of EMS competency. Extracted from [taskEmsUnitType / Akutlaegeinvolveretfoerankomstti / Laegemed / Laegeledsagelseunder-transport / laege_bil_helikopter / free_text_field] in the PEMR.	Categorical, ordinal. Ambulance; Paramedic; Prehospital ground-based EMS physician; Prehospital HEMS physician
Type of response to patient [respons_ud]	EMS response to the patient. A: Life-threatening or potentially life-threatening condition, immediate response required; B: Urgent, but not life-threatening. Extracted from [respons] in the PEMR.	Categorical, dichotomous. A; B
Type of response to hospital [respons_hjem] (PEMR)	EMS response to the hospital: A: Life-threatening or potentially life-threatening condition, immediate response required; B: urgent, but not life-threatening condition. Extracted from [koerselsformretur] in the PEMR.	Categorical, ordinal. A; B
EMS GCS [GCS] (PEMR)	First GCS score at the first EMS assessment. GCS score ranges from 3 to 15. Extracted from [GlasgowComaScale_Oejne / GlasgowComaScale_Verbal / GlasgowComaScale_Motoriskrespons / GlasgowComaScore / GlasgowComaScore_first / GlasgowComaScore_firstDT] in the PEMR.	Integer. GCS score
Out-of-hospital cardiac arrest [OHCA] (PEMR)	Out-of-hospital cardiac arrest was defined as unresponsive and not breathing normally at any time prehospital. Extracted from [Hjertestop-registreringer] in the PEMR.	Categorical, dichotomous. No; Yes
Witnessed cardiac arrest [bevidnet_OHCA] (PEMR)	Witnessed cardiac arrest (did someone see the person collapse?). Extracted from [Givetaf / Bevidnet / Hjertestopovervaeret / free_text_field] in the PEMR.	Categorical, nominal. Unwitnessed; Witnessed by a bystander; Witnessed by a lifeguard or EMS
Bystander CPR [bystander_hlr] (PEMR)	Cardiopulmonary resuscitation performed by bystander (non-EMS person). Extracted from [Behandling / StartHLR / free_text_field] in the PEMR.	Categorical, dichotomous. No; Yes
Bystander defibrillation [ems_stoed] (PEMR)	Defibrillation performed by bystander (non-EMS person). Extracted from [Behandling / Defibrillering / Defibrillering_2] in the PEMR.	Categorical, nominal. No; Yes, public access AED; Yes, other AED
EMS initial cardiac rhythm [rytme] (PEMR)	The initial cardiac rhythm from a cardiac monitor. Extracted from [rytme / Hjerterytme] in the PEMR.	Categorical, nominal. VF; pVT; PEA; Asystole; Other
EMS SpO2 [ems_sat] (PEMR)	Devices are necessary to measure vital signs (first, lowest). The maximum SpO2 is 100%. Extracted from [SpO2_first / SpO2_firstDT / SpO2_mon_first / SpO2_mon_firstDT / SpO2_mon_lowest / SpO2_mon_lowestDT / SpO2_lowest / SpO2_lowestDT] in the PEMR.	Integer. Peripheral capillary oxygen haemoglobin saturation (SpO2)

Table 1 (continued)

