AED applied, not recommending defibrillation - A validation study of the new variable “AED” in the Danish Cardiac Arrest Registry

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Abstract

Background: to design and implement a new variable, in accordance with the Utstein style – namely the variable “AED” - considering the challenges of reporting cases in which the AED did not recommend an electrical shock after analyzing cardiac arrhythmias, for use in the Danish Cardiac Arrest Registry.

Participants: Patients with out-of-hospital cardiac arrest for which resuscitation was attempted between 2016 and 2019, identified in the nationwide Danish Cardiac Arrest Registry. Their medical records were reviewed to establish a positive variable in “AED”.

Methods: Data from the national Danish Cardiac Arrest Registry were used to identify core features of out-of-hospital cardiac arrests medical recording in Denmark and its possible improvement.

Results: Among n= 1080 cases, summary statistics on core recording variables of interest were collected. We found statistically significant differences in the two cohorts of cardiac arrests where an AED was present on the scene and recorded in the Danish Cardiac Arrest Registry, regarding age, location, emergency medical service response time, witnesses, bystander cardiopulmonary resuscitation, first monitored rhythm, direct current cardioversion shock delivered by the medical staff and survival outcomes such as return of spontaneous circulation at any time, status at arrival at hospital and 30-day survival.

Conclusions: This validation study showed an improved completeness of registration of out-of-hospital cardiac arrests when implementing the new AED-variable, in accordance with the Utstein style. Thus, the new AED-variable is a valid and substantial resource for future epidemiological studies. However, a future effort to improve registration completeness along with continuous improvement of the Danish Cardiac Arrest Registry is needed.

Background

Out-of-hospital cardiac arrest (OHCA) is a severe medical condition, by and large associated with poor outcomes and serious implications for the affected patients¹. Early identification and intervention are crucial for return of spontaneous circulation (ROSC) and for long-term patient survival². Bystander cardiopulmonary resuscitation (CPR) coordinated with the use of automated external defibrillation (AED) is decisive for this purpose^{3 4}, and so is CPR-training of laypersons and AED coverage.

Over the past twenty years several national efforts were conducted in Denmark to increase survival rates after OHCA^{2 5}. The medical personnel operating in the emergency medical services (EMS) has been registering OHCA in which resuscitation was attempted since 2001, with approximately 5,000⁶ OHCA registered annually. Denmark has witnessed a positive progress during the 18 years of the registry with both bystander CPR rate and survival quadrupled⁶. Data were initially registered manually and as of 2015^{7 8} subsequently electronically. Henceforth these registrations allowed thorough documentation of the incidence and the treatment of out of hospital cardiac arrest, along with the possibility for a follow-up

on the prognosis and survival rate of the affected patients. The Danish Cardiac Arrest Registry has ever since been a national quality database and thus constitutes a cardinal point in association with other records and biobanks, providing a strong basis for significant knowledge relevant to the etiological and prognostic understanding of several medical conditions. Quality treatment and survival after cardiac arrest are internationally recognized and well-defined *key-performance* indicator for the overall pre-hospital exertions, including the citizen-oriented EMS' efforts⁹. According to the 2019 Annual Report of the Danish Cardiac Arrest Registry⁶, bystander CPR rate was 79%, AED defibrillation by laypersons was performed in 23% of OHCA in public places and ROSC (including EMS) was 29% on arrival to hospital. The overall 30-day survival was $n = 776 = 14$ pr. 100.000 citizens – of which 76 % was able to return to work. The annual report documents that Denmark is in the world elite when it comes to engaging population, and measured by survival, Denmark is now comparable to Seattle in the United States of America - a city that for many years has been the absolute leading area in the world. The results make AMPAit difficult to achieve further improvement, but the report points out areas and development initiatives that can further improve survival after cardiac arrest in Denmark. This validation study aims to improve recording of OHCA in Denmark.

The choice of implementing a new variable in the Danish Cardiac Arrest Registry – namely the variable “AED” – was taken in the light of the challenges of reporting cases in which the AED did not recommend the application of an electrical shock after analyzing cardiac rhythm. EMS personnel uses contrasting nomenclature and formulations to register this occurrence when compiling the Pre-hospital Patient Journal (PPJ), resulting in multiple misapprehensions which can delay the treatment of the patient. Validating the new “AED” variable would optimize registration and be timesaving in terms of interpretation of the record – being time of the uttermost importance in the event of cardiac arrest.

