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Clinical paper

Bystander interventions and survival following out-of-hospital cardiac arrest at Copenhagen International Airport

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Abstract

Aim: To examine incidence and outcome following out-of-hospital cardiac (OHCA) arrest in a high-risk area characterised by high density of potential bystanders and easy access to nearby automated external defibrillators (AEDs).

Methods: This retrospective observational study investigated pre-hospital and in-hospital treatment, as well as survival amongst persons with OHCA at Copenhagen International Airport between May 25, 2015 and May 25, 2019. OHCA data from pre- and in-hospital medical records were obtained and compared with public bystander witnessed OHCAs in Denmark.

Results: Of the 23 identified non-traumatic OHCAs, 91.3% were witnessed by bystanders, 73.9% received bystander cardiopulmonary resuscitation (CPR), and 43.5% were defibrillated by a bystander. Survival to hospital discharge was 56.5%, with 100% survival among persons with an initial shockable heart rhythm. Compared with nationwide bystander witnessed OHCAs, persons with OHCA at the airport were less likely to receive bystander CPR (73.9% vs. 89.4%, OR 0.33; 95% CI, 0.13−0.86), more likely to receive bystander defibrillation (43.5% vs. 24.8%, OR 2.32; 95% CI, 1.01−5.31), to achieve return of spontaneous circulation (78.2% vs. 50.6%, OR 3.51; 95% CI, 1.30−9.49), and survive to hospital discharge (56.5% vs. 45.2%, OR 1.58; 95% CI, 0.69−3.62).

Conclusion: We found a high proportion of bystander defibrillation indicating that bystanders will quickly apply an AED, when accessible. Importantly, 56% of all persons, and all persons with a shockable heart rhythm survived. These findings suggest increased potential for survival following OHCA and support current guidelines to strategically deploy accessible AEDs in high-risk OHCA areas.

Keywords: Resuscitation, Out-of-hospital cardiac arrest, International airports, Defibrillation, Strategic AED placement

Introduction

Early recognition, bystander cardiopulmonary resuscitation (CPR), and early defibrillation are important factors for improved survival after out-of-hospital cardiac arrest (OHCA).[1–5] Along with a rising number of automated external defibrillators (AEDs), an increased focus on strategic placement and accessibility has arisen.[6,7] International guidelines recommend placement of AEDs in areas with a high risk of OHCA, characterized by high population density and movement of people such as airports, railway stations, and sport facilities.[8] In Denmark, more than 20,000 publicly available AEDs (357 AEDs/

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100,000 inhabitants by 2019) were registered in a nationwide AED-network linked directly to the emergency medical dispatch centres.[9] Furthermore, a remarkable increase in bystander CPR has been observed, from 19% in 2001 to 77% in 2018 in Denmark, with a quadrupling in 30-day survival from 4% to 16% in the same period.[10,11]

The maximum potential for bystander interventions and OHCA survival is best examined in public areas with high risk of OHCA, potentially numerous bystanders, easy access to AEDs, and fast emergency medical response systems. Airports provide such a setting, and were therefore one of the earliest sites where use of publicly accessible AEDs was tested with a positive impact on OHCA survival.[12] Now, two decades later, AEDs have been placed in many international airports,[13] including Copenhagen International Airport. Copenhagen International Airport has a large flow of passengers and employees, with more than 30 million annual travellers, a high density of AEDs available 24 h a day, 7 days a week and a dedicated professional first responder response system aiming to arrive on site within 3 min.

The purpose of this observational study was to investigate bystander interventions, pre- and in-hospital treatment, and survival for persons with OHCA in an optimal setting like the Copenhagen International Airport. In a secondary analysis we compared OHCA characteristics from the Airport with nationwide numbers for bystander witnessed OHCA in other public locations in Denmark.