Variable name [Variable coding] (Extraction method)	Definition of variable	Data coding
EMS respiratory rate [ems_rf] (PEMR)	Devices are necessary to measure vital signs (first, highest). Extracted from [RespFrekvens_first / RespFrekvens_firstDT / RespFrekvens_mon_first / RespFrekvens_mon_firstDT / RespFrekvens_highest / RespFrekvens_highestDT / RespFrekvens_mon_highest / RespFrekvens_mon_highestDT] in the PEMR.	Integer. Respiratory rate (BPM)
EMS systolic blood pressure [ems_sbt] (PEMR)	Devices are necessary to measure vital signs (first). Extracted from [NInvSysBlodtryk_first / NInvSysBlodtryk_firstDT / NInvSysBlodtryk_mon_first / NInvSysBlodtryk_mon_firstDT] in the PEMR.	Integer. Blood pressure (mmHg)
EMS diastolic blood pressure [ems_dbt] (PEMR)	Devices are necessary to measure vital signs (first). Extracted from [NInvDiaBlodtryk_first / NInvDiaBlodtryk_firstDT / NInvDiaBlodtryk_mon_first / NInvDiaBlodtryk_mon_firstDT] in the PEMR.	Integer. Blood pressure (mmHg)
EMS heart rate [ems_hr] (PEMR)	Devices are necessary to measure vital signs (first). Extracted from [Hjertefrekvens_first / Hjertefrekvens_firstDT / Hjertefrekvens_mon_first / Hjertefrekvens_mon_firstDT / Puls_first / Puls_firstDT / Puls_mon_first / Puls_mon_firstDT] in the PEMR.	Integer. Heart rate (BPM)
EMS temperature [ems_tp] (PEMR)	Devices are necessary to measure vital signs (first, lowest). Extracted from [Temperatur_first / Temperatur_firstDT / Temperatur_lowest / Temperatur_lowestDT] in the PEMR.	Decimal. Temperature (degrees Celsius)
Respiratory exam finding [resp] (PEMR)	The severity of lung injury immediately after the drowning process was stopped. Extracted from [free_text_field / B_Respiration / SekundaerB / SekundaerBAndet / Respiration / Respiration_2 / Respiration_3 / Aandedraet / Traume_aandedraetsfunktion] in the PEMR.	Categorical, nominal. One or more: Normal lung examination; Patient coughing; Unilateral rales; Bilateral rales; Increased work of breathing
Latitude [lat] (manually validated)	Latitude of the drowning incident. Extracted from incident road name [AnkomstVejnavn], road number [AnkomstVejnummer], and incident postal code [AnkomstPostnr] in the PEMR.	Decimal
Longitude [lon] (manually validated)	Longitude of the drowning incident. Extracted from incident road name [AnkomstVejnavn], road number [AnkomstVejnummer], and incident postal code [AnkomstPostnr] in the PEMR.	Decimal
Type of liquid [vaeske] (manual validation)	Type of liquid. Manually validated from [free_text_field] in the PEMR, latitude [lat], and longitude [lon].	Categorical, nominal. Freshwater; Saltwater; Water containing chemicals; Other
Body of water [lokation] (manual validation)	Body of water. The location type "Natural waters " was used for all coastlines, open oceans, creeks, streams, lakes etc. The location type "Other" included drowning incidents in wells, manure stores, etc. Manually validated from [free_text_field] in the PEMR, latitude [lat], and longitude [lon].	Categorical, nominal. Bathtub/Spa/Hot tub; Swimming pool (public); Swimming pool (private); Harbour; Natural waters; Other (specify) [c]
Population density [befolknings_taethed] (manual validation)	The municipal population density was used to estimate population density at the site according to the EUROSTAT degree of urbanisation system (DEGURBA) [54]. Manually validated from [free_text_field] in the PEMR / latitude [lat] and longitude [lon].	Categorical, ordinal: Low density; Intermediate density; High density

Table 1 (continued)