Methods

1. Study population:

This validation study is a population-based retrospective cohort study. The collected data source used is the nationwide Danish out-of-hospital cardiac arrest registry, in collaboration with the five regional Prehospital Emergency Medical Services. The selection of study population started from all cases of out-of-hospital cardiac arrest (OHCA) occurring in Denmark from 2016 to 2019, where resuscitation was initiated by either bystanders or emergency medical services. Of all OHCA only the cases where an AED was present were included in the study. The cases where direct current cardioversion (DC) was carried out, normally performed by health professionals, were excluded from the study. This led to a final number of $n = 1080$ cases. Both persons with and without a danish Central Person Registry (CPR-number) - a unique personal identification number, which each citizen is provided with at birth, and which facilitates accurate linkage between all Danish national registers¹⁰ - were included. It is a provider of personal data to the public authorities and if given permission of personal information by law, it can be shared with private institutions, it is thus a benchmark for research purposes¹⁰. Citizens without a CPR number are

accurately registered in the pre-hospital patient journal, but not included in further analysis from other registers.

2. Prehospital healthcare in Denmark:

Denmark is a country located in northern Europe with a population size of approximately 5.8 million on 43,094 km² (16,639 mile²) of land, divided into five public administrative regions: North Denmark Region, Central Denmark Region, Region of Southern Denmark, Region Zealand, and Capital Region of Denmark.

Each region is responsible for its respective healthcare services, funded by the public and therefore available and provided to all danish citizens as well to non-citizens¹¹

The Danish medical emergency services (EMS) are activated by a call to the Danish emergency number 1-1-2. Once a call is assessed as being police-related, fire-emergency, or medical affiliated, it is then located, and – if identified as a medical emergency - it is then forwarded to the Emergency Medical coordination center. Here the situation is assessed using the criteria dictated by the Danish Index for Emergency Care¹². The level of urgency is thereby determined, and the appropriate services dispatched to the location¹¹. If needed, the Emergency Medical coordination personnel will provide the person in need with a civilian assisted AED in the case of a suspected cardiac arrest². This person can either be the first aider or someone else who is able to bring an AED to the location of need. First responders are mostly civilians that either happen to be at the spot of the incident or – only in the Capital Region - volunteers who have received alerts on their mobile device upon registration on a text-message based application. When registered in the app (called “hjerteløber”, heart runner), one or several volunteers will be notified of the need of an AED based on their location and sent to the nearest AED device to bring to the location of need¹³.

3. Organization and registration

Electronic pre-hospital medical record and the Danish cardiac arrest registry:

EMS will be sent to the location and in most cases arrive after laypersons have initiated first aid. When the emergency team arrives at the location, the professionals take charge. The pre-hospital staff start by identifying the patient or scanning the patient's health insurance card and thus have access to the patient's medical record. When treating patients on the scene and along the way to the hospital, Danish health professionals document the patient conditions using the electronic prehospital patient journal (PPJ)¹¹. While the ECG transfers data directly to the electronic record system via Bluetooth, paramedics can fill in the premade columns with the relevant information, thereby vehiculating vital parameters to the hospital staff in real time.

One of the tabs of the PPJ is titled “cardiac arrest”. This is specifically to be filled out whenever the patient has been given CPR or been attached with either an AED or a DC. The paramedics can either answer a close-ended multiple-choice questionnaire or write a short note about initiation of CPR, defibrillation and ROSC. Data are then entered in electronic databases and linked to the Danish Register

of Causes of Death¹⁴ to monitor 30-day survival. These information are associated with Danish out-of-hospital Cardiac Arrest Registry which supervises and investigates trends in survival and treatment of OHCA in Denmark aiming to study and improve the prognosis of OHCA victims. The nationwide pre-hospital patient record stores all data concerning the pre-hospital patient course, and the database is therefore suitable for population-based research and ongoing quality assurance.