Methods

Study setting

This is a retrospective observational study of adult persons with non-traumatic OHCA in Copenhagen International Airport during the period May 25, 2015 to May 25, 2019. In 2018, the airport served 30.3 million passengers and had 30 AEDs placed in public areas, 4 of which were placed in the terminal pre-check-in whereas the other 26 were placed at, or after security check (Fig. 1).

The emergency response at the Copenhagen International Airport consists of a professional first responder system and the Copenhagen Emergency Medical Services (EMS) system. In case of a suspected cardiac arrest, both systems are always simultaneously activated but the point of entry depends on the caller. Most often a member of ground staff is present or summoned and will call the internal emergency dispatch service number. This number is also displayed on the publicly available AEDs. This dispatch service will immediately activate the Copenhagen EMS response system, a two-tiered response, including a physician-staffed Mobile Critical Care Unit and an ambulance providing basic life support (BLS). Simultaneously the local professional first responders from the Airport Fire and Rescue department are alerted and aim to arrive at scene within 3 min. In addition, emergency help buttons are distributed in the busiest areas of the airport. Regarding intervention and treatment both airport professional first responders and Copenhagen EMS are referred to commonly as EMS. All interventions before the arrival of EMS are referred to as bystander interventions.

Study population

We included all adult persons (≥18 years of age) with non-traumatic OHCA that occurred at Copenhagen International Airport during the study period. Eligible persons were obtained via first responder reports from the Department of Fire and Rescue at Copenhagen International Airport. These reports contained information on patient identification data (unique personal ID-number), location, time and date of incident, as well as tentative diagnosis and treatment before arrival of external EMS. This was linked with data from pre-hospital records and the Danish Cardiac Arrest Registry to match persons on identification data, time of 1-1-2 emergency call, and addresses known to be within the airport premises. Persons without Danish Personal ID-numbers were also matched on replacement ID-numbers.

By combining information from the airport first responder reports, pre-hospital records, the Danish Cardiac Arrest Registry, and the hospital medical records, we were able to construct a timeline for every person included in the study, from the moment of cardiac arrest until discharge. Parameters included: bystander witnessed status, initial rhythm shockable/non-shockable (ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT)), age, sex, bystander CPR, bystander defibrillation, EMS treatment (drugs administered, intubation, CPR, and defibrillation), return of spontaneous circulation (ROSC), in-hospital data (length of hospital stay, intensive care unit admission, therapeutic hypothermia (TTM), coronary angiography, coronary artery bypass grafting (CABG), percutaneous coronary

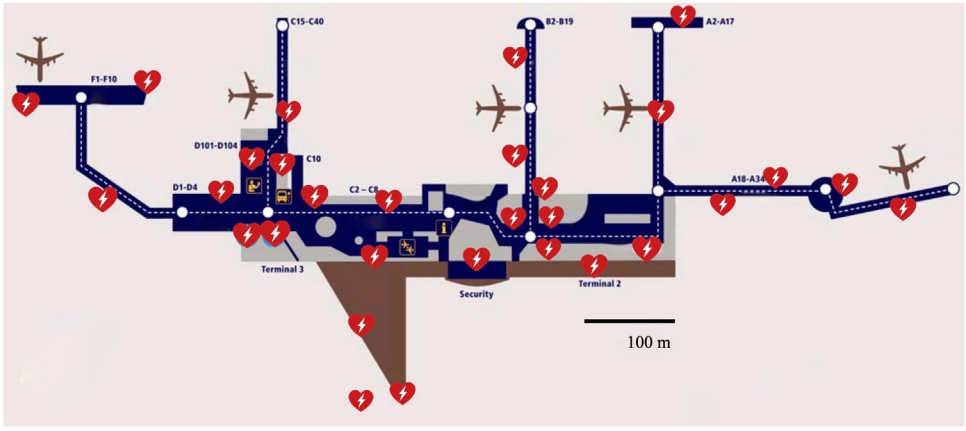

Fig. 1 – Distribution of publicly available AEDs in Copenhagen International Airport. The brown areas indicate the terminals and check-in areas pre security and the dark blue areas indicate shopping and gate areas post-security (2019).

intervention (PCI), implantable cardioverter defibrillator (ICD), and drugs administered), comorbidities (previous heart disease, hypertension, and diabetes), and survival to discharge (Table 1).

