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Intrahospital Dissemination of Automatic External Defibrillators Decrease Time to Defibrillation of In-Hospital Cardiac Arrests

D. Fredman[1], Leif Svensson[1*], M. Jonsson[1], J. Beltzikoff[2], M. Ringh[1], P. Nordberg[1], J. Hollenberg[1], M. Rosenqvist[3]

[1]Department of Cardiology, Center of Resuscitation and Science, Karolinska Institutet, Södersjukhuset, Sweden; [2]Section of Anaesthiology, Department of Clinical Science and Education, Karolinska Institutet, Södersjukhuset, Sweden; [3]Department of Clinical Sciences, Danderyd Hospital, Karolinska Institutet, Stockholm, Sweden.
Email: [*]leif.svensson@sodersjukhuset.se

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ABSTRACT

Background: Survival rates for in-hospital cardiac (IHCA) arrest are low. Early defibrillation is vital and international guidelines, which requests defibrillation within three minutes. Can dissemination of automatic external defibrillators (AED) at hospital wards shorten time to defibrillation compared to standard care, calling for medical emergency team (MET)? Material & Methods: Forty-eight (48) units at Södersjukhuset, Sweden, were included in the study. They were divided into the intervention group (24 units equipped with AEDs) and the standard care group (24 units with no AEDs). Intervention group staff were trained in CPR to use AEDs and standard care group staff were trained in just CPR. Data were gathered from patient records, AEDs and the Swedish National Registry of Cardiopulmonary Resuscitation (NRCR). Results: 126 IHCA patients were included, 47 in the standard care group, 79 in the intervention group. AEDs in the intervention group were connected to a defibrillator and it was ready to shock before arrival of MET in 83.5% of all cases. AEDs were ready to be used on average 96 seconds (14 - 427 s) before arrival of MET. Seven (15%) patients were defibrillated in the control group and Twenty (25%) in the intervention group. Defibrillation within three minutes occurred in 67% in the intervention group (11/17), compared with none (0/7) in the control group (p = 0.02). Conclusion: A systematic implementation of AEDs in hospital wards decrease time to defibrillation compared to a standard MET response system. Larger studies are needed to evaluate the impact on the outcome.

KEYWORDS

Cardiac Arrest; In-Hospital Cardiac Arrest; Defibrillator; AED

1. Introduction

Approximately 3500 adult in-hospital cardiac arrests (IHCA) occur every year in Sweden and the overall survival rate is poor, 18% - 30% [1]. However, those figures are also uncertain. As in out of hospital cardiac arrests (OHCA), the delay to defibrillation seems to be the most significant problem also in cases of IHCA [2]. Therefore, shortening the time to defibrillation is the key for improving survival in IHCA situations. The response to an IHCA alarm is usually based upon action from a medical emergency team (MET). This team carries a defibrillator and equipment including drugs for advanced life support (ALS) and is dispatched in cases of suspected IHCA and other medical emergencies at the hospital's general wards and outpatient clinics. International guidelines have suggested that the alerted MET should be present within one minute, cardiopulmonary resuscitation (CPR) should be started within one minute and "defibrillation possibilities"

[*]Corresponding author.

should be prepared within three minutes [3]. The compliance to these guidelines is, however, probably low. In a previous report, Aune *et al.* found only 53% of all patients with shockable rhythm (ventricular fibrillation (VF) and pulseless ventricular tachycardia (VT)) were defibrillated within three minutes [4]. Dissemination of Automated external defibrillators (AED) could theoretically facilitate a local response to IHCA and thereby give a shock within three minutes and most likely, prior to the arrival of the MET.

The aim of this pilot-study was to evaluate whether a general dissemination of AED at general hospital wards could shorten time to defibrillation compared to the standard care, calling for MET. Secondly we wanted to observe the impact of this intervention on the proportion of patients defibrillated within three minutes.

2. Material and Methods

2.1. The Hospital

Södersjukhuset located in Stockholm, Sweden, provides emergency medical care to approximately 600,000 inhabitants in Stockholm and has in all 659 beds.

2.2. Study Period

The study was performed over three years from January 2007 to December 2010.

2.3. Study Patients and Data Collection

The decision to include units in the survey was based on the retrospective occurrence of one or more IHCA during the past five years. A total of 48 units met those inclusion criteria, these units consisted of both wards and outpatient clinics from all the hospitals clinics.

All 48 units were prospectively stratified and evenly divided into either an interventional arm (24 units) equipped with AEDs or acted as a standard care group (24 units) not equipped with AEDs. Stratification to the interventional group was done with regard to three non-intensive cardiac care wards that were the only non-intensive units at the hospital already equipped with AEDs and the staff there was already trained to use them. These three cardiac wards were therefore included in the intervention group.

Due to ethical reasons IHCA which occurred at the emergency department (ED), operation theatre, Intensive care unit (ICU) and Coronary care unit (CCU) were excluded from the study. We found it impractical and unethical to make a traditional randomized trial in terms of randomly dividing all wards, including ED, ICU/CCU and general cardiac wards to either standard care or intervention group. Since they already were equipped with AEDs to remove defibrillators from those departments was never an alternative.

Patients could thereafter, in a prospective manner be included in the study if they were admitted to one of the hospitals study ward or visiting an outpatient clinic and there suffered an IHCA and received CPR.