Variable name [Variable coding] (Extraction method)	Definition of variable	Data coding
Time points and intervals from EMS data		
Time call [tid_opkald] (PEMR)	Time of first call to the Emergency Medical Dispatch Centre. Extracted from [AMKModtagetDateTime] in the PEMR.	Time. hh: mm
Time EMS arrival [tid_ankomst] (PEMR)	Time of first EMS assessment. Extracted from [Patientkontakttid / AnkomstOpgaveDT] in the PEMR.	Time. hh: mm
Response time [tid_respons] (manually validated)	Time from first call to the Emergency Medical Dispatch Centre [tid_opkald] until time of EMS arrival [tid_ankomst].	Time. hh: mm
ROSC time [tid_ROSC] (PEMR)	Time of first Return Of Spontaneous Circulation. Extracted from [ROSC_tid] in the PEMR.	Time. hh: mm
Submersion duration [tid_submersion] (manual validation)	Derived from when the face was first seen underwater to the time of removal from the water. If no exact times are provided, best judgment will be used according to the USFD. Manually validated from [free_text_field] in the PEMR.	Categorical, ordinal. <6 min; <11 min; <16 min; <20 min; <25 min; ≥25 min
EMS treatment, including resuscitation factors		
EMS CPR [ems_hlr] (PEMR)	Cardiopulmonary resuscitation performed by EMS. Extracted from [HLR / StartafHLRafmandskab] in the PEMR.	Categorical, dichotomous. No; Yes
EMS defibrillation [ems_stoed] (PEMR)	Defibrillation performed by EMS. Extracted from [Defibrillering_2 / GavPraehospitalDC_stoedS] in the PEMR.	Categorical, dichotomous. No; Yes
Airway support [a_support] (PEMR)	Highest level of airway support performed by EMS. Extracted from [Sugning / Nasal airway / Tungeholder / Larynxmaske / Intubation / Oralintubation / Noedtrakeotomi / free_text_field]] in the PEMR.	Categorical, ordinal. Suction; Nasopharyngeal airway; Oropharyngeal airway; Supraglottic airway; Endotracheal intubation; Surgical airway
Ventilatory support [b_support] (PEMR)	Highest level of ventilatory support performed by EMS. Extracted from [Ilt_naesebrille / Ilt_nebulisator / Ilt_hudsonmaske / CPAP_ASB / Naaledekompression / Pleuradraen / Respiration_4 / Pleuradraen_2 / Maskeventilation / Ventilation_2 / free_text_field] in the PEMR.	Categorical, ordinal. Nothing; Nasal cannula; Non re-breather mask; Venturi mask; Non-invasive (CPAP); Needle decompression; Chest drain; Bag-mask ventilation; Invasive Mechanical ventilation
Circulatory support [c_support] (PEMR)	Highest level of circulatory support performed by EMS. Extracted from [Perifertvenekateter / Intraossoeskanyle / Tourniquet / Natrium-Clorid / Noradrenalin / Dopamin / Efedrin / Isoprenalin / Phenylephrin / Mekaniskbrystkompression / ErderanvendtkompressionsmaskineS / free_text_field] in the PEMR.	Categorical, nominal. One or more. Nothing; intravenous access; Intraosseous access; Tourniquet; Fluids; Vasopressors; Inotropes (Norepinephrine, Dopamine); Chest compression device
Hypothermia [hypotermi] (PEMR)	Treatment for suspected hypothermia. Extracted from [Kuldeindpakning] in the PEMR.	Categorical, dichotomous. No; Yes

Table 1 (continued)

Variable name [Variable coding] (Extraction method)	Definition of variable	Data coding
Spinal motion restriction [smr] (PEMR)	Spinal motion restriction performed with or without equipment to stabilise a suspected spinal injury performed by EMS. Extracted from [Halskrave / Spinalstabilisering / Vacuummadras] in the PEMR.	Categorical, dichotomous. No; Yes
Prehospital diagnosis [diagnose_prehos] (PEMR)	Prehospital diagnosis. Extracted from [CNS / Respiration / Kredsloeb / Abdomen / Bevaegeapparatet / Hormon / Psykiatri / Socialt / Andet] in the PEMR.	Categorical, nominal. One or more
Outcome measures		
Prehospital mortality [doed_prehos] (PEMR)	Declared dead prehospital. Extracted from [Afsluttetpaastedet / Afsluttetpaastedet_2 / Fortsathjertestop / Behandlingsprioritet / free_text_field] in the PEMR.	Categorical, dichotomous. Dead; Alive
30-day survival [overl_30d] (Civil Personal Register)	Survival status 30 days after the drowning incident collected from the Civil Personal Register via the patient's civil registration number.	Categorical, dichotomous. Dead; Alive
Status at hospital admission [status_hospital] (PEMR)	Patient's status at hospital admission. Extracted from [Patientenstilstandvedankomsttilh / ROSC] in the PEMR.	Categorical, nominal. Terminated CPR; Ongoing CPR; ROSC, unconscious; ROSC, conscious
Non-conveyance [afsluttet_paa_sted] (PEMR)	Final decision not to transport the patient to a healthcare facility. Extracted from [Afsluttetpaastedet / Afsluttetpaastedet_2] in the PEMR.	Categorical, dichotomous. No; Yes
Severity of drowning injury [alvorsgrad_drukning] (manual validation)	Highest level of drowning injury according to the categorisation of severity of drowning [55]. "Dead body" includes obvious clinical signs of irreversible death (decapitation, decomposition, postmortem lividity, postmortem rigidity). Manually extracted from [free_text_field / Afsluttetpaastedet / Afsluttetpaastedet_2] in the PEMR.	Categorical, ordinal. Rescue; Grade 1; Grade 2; Grade 3; Grade 4; Grade 5; Grade 6; Dead body
Severity of respiratory impairment [alvorsgrad_resp] (manual validation)	Highest level of respiratory impairment according to the categorisation of severity of respiratory impairment [31]. Manually validated from [B_Respiration / SekundaerB / SekundaerBAndet / free_text_field] in the PEMR.	Categorical, ordinal. Mild; Moderate; Severe