The Danish Cardiac Arrest Registry

Data on OHCA at Copenhagen International Airport was compared with nationwide data on bystander witnessed OHCA in public locations from the Danish Cardiac Arrest Registry from May 25, 2015 to December 31, 2018. Data from January 1 to May 25, 2019 was not included as this was unavailable at the time of retrieval. Detailed information on this registry has been published previously.[10] The following parameters were compared: sex, age, initial heart rhythm, bystander CPR, bystander defibrillation, ROSC, and 30-day survival (Table 2). Persons with missing Danish Personal ID-number were not included in the survival data from the Danish Cardiac Arrest Registry.

Outcomes

The main outcome was survival to hospital discharge. Secondary outcome measures were initial heart rhythm, bystander CPR, bystander defibrillation, and ROSC.

Statistical analysis

Categorical variables were presented as proportions and percentages and analysed with Fisher's Exact Test. Continuous variables following normal distribution were presented as means with standard deviations and analysed with 2-sample t-test, otherwise continuous variables were presented as median with interquartile range (IQR). Odds ratio (OR) with 95% confidence interval (CI 95%) was chosen to assess OHCAs occurring at the airport and the association to the primary and secondary outcome measures with witnessed OHCAs occurring in a public location on a national level as the reference group. Analysis is univariate and odds ratios are unadjusted. Level of statistical significance was defined as two-sided *P*-value <0.05. Statistical analyses were done in RStudio version 1.2.1335 (RStudio Inc.)

Ethical approval

Patient data collection was approved by the Data Protection Agency (Journal number: 2012-58-0004, VD-2018-28, I-Suite number: 6222), and the study was registered with the Danish Patient Safety Authority (31-1522-14). In Denmark, no ethical approval is required for retrospective registry studies.

Table 1 – Characteristics persons with non-traumatic cardiac arrest in Copenhagen International Airport based on survival to hospital discharge.

OHCA characteristics	All cases	Survival to discharge	Died before discharge
Number (%)	23 (100%)	13 (56.5%)	10 (43.5%)
Male sex, n (%)	20 (87.0%)	13 (100%)	7 (70.0%)
Mean age ± SD years	65.7 ± 14.7	65.7 ± 14.1	65.8 ± 15.5
Bystander witnessed arrest, n (%)	21 (91.3%)	13 (100%)	8 (80.0%)
EMS witnessed arrest, n (%)	1 (4.4%)	0 (0%)	1 (10.0%)
Unwitnessed arrest, n (%)	1 (4.4%)	0 (0%)	1 (10.0%)[a]
Pre-hospital data			
VF/pVT, n (%)	12 (52.2%)	12 (92.3%)	0 (0%)
Asystole/PEA, n (%)	11 (47.8%)	1 (7.7%)	10 (100%)
Bystander CPR, n (%)	17 (73.9%)	11 (84.6%)	6 (60.0%)
Bystander defibrillation, n (%)	10 (43.5%)	9 (69.2%)	1 (10.0%)
EMS or first responder defibrillation, n (%)	8 (34.8%)	5 (38.5%)	3 (30.0%)
Intubation at site, n (%)	13 (56.5%)	7 (53.9%)	6 (60.0%)
ROSC, pre-hospital, n (%)	18 (78.2%)	13 (100%)	5 (50.0%)
Regained consciousness before EMS arrival	6 (26.1%)	6 (46.2%)	0 (0%)
In-hospital data			
Hospital admission, n (%)	18 (78.2%)	13 (100%)	5 (50.0%)
Median duration of hospitalisation in days (IQR)	8 (5.5–17.5)	16 (6–19.5)	6 (1–7.5)
Admitted at ICU, n (%)	12 (66.7%)	9 (69.2%)	3 (30.0%)
Therapeutic hypothermia (TTM) in ICU patients, n (%)	8 (66.7%)	6 (66.7%)	2 (40.0%)
Initial ejection fraction	35% ± 11.9 (n = 13)	35.4% ± 12.3 (n = 12)	30.0% (n = 1)
Coronary angiography, n (%)	14 (60.8%)	12 (92.3%)	2 (20.0%)
Primary PCI, n (%)	5 (35.7%)	5 (41.7%)	0 (0%)
CABG during admission, n (%)	4 (28.6%)	4 (33.3%)	0 (0%)
No revascularisation, n (%)	5 (35.7%)	3 (25.0%)	2 (100%)
ICD implantation before discharge, n (%)	6 (26.1%)	6 (46.2%)	0 (0%)
Comorbidities			
Previous heart disease, n (%)[b]	7 (30.4%)	4 (30.8%)	3 (30.0%)
Hypertension, n (%)	14 (60.9%)	10 (76.9%)	4 (40.0%)
Diabetes, n (%)	5 (21.7%)	1 (7.7%)	4 (40.0%)