4. Data collection and handling:

The collected data comprising potential OHCA candidates in the years 2016-2019 (n=24351) were validated and analyzed methodically through manual review of the medical records conducted by trained health professionals. A total of n=21791 cases were excluded from this study since no AED was mentioned and a number of 1660 cases were recorded in which an AED was brought to the location of cardiac arrest. Of these 1660, ten were duplicates and 43 had no AED on scene, and therefore were excluded from the study. This left us with n= 1607 cases where an AED was on scene. A total of n=527 cases were further excluded from this study being not related to OHCA. This added up to a total of n=1080 cases with an AED on scene of the OHCA, which were included in the study and subsequently manually reviewed and divided in two categories: AED present, no shock delivered / AED present, shock delivered. Each review was initiated by confirming the CPR-number of each patient or - if not present - the EVA-number (RECORD-NUMBER) assigned to the citizen. The cases that received a treatment with DC instead of AED were carefully excluded from the study population.

For every single case included in the study population an assessment on whether the AED had been attached on- and delivered a shock to- the patient was made. We chose to assign the variable "AED" to the case each time this specific circumstance occurred. This new variable was designed considering the challenges of reporting the cases in which the AED did not recommend defibrillation. Evidence was gathered regarding the use of contrasting terminology to address this occurrence in the pre-hospital medical chart by the EMS. This disparate terminology led to misinterpretations. Thus, introducing the "AED" variable in pre-hospital journals aims to simplify the records of OHCA hence optimizing the treatment of cardiac arrest and survival rate and the analysis registration of future research in out-of-hospital cardiac arrest.

Results

During the study period 2016 to 2019, n_{tot}=1080 patients were recorded in the Danish Cardiac Arrest Registry with an AED on scene of the OHCA. The demographics and incident characteristics, as well as comparisons between cases where an AED was present and did not deliver a shock, or present and delivered a shock, are shown in table 1. We found statistically significant differences in the two cohorts of cardiac arrests where an AED was present on the scene and recorded in the Danish Cardiac Arrest Registry, regarding age, location, EMS response time, witnesses (either bystander or EMS), bystander CPR, first monitored rhythm, DC shock delivered by the EMS and survival outcomes such as ROSC at any time, status at arrival at hospital and 30 day survival.

In 520 cases an AED was present but did not deliver a shock, in 488 cases an AED was present and a shock was delivered. We found that OHCA cases where an AED was present and had given a shock were more likely to be younger patients (68,7 years on average) and to have a relatively shorter response time (9,6 minutes on average versus 10,4 minutes when the AED did not deliver a shock). Additionally, the majority of patients that received a shock with an AED were to be found in public settings (325 (60,2%)), conversely, the majority of patients who did not receive a shock had a cardiac arrest in their private habitations (351 (65,4%)). Furthermore the greatest part (391 (72,3%)) of OHCA that received a shock by an AED, were witnessed, again patients who did not receive a shock showed a reversed fashion (256 were witnessed (47,6%)). Both the patients who did receive a shock (536 (99,1%)) and who did not receive a shock (519 (96,3 %)) by an AED present on the scene were delivered bystander CPR for the vast majority of the cases. Moreover the recorded data have shown a slight increase in rate of first rhythm being shockable, observed by the EMS on patients that previously received a shock delivered by an AED (156 (29,3%)), showing a less steep ventricular fibrillation decline than patients that were not delivered a shock by a present AED in the first place (the latter had a shockable rhythm in 28 cases (5,3%)). Patients that received a shock with an AED had overall positive responses to EMS treatment, receiving a DC shock in 38,5% of the cases (207). Finally they also presented the greatest number (212 (55,88%)) of ROSC and a slightly higher 30 day survival (171 (35,2%)) versus cases who did not receive a shock by an AED (41 (7,9%)).

Discussion

The result of this study is an important progress in applying updated guidelines in reporting OHCA in Denmark, in compliance with the International Liaison Committee on Resuscitation (ILCOR) recommendations and with Utstein style¹⁵. The passage from the older paper-based registration scheme to the now universally used electronic chart, together with the meticulous registration in the Danish Cardiac Arrest Registry, paved the way to continuous revision and perfecting of the registration of OHCA in Denmark¹⁶. Moreover, the thorough evaluation of medical records in this validation study, allowed for validation of key variables in the Danish Cardiac Arrest Registry and makes it a valid tool for future research. The proposal of the AED variable this study is about is yet a step in this revision process and the gathered results demonstrate that this further report could be a benchmark in better survival rates.