Variables with "PEMR" originate from the Danish Prehospital Electronic Medical Record. Variables with "manual validation" were manually extracted from the PEMR

Abbreviations: *AED* Automated External Defibrillator, *BiPAP* Bilevel Positive Airway Pressure, *BPM* Breaths/Beats Per Minute, *CPAP* Continuous Positive Airway Pressure, *CPR* Cardiopulmonary Resuscitation, *DD* Date, *EMS* Emergency Medical Service, *GCS* Glasgow Coma Scale, *HEMS* Helicopter Emergency Medical Service, *hh* Hours, *mm* Minutes, *MM* Month, *PEA* Pulseless Electrical Activity, *PEMR* Prehospital Electronic Medical Record, *pVT* pulseless Ventricular Tachycardia, *ROSC* Return Of Spontaneous Circulation, *VF* Ventricular Fibrillation, *YYYY* Year

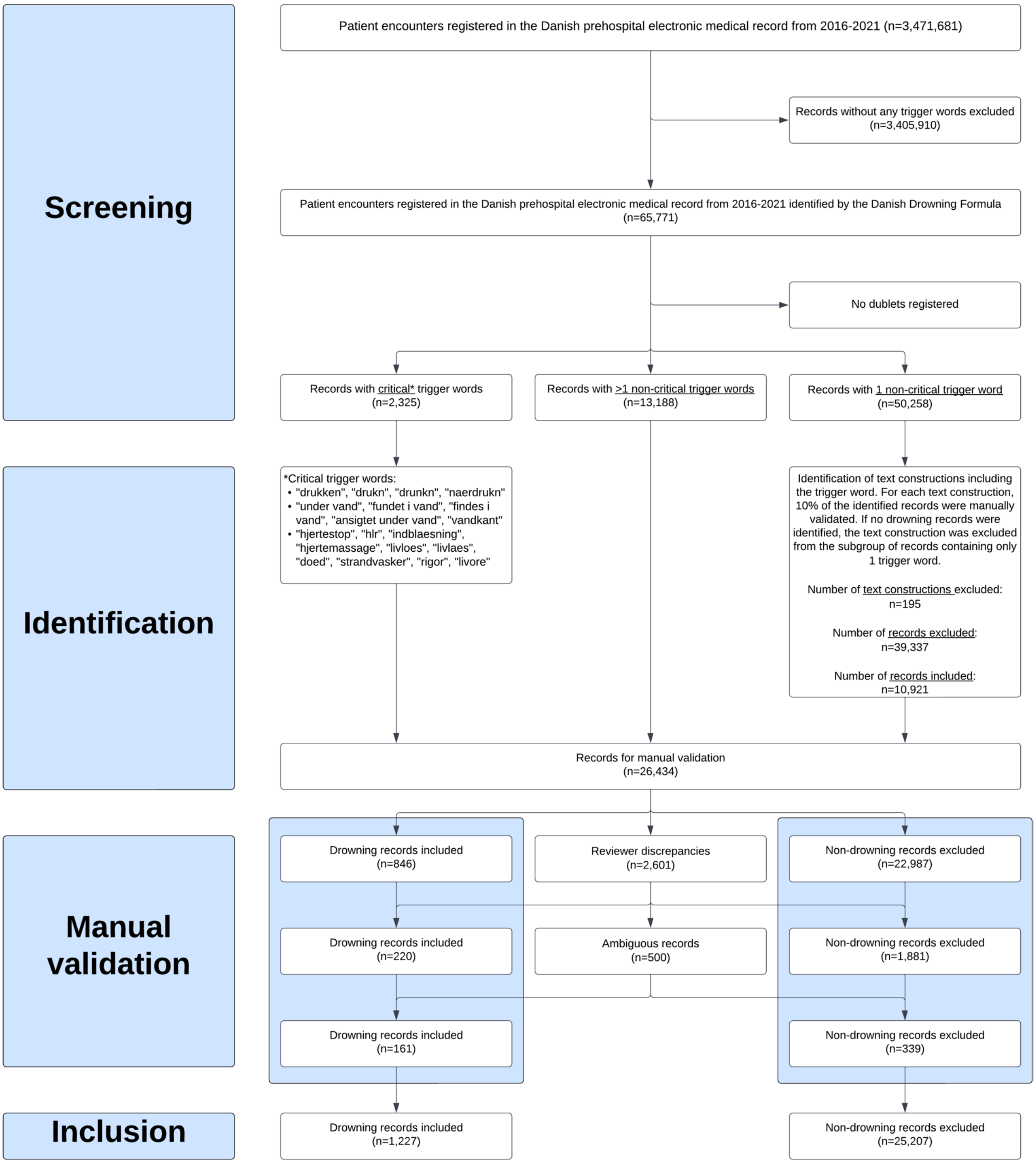


Fig. 2 Inclusion flowchart for the Danish Drowning Cohort from 2016–2021

of Causes of Death for relevant diagnosis codes in the International Classification of Diseases (ICD) 10th Edition (V90, V92, W65-74, X31, X38, X39, X71, X92, Y21, T68, and T75.1, Supplementary Table S2) [36–43]. The search results were combined with other data sources to create a triangulation method and improve data quality (e.g. reports on rescue missions, year-round media monitoring including newspapers and social media, police reports, and internet searches). For drowning persons with foreign nationality, media monitoring was the only source of information [36]. Other studies have used multiple and complex criteria for data extraction, a

Table 2 Diagram demonstrating the performance metrics of the Danish drowning formula from 2016–2021

Total population N = 3,471,681		**Danish Drowning Formula**		**Danish Drowning Formula as a drowning identification tool**
		Drowning	**Non-drowning**	
Actual condition	**Drowning**	TP (*n* = 1,227)	FN (*n* = 0)	Sensitivity = 100%