OHCA, out-of-hospital cardiac arrest; EMS, emergency medical services; VF/pVT, ventricular fibrillation/pulseless ventricular tachycardia; CPR, cardio-pulmonary-resuscitation; ROSC, return of spontaneous circulation; ICU, intensive care unit; PCI, percutaneous coronary intervention; CABG, coronary artery bypass grafting; ICD, implantable cardioverter defibrillator; TTM, targeted temperature management.

[a] Unwitnessed case of cardiac arrest received CPR within 5–7 min after the arrest.

[b] Arrhythmia, ischemia, or congestive heart failure.

Table 2 – Outcomes for airport out-of-hospital cardiac arrests compared with bystander witnessed out-of-hospital cardiac arrests in public locations on a nationwide level in Denmark.

OHCA Outcomes	Airport OHCA[a]	Bystander witnessed OHCA in public locations in Denmark[b]	Odds ratio (CI 95%)
Number of cases, n (%)	23	2254	
Initially shockable rhythm, n (%)	12 (52.2%)	691 (31.9%)	2.33 (1.02–5.28)
Bystander CPR, n (%)	17 (73.9%)	2015 (89.4%)	0.33 (0.13–0.86)
Bystander defibrillation, n (%)	10 (43.5%)	556 (24.8%)	2.32 (1.01–5.31)
ROSC, n (%)	18 (78.2%)	1141 (50.6%)	3.51 (1.30–9.49)
Survival to discharge/30-day survival[c], n (%)	13 (56.5%)	918 (45.2%)	1.58 (0.69–3.62)

OHCA, out-of-hospital cardiac arrest; CPR, cardio-pulmonary-resuscitation; ROSC, return of spontaneous circulation; CI, confidence interval.
[a] Including one unwitnessed OHCA and one EMS witnessed OHCA.
[b] Data from 2015–2018.
[c] Survival for Airport OHCA was registered as 'survival to discharge' whereas survival for bystander witnessed OHCA in public locations was 30-day survival.

Results

Study population

From the pre-hospital patient records and first responder reports we excluded 11 of the 34 persons with suspected OHCA, five of which were not OHCA (e.g., vasovagal syncope), and five of which were excluded because the OHCA took place on board an aircraft during flight, Fig. 2. One person presented with traumatic cardiac arrest and was excluded. Consequently, we included 23 persons with non-traumatic adult OHCA (average of six OHCAs per year, equal 0.021 OHCAs per 100,000 passengers per year) (Table 1).

From the Danish Cardiac Arrest Registry, we included 2254 bystander witnessed OHCAs in public locations from May 25, 2015-December 31, 2018.

Demographics

Mean age was 65.7 years (SD ± 14.7) and 66.5 (SD ± 17.5), for persons with OHCA at the airport and for bystander witnessed OHCA in public locations in Denmark, respectively. Most persons with OHCA at the airport were male (87.0%) which was the same for public bystander witnessed OHCA (73.1%).