The original Utstein recommendations focused on reporting cardiac arrests – of presumed cardiac cause - witnessed by bystanders (non-EMS), with ventricular fibrillation (VF) as first observed rhythm. This first definition was then revised in 2004¹⁷, aiming to reduce the complexity and update the Utstein template, now expanding the focus to include all-EMS treated cardiac arrests¹⁸ regardless the first monitored rhythm and witnessing of the cardiac arrest. Since this update, a considerable raise in the number of databases and registries in the US¹⁹, Europe²⁰, Asia²¹, Australia²², Japan²³ lifted the need of a further amend. In 2013, ILCOR has started a systematic review aiming – if necessary – to update the Utstein templates for cardiac arrests in order to compare the epidemiology and outcome of OHCA around the

world, striving for a quality improvement in registration and thus identification of lacks in resuscitation theory²⁴.

Several variables and factors are correlated with long-term survival after OHCA. Studies of OHCA and national databases comprising recordings of these events following the Utstein template encompass some of these elements: whether the OHCA was witnessed, whether the patient was given CPR by laypersons, EMS timely response, first observed rhythm, survival at the scene and discharge to the hospital²⁵. The 2015 update to Utstein style²⁴ focused more on further key-elements in understanding prognostic determinants of survival in OHCA, dividing them in five domains: System, Dispatch, Patient, Process, Outcome, each of them containing core and supplemental elements. With this background, there is a number of successful variables²⁶ that other registries have implemented and that are good candidates for a further improvement of the Danish Cardiac Arrest Registry. Concerning the importance of an AED variable, the 2015 update of Utstein style recognizes under the domain Patient Variables that “all systems should capture the number of cases in which bystander resuscitation is started (...) whether or not an AED was deployed and whether or not it delivered a shock”²⁴. Variables of concern are *AED used, shock delivered / AED used, no shock delivered / AED not used*, and the variable *AED shockable/AED not shockable/unknown/not recorded* – containing another important core element, namely *first monitored rhythm*, presented by the AED monitor when deployed. Some of these variables have been used by different national and regional registries across the world²⁷, such as the Pan Asian Resuscitation Outcomes Study (PAROS)²¹ of Singapore and South Korea, the Ticino Registry of Cardiac Arrest in Switzerland²⁸.

Ideally the AED variable would be implemented in the Danish Cardiac Arrest Registry obediently to the Utstein template and present a layout as demonstrated in Figure 4 and Figure 5, comprising *AED used, shock delivered / AED used, no shock delivered / AED not used*, and the variable *AED shockable/AED not shockable/unknown/not recorded*.

Limitations

Despite the clear results that show how the AED variable will improve the Danish Cardiac Arrest Registry database, there are some challenges related to both the registry and the AED-variable. One of these is the administrative data coverage levels on a national level. The Danish data coverage using the CPR-number system is considered of very high quality, with the possibility of lifelong follow-up and precise censoring at emigration or death²⁹. Nevertheless, it is not completely free from different biases of administrative data (such as numerator/denominator biases). Additionally, the register's disease completeness³⁰ – largely determined by its sensitivity and missing data – cannot always be ensured and does not consistently include lifestyle risk-factors such as obesity, particularly important in the pathogenesis³¹ of cardiac arrests. Moreover, cases have been registered where no data were recorded in the PPJ. These “gaps” – though minor - present a challenge and a limitation of the database. Furthermore, it must be highlighted that it is not possible on every occasion to draw a clear line between OHCA and in-hospital

cardiac arrest (IHCA) and some borderline cases do pose a challenge in classification and thus quality of the Danish Cardiac Arrest Registry. Another national database, the Danish In-Hospital Cardiac Arrest Registry (DANARREST), handles all the supposed IHCA in Denmark³², using different templates and standards from the Danish Cardiac Arrest Registry. This dispersion and fragmentation in recording have thus been a limitation in covering the occurrence of cardiac arrest in Denmark in a harmonious and coordinated way. Another obstacle is posed by the correlation of better survival rate in case of *AED used, no shock delivered*, due to the possible “contamination” of other occurrences. The aspect that most people who were applied an AED and received a shock were generally younger and to be found in public settings, can be for instance correlated to the fact that these people were able to move outside their own habitation and were hence healthier individuals. Consequently, patients that received a shock from an applied AED had better response to treatment, less VF decline and overall better survival rates. Similarly, the parameter ROSC comes with its limitations since it does not ensure survival after 30 days. Lastly, the designation of OHCA pathogenesis - something highlighted by ILCOR itself – is one of the most contentious areas and still widely discussed. The Utstein process has for decades tried to separate cardiac (or presumed cardiac) from noncardiac (or presumed so) causes. However, this distinction has been proved to be rather subjective²⁴, with discordance in reporting causes across different communities.