	Non-drowning	FP (*n* = 64,544)	TN (*n* = 3,405,910)	Specificity = 98%
The Danish Drowning Formula test result		PPV = 1.87%	NPV = 100%	

The performance metrics of the Danish Drowning Formula applied to the Danish Prehospital Electronic Medical Record from 2016–2021 on unrestricted terms

Abbreviations: *FN* False Negative, *FP* False Positive, *NPV* Negative Predictive Value, *PPV* Positive Predictive Value, *TN* True Negative, *TP* True Positive

Table 3 Association between drowning identification and trigger words' type and number

Incidence of drowning by type of trigger words		
Critical trigger words	> 1 non-critical trigger words	1 non-critical trigger word
817 (66.6%)	338 (27.5%)	72 (5.9%)
Incidence of drowning by an increasing number of trigger words		
Exact number of trigger words from the Danish Drowning Formula	Drowning (*n* = 1,227)	Non-drowning (*n* = 25,207)
1 trigger word, n (%)	200 (1.7)	11,728 (98.3)
2 trigger words, n (%)	234 (2.4)	9,502 (97.6)
3 trigger words, n (%)	228 (8.8)	2,374 (91.2)
4 trigger words, n (%)	163 (15.5)	890 (84.5)
5 trigger words, n (%)	129 (27.5)	341 (72.6)
6 trigger words, n (%)	90 (34.2)	173 (65.8)
7 trigger words, n (%)	59 (42.1)	81 (57.9)
8 trigger words, n (%)	44 (44.4)	55 (55.6)
9 trigger words, n (%)	28 (52.8)	25 (47.2)
≥ 10 trigger words, n (%)	52 (57.8)	38 (42.2)

This table is based on data extracted from the Prehospital Electronic Medical Record from 2016–2021 and shows (1) the incidence of drowning stratified for critical trigger words, multiple non-critical trigger words, and single non-critical trigger words as counts and row percentages, and (2) the incidence of drowning and non-drowning by an increasing number of exact trigger words in the PEMR

Abbreviations: *CI* Confidence Interval, *PEMR* Prehospital Electronic Medical Record