Pre-hospital treatment

Bystander witnessed OHCA was reported in 21 of 23 OHCAs (91.3%), one OHCA was unwitnessed (in a public restroom) and one was witnessed by EMS. The airport professional first responders arrived prior to the external EMS in 20 out of 23 instances and initiated or continued bystander initiated BLS along with oxygen supplement.

Overall, 17 persons (73.9%) received bystander CPR. A greater proportion of the survivors received bystander CPR compared to non-survivors (84.6% vs. 60.0%, p = 0.34). Ten persons (47.6%) with bystander witnessed OHCA were bystander-defibrillated with a publicly available AED from the airport. A significantly larger proportion of persons who survived to hospital discharge received bystander defibrillation compared with non-survivors (69.2% vs. 10.0%, p = 0.01).

Initial shockable rhythm was observed in 12 persons (52.2%) whereas 11 (47.8%) had a non-shockable rhythm on initial recording.

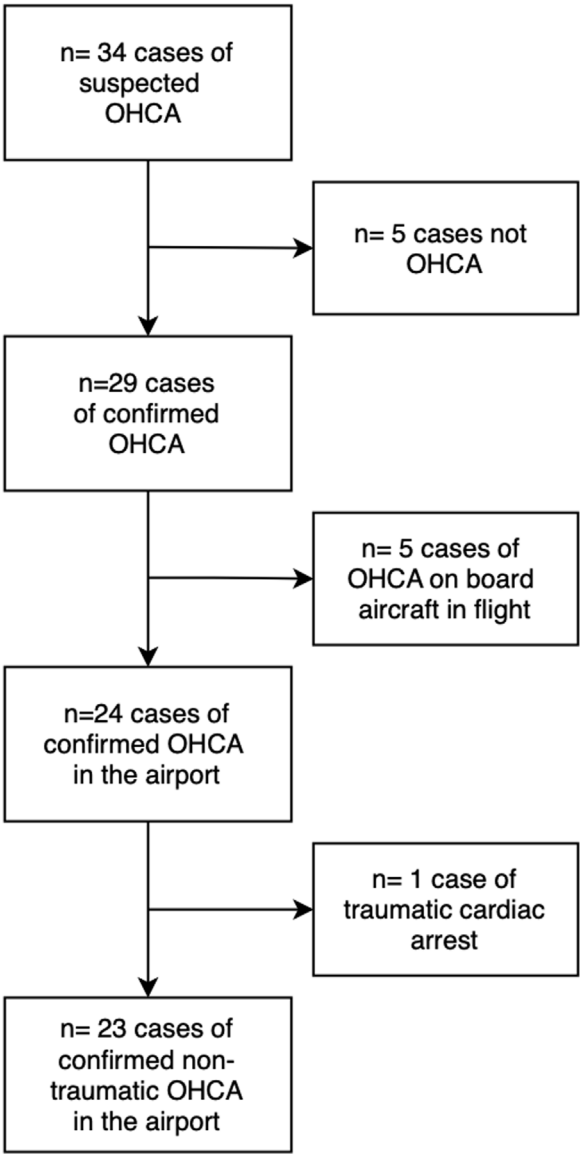

Fig. 2 – In- and exclusion process for OHCAs at Copenhagen International Airport.
OHCA; out-of-hospital cardiac arrest.

ROSC was obtained for 18 persons (78.2%) before hospital arrival, and six persons (26.1%) had regained consciousness before EMS arrival. Five out of six persons (83.3%) were defibrillated by a bystander. A significantly larger proportion of persons with prehospital ROSC survived to hospital discharge (72% vs. 28%, p = 0.008).

In-hospital treatment

Of all persons admitted to the hospital, 14 persons (77.8%) underwent coronary angiography during hospitalisation. Five of these persons (35.7%) underwent primary PCI, four (29%) underwent acute CABG, and five persons (35.7%) had no revascularisation performed (due to either chronic ischemic heart disease or severe anoxic brain damage). Six of the fourteen persons (43%) had an ICD implanted.