Conclusions

This validation study showed an improved completeness of registration of OHCA when implementing the new AED-variable, in accordance with the Utstein style.

Thus, the new AED-variable is a valid and substantial resource for future epidemiological studies. However, a future effort to improve registration completeness along with continuous improvement of the Danish Cardiac Arrest Registry is needed.

Declarations

- **Ethics approval and consent to participate**

Being part of the EU, Danish citizens are subject to data protection regulated by the GDPR (general data protection regulation) standards. In addition are these regulations supplemented by specific Danish regulations and the Danish Executive Order of the Health Act. Ethical approval is not required for population-based retrospective registry study in Denmark and medical information may thus be accessed for research purposes.

In this study there has been given permission for access by the Danish Patient Safety Authority and storage of personal data for a longer period by the Data Protection Agency, since it has been recognized as necessary for the purpose of the study. Therefore, all the GDPR requirements and other ethical considerations have been met.

- **Consent for publication**

Not applicable.

- **Availability of data and materials**

The data that support the findings of this study are available from the Danish Patient Safety Authority, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the Danish Patient Safety Authority.

- **Competing interests**

The authors declare that they have no competing interests.

- **Funding**

Not applicable as no funding was received.

- **Authors' contributions**

EC, the first author, was involved in the data collection, research, and drafting of the manuscript,

TA was involved in the data collection and drafting of the illustrations and manuscript,

KBR was involved in the data collection of the manuscript,

SNFB was involved in the data collection of the manuscript,

HCC reviewed and was a major contributor in writing the manuscript.

All authors agreed on the study setup, data collection and analysis.

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Abbreviations

AED = Automatic External Defibrillator

CPR = cardiopulmonary resuscitation

OHCA = out-of-hospital cardiac arrest

ROSC = return of spontaneous circulation

EMS = emergency medical services

DC = direct current cardioversion

PPJ = pre-hospital patient journal

CPR = Central Person Registry

ACLS = Advanced Cardiac Life Support

GDPR = general data protection regulation

VF = ventricular fibrillation

IHCA = in-hospital cardiac arrest

DANARREST = Danish In-Hospital Cardiac Arrest Registry

ILCOR = International Liaison Committee on Resuscitation

PAROS = Pan Asian Resuscitation Outcomes Study

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Table

Due to technical limitations, Table 1 is only available as a download in the supplementary files section.

Figures

Early identification and EMS call

Early CPR

Early defibrillation

**ACLS and post
resuscitation care**

Figure 1

Chain of Survival, timeline of events associated with out-of-hospital cardiac arrest attempts.

Action before arrival			Condition upon arrival				Action on the spot		
Witnessed			Breathing				Start of CPR by crew		
Yes	No	[indicate time]	Normal	Difficult	Agonal	None	Yes	No	[indicate time]
Begin CPR			Rhythm		Glasgow coma score		First rhythm analyzed by EMS personnel		
Yes	No	[indicate time]	[click here to enter]		[click here to enter]		Yes	No	[indicate time]
Defibrillation			Cardiac arrest witnessed				Did EMS personnel defibrillate?		
		No [indicate time]	Yes	No	Yes	No	Yes	No	[indicate time]
AED brought to hospital?			Status after action				Energy		
Yes No			ROSC				Amount of times		
			Yes No [indicate time]				[click here to enter] [click here to enter]		
Place of cardiac arrest			Returned respiration				AED modus		
[click here to enter]			Yes No [indicate time]				Yes No		
Patients condition upon arrival at hospital			Continued cardiac arrest				Dr. Involved before arrival to hospital		
[click here to enter]			Yes No [indicate time]				[click here to enter]		
			Mechanical compression						
			Yes No [indicate time]						

Figure 2

AMPHI's cardiac arrest tab.

Figure 3

Flow Chart

AED USED		
Yes, shock delivered	Yes, no shock delivered	No

Figure 4

Recommended Utstein style template for reporting data on cardiac arrest

FIRST MONITORED RHYTHM AED			
AED shockable	AED not shockable	Unknown	Not recorded

Figure 5

Recommended Utstein style template for reporting data on cardiac arrest

Supplementary Files

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

- [Table1.docx](#)