correction factor to report an estimate of the true incidence of drowning accidents, or the presenting problem or discharge diagnosis of drowning or immersion to enroll all drowning patients presenting to the emergency department [14, 39, 44]. These methods have several limitations regarding the identification of drowning incidents and data collection compared to searching the prehospital electronic medical record using text-search algorithms, such as the Danish Drowning Formula, followed by extensive manual validation [29]. First, using primary-cause ICD codes significantly underreport the true incidence of fatal and non-fatal drowning incidents, as the codes are not sufficiently specific [6, 39, 45, 46]. Second, collecting death certificates and confirming the cause of death may take several years, may not include drowning incidents with a delayed fatal outcome due to incorrect coding in the reports, systematically excludes non-fatal drowning, and does not include information on prehospital treatment performed by bystanders or EMS personnel [36, 44]. Third, accessing and linking data from various sources, including media, is time-consuming and increases the risk of bias and missing data. Future studies should focus on developing and validating a formula for drowning identification in different settings using the prehospital electronic health record. In Australia, the prehospital electronic health record is used to monitor mental health and self-harm, presenting an opportunity to develop a formula for drowning identification based on English-language records [47]. In the United States, drowning incidents can be identified through the National Syndromic Surveillance Program, which relies on in-hospital data [17, 18]. However, the decentralized and non-unified data systems in the United States challenge using the electronic health record to exchange health information, limiting its use for drowning identification [48]. Furthermore, many resource-limited settings need financial support to acquire the essential technology and provide staff training to implement an electronic health record and utilize data for syndromic surveillance [49, 50].

Limitations

This study has several limitations. First, the Danish Drowning Formula was designed to search the unstructured text fields in the prehospital electronic medical record on unrestricted terms with comprehensive search criteria to identify all potential water-related incidents and achieve a high sensitivity. This was important as drowning is a rare occurrence, but it resulted in a low PPV for detecting drowning incidents specifically. Ongoing studies aim to augment the PPV of the Danish Drowning Formula and reduce the temporal demands associated with manual validation (ClinicalTrials.gov: NCT06310525). The Danish Drowning Formula may still be used as the basis for future studies investigating rare water-related incidents, such as in-water traumatic spinal cord injuries, to support the development of guidelines [51]. Second, using the prehospital electronic medical record may introduce selection bias, as this source of information does not contain drowning incidents where the body is never recovered, self-referred patients in the emergency department, and incidents in the open ocean where the patient or the body is retrieved by Royal Danish Air Force's Search and Rescue (SAR) helicopters that do not register missions in the prehospital electronic medical record (ClinicalTrials.gov: NCT06322134) [52]. Third, all manually extracted variables are retrospectively extracted from the prehospital electronic medical record, possibly introducing information bias through missing data. Fourth, uncertainty persists in unwitnessed incidents where the body is recovered from the water, as it remains challenging to conclusively differentiate drowning from other causes of death (e.g. suicide, homicide, or other medical conditions occurring while the patient was in the water) [53]. Linkage with the patients' unique civil registration numbers may enable future access to the Danish Register of Causes of Death and their autopsy reports to specify the cause of death (ClinicalTrials.gov: NCT06310499) [37].

Conclusions

The Danish Drowning Cohort is an established and growing dataset. It contains nationwide prehospital data on all fatal and non-fatal drowning incidents treated by the Danish Emergency Medical Services.

Abbreviations

EMS	Emergency Medical Services
FN	False Negative
FP	False Positive
HEMS	Helicopter Emergency Medical Services
ICD	International Classification of Diseases
NPV	Negative Predictive Value
PPV	Positive Predictive Value
SAR	Search and Rescue
TN	True Negative
TP	True Positive
USFD	Utstein Style For Drowning

Supplementary Information

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Supplementary Material 1.

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Authors' contributions

NB, SNFB, and HCC participated in the study conception and design. NB, KB, OBS, and AW were involved in data acquisition. NB analysed the data. NB, KB, SAW, TL, JS, SNFB, and HCC contributed to the interpretation of data. NB drafted the manuscript. KB, OBS, AW, SAW, TL, JS, SNFB, and HCC were involved in critically revising the manuscript. All authors have agreed to submit the manuscript. All authors read and approved the final version of the manuscript. All authors agree to take responsibility and be accountable for the contents of the article.

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Data availability

The data are intended for use nationally and internationally by researchers to reduce the incidence, mortality, and morbidity of drowning. The data are available from the corresponding author upon reasonable request. Access to the data requires approval by the relevant regulatory bodies to ensure compliance with ethical and legal requirements.

Declarations

Ethics approval and consent to participate

According to Danish law, registry-based research projects that are based on pure data (i.e. numbers and characters) are exempted from ethical approval and do not require informed consent from the participants (assessed by the Regional Committee on Health Research Ethics for Region Zealand ID-number: EMN-2022-03474). The Danish Data Protection Agency approved data management and processing of the current dataset from 2016 to 2021 (ID-number: REG-041-2022). The Regional Council in Region Zealand approved the handover of medical records from the same period (ID-number: R-22025982).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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