Survival to hospital discharge

Overall, 13 of the 23 persons (56.5%) survived to hospital-discharge after a median duration of 8 days (5.5−17.5) of admission. Twelve persons (100%) with initial shockable rhythm survived to hospital discharge compared to one person (9.0%) with a non-shockable rhythm.

Survival at Copenhagen International Airport vs. Danish Cardiac Arrest Registry

From May 25, 2015 to December 31, 2018, there were 18,101 OHCAs in Denmark. The proportion of bystander witnessed OHCAs in this time period was 48.3%, 75.9% received bystander CPR, 7.1% were bystander defibrillated, and 14.1% survived 30-days.[11]

A total of 4557 OHCAs (25.2%) occurred in public locations and with bystander witnessed arrest in 2254 (51.1%) of these cases (Table 2). Among bystander witnessed OHCA in public locations, 45.2% were alive 30-days after OHCA.

Discussion

This observational study examined characteristics, pre-hospital and in-hospital treatment, and survival for persons with OHCA at Copenhagen International Airport exemplifying an optimal setting with high density of available AEDs, high proportion of bystander witnessed cardiac arrests, and a rapid professional first responder system. We found overall survival to be 56.5% for all persons, and a survival rate of 100% among persons presenting with an initial shockable rhythm. When comparing OHCAs at Copenhagen International Airport with persons with bystander witnessed OHCA in public locations, we found lower odds for bystander CPR, but more than a two-fold increase in chance of bystander defibrillation, and an increase in odds of survival to hospital discharge.

Several factors related to this airport setting could explain our findings of remarkably high survival rates and high rate of initial shockable heart rhythm. International airports generally have a large flow of passengers and accordingly, an increased risk of OHCA. OHCA in Copenhagen International Airport was 0.21 OHCA per million passengers, which is comparable with the 0.24 OHCA per million passengers reported across 70 airports in 9 different countries by Masterson et al.[13] A large flow of passengers increases the chance of a bystander witnessed arrest and early bystander interventions. As expected, we found a high proportion of bystander witnessed OHCAs at the airport (91.3% at the airport vs. 48.3% for Denmark) compared with the Danish Cardiac Arrest Registry. Despite this, the proportion of OHCAs that received bystander CPR at the airport was almost the same as the nationwide numbers in Denmark (73.9% vs. 75.9%).[11] These proportions are similar to what other studies on airport OHCA have found ranging from 72.4% to 77.0%,[13,14] but lower compared to bystander witnessed arrest in public areas in Denmark (89.4%). This difference is most likely due to the fact that the median response time for EMS to an OHCA in the rest of the country is seven minutes,[11] where first responders usually arrive within three minutes at the airport. A longer response time will itself increase the likelihood of bystander-initiated CPR.[15,16]

The frequency of initially shockable rhythm at the airport was significantly higher than what is reported for OHCA in general in Denmark (15.8%) and bystander witnessed OHCA in public locations (31.9%) but equivalent to what other studies have found on public OHCA.[17–20] Sex and age characteristics were comparable in the two groups as well as to previous airport settings and all OHCAs in Denmark as a whole.[11–14] Compared to a previous study on OHCA in Copenhagen City Centre, fewer persons had previous heart disease but more had diabetes at the airport.[7]

Bystander defibrillation occurred substantially more often at the airport (43.5%) compared to bystander witnessed OHCA in public spaces (24.8%) and among the general population in Denmark (7.1%).[11] This is likely due to the high accessibility of AEDs at the airport, where AEDs are placed strategically according to passenger density, thus allowing for timely AED application and defibrillation.[6,21] At the airport 9 out of 12 persons (75.0%) with initial shockable rhythm were bystander defibrillated and importantly, 9 out of 10 persons (90.0%) who were bystander defibrillated survived to discharge. Previous studies assessing OHCAs at airports reported bystander defibrillation in 32% and 42% of instances,[13,14] and overall chances of survival in previous studies ranged from 17.7% to 61.1% (the latter including only persons with an initial shockable rhythm).[12–14]

As expected, a strong association between bystander defibrillation and survival was identified since 69.2% of survivors were bystander defibrillated compared to 10.0% of non-survivors. Importantly, all airport OHCAs with a shockable heart rhythm survived to hospital discharge underlining the importance and potential of early bystander CPR and defibrillation.[18] This is in accordance with previous studies.[1–4]

The highest observed survival after OHCA is from a study in casinos, which reported a survival of 74% when the OHCA was witnessed and the person was defibrillated no later than 3 min after collapse.[22] Though we had no recordings of time to defibrillation, these numbers compared to the survival in this study could indicate that defibrillation likely happened within few minutes. This underscores the potential of early bystander intervention and illustrate the importance of continuous efforts to optimize AED deployment in high-risk areas for on-site use and implementing citizen responder programs to quickly deliver nearby AEDs which are not on-site.[16,19] Thus, the high-potential setting at the airport, with a large population density and movement and high AED-accessibility may generalize to other public settings such as sports facilities,[19] malls, bus — and railway stations[8] thus emphasizing the potential to improve overall OHCA survival in society.

The local first responder system in Copenhagen Airport aims to arrive on scene within three minutes after dispatch call. Having professional first responders on the scene only minutes after the event of OHCA ensures early BLS thus optimising treatment and saving valuable time.[1,27] Early bystander and first responder treatment resulted in regained consciousness for 6 of 13 survivors even before

EMS arrival, a factor previously associated with improved outcome.[28] This may also explain the observed OR of 1.58 for survival at Copenhagen International Airport compared to bystander witnessed OHCA in public locations in the rest of Denmark, which would seem a comparable reference group. The high proportion of bystander intervention and rapid first responder involvement observed in this study may prove to be important for long-term survival, neurological outcome, and health related quality of life as well.[17,23–26]

All persons with initial shockable rhythm underwent coronary angiography and all were found to have underlying ischemic heart disease (IHD). The role of immediate coronary angiography and subsequent PCI for persons with ST-elevation in their electrocardiogram (ECG) following OHCA is well established and associated with improved short- and long-term outcome and is currently recommended by international guidelines.[29–32] Of the nine persons (39.1%) revascularised, all presented with an initial shockable rhythm. Investigating in-hospital treatment is important to better understand the etiology of OHCA, which in this study shows a large proportion of ischemic heart disease. No previous study on airport OHCA has investigated in-hospital treatment.

Limitations

This study potentially has several limitations. First, this was an observational study why all findings indicate associations and not causality. Second, the small number of persons included presents a limitation and interpretations should be made with caution. Third, data on response time for the airports professional first responder system was missing. Fourth, we have no recording of the time from incidence of OHCA to initiated CPR (no-flow time) or the time from initiated CPR to reestablishment of spontaneous circulation (low-flow time). Since both are important predictors of outcome this might explain the difference that we observe between the airport and public bystander witnessed cardiac arrests in Denmark. Because a large proportion of persons with OHCA at the airport were international citizens, without Danish Personal ID-number, we were only able to retrieve information on survival to discharge and not 30-day survival as we report for the national OHCA data. This may affect the result, and the true proportion of survival may be different to what we report in this study.

Conclusion

This study of OHCAs at Copenhagen International Airport, an OHCA high-risk area with potentially numerous bystanders, a high density of accessible AEDs and rapid professional first responders found a high proportion of early bystander defibrillation, indicating that bystanders will quickly apply and use an AED when accessible. Importantly, more than half of all persons and all persons with a shockable heart rhythm survived. These findings indicate an increased potential for survival following OHCA and support current guidelines to strategically deploy AEDs for on-site use in areas with a high-risk of OHCA as well as continuous efforts to facilitate early defibrillation in society.

Conflicts of interest

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