All patient data was obtained from patient's charts, the Swedish National Registry of Cardiopulmonary resuscitation (NRCR) and in the intervention group also the data retrieved from the AEDs used. Information about the IHCA and the resuscitation attempts had to be entered in NRCR for the patient to be enrolled in the study. The NRCR started in 2005 and as of today 63 of the 74 Swedish hospitals (85%) are reporting and participating in the registry. Also, data from the AEDs were internally stored on a Secure Digital (SD) memory card and included recordings of ECG, event data and ambient noise. This data was retrieved and analyzed using Schiller-Medical SAED reader software (Version 06.07.B1). The sound files with ambient noise (*i.e.* recordings of the AEDs immediate surroundings) were later analyzed to more exactly determine when the MET arrived on scene.

2.4. Study Endpoint and Study Setting

The primary goals of this study was to compare the proportion of patients with an AED in place and ready to use within three minutes after occurrence of IHCA but also study the time gained by using AEDs in more general wards before arrival of the MET.

In this study the definition "ready to use" means that the defibrillator is switched on and that the electrodes were applied to the patient.

The units in the interventional arm were equipped with Schiller-Medical AG; FRED easy AED (CE-0459).

All staff on the intervention group units, regardless if medical or administrative was trained to perform CPR and to use the AED. This training was required and mandatory before the implementation of the AEDs. The standard care units continued as earlier with CPR training once a year but were not equipped with AEDs. CPR training at the wards in the two groups was mandatory carried out every six months during the three-year study period.

In suspected IHCA cases, the staffs immediately called the hospital internal alarm number handled by the switchboard operator who immediately dispatches the MET. The switchboard operator then registers the time for dispatch and this information was later faxed to the nurse in charge for data handling and later used to localize the patient in the NRCR. At Södersjukhuset the MET consists of an anesthetist, an intensive care nurse and an ICU staff nurse manning a kick bike/crash cart equipped with a defibrillator/AED (Philips Mr X) alongside with

material for airway management as well as drugs suitable for any acute situation in accordance to ALS guidelines.

2.5. Ethics

This study was planned to be started before the International Committee of Medical Journal Editors (ICMJ) recommendation to register new clinical trials in meta-registers and the study was therefore not registered in an open access trial registry.

This study was approved by the Regional Ethics Committee of Stockholm (2006/278-31).

2.6. Statistics

Primarily data was put in to excel datasheets and completed manually. For statistical analysis the data was exported to the SPSS for Windows 20.0 package (SPSS, Chicago, IL). The mean time comparisons were tested with independent sample T-test for the normally distributed variables. For the non-normally distributed variables Mann-Whitney test were used. Outcome and other categorical variables were tested with Pearson's Chi^2-test. If the *P*-value was < 0.05 the results were regarded significant. As this was a pilot study with the intention for later larger prospective studies on mortality, no formal power test for survival was performed.

3. Results

During a three-year study from January 2007 to December 2010 period a total of 126 IHCA patients were included in the study. Seventy-nine (79) patients in the intervention group and forty-seven (47) patients in the standard care group. To our knowledge only five additional IHCA entered in to NRCR occurred outside the study population at a ward not included in the study this ward were opened during the study period and these patients were therefore not included in the material.

3.1. Patient Characteristics (Table 1)

Clinical characteristics and background data are presented in **Table 1**.

There were no significant differences concerning age and sex between the two groups. Previous medical history and ward where the CA occurred presented in **Table 1** represent outtakes from patient's charts and NRCR.

3.2. First Responder Actions (Table 2)

Time from call to start of CPR and time from call to MET arrival are not associated with any significant differences between the two groups. Time from call to defibrillation however, is significantly longer in the control group ($p = 0.05$).

Table 1. Patient characteristics.

Demography	Control	Intervention	*P*-value
Male (%)	57.4% (n = 27)	68.4% (n = 54)	0.22
Age (Mean)	76.2 (n = 47)	73.8 (n = 79)	0.29
Previous medical background (Percentage in material presenting)	**Control**	**Intervention**	
Heart failure	14%	19%	
Diabetes	26%	19%	
Ischemic heart disease	24%	24%	
COPD	13%	41%	
Stroke	13%	8%	
Cancer	22%	22%	
Type of ward where CA occurred	**Control**	**Intervention**	
Surgical	21%	20%	
Medical	38%	43%	
Orthopedic	26%	9%	
Cardiac	N/A	28%	
Out-patient clinic	15%	N/A	

Table 2. First responder actions.

First responder actions	Control	Intervention	*P*-value
Time: Call to CPR (min)	0.1 (n = 47)	−0.9 (*n* = 79)	0.34
Time: Call to MET-team arrival (min)	2.6 (n = 43) Missing 4 cases	2.9 (*n* = 74) Missing 5 cases	0.53
Time to defibrillation (min)	10.5 (n = 4)	2.9 (*n* = 17)	0.05

3.3. Defibrillation (Table 3)

In the intervention group 25.3% (20/79) of the patients were defibrillated and in the control group 14.9% (7/47) were defibrillated.

In the intervention group 65% (11/17) of the patients defibrillated were defibrillated within three minutes versus none (0/7) in the control group ($p = 0.02$).

In the intervention group 29% (5/17) of the patients defibrillated were defibrillated within one minute ($p = 0.21$).

The mean time to defibrillation in the intervention group was less than 3 minutes compared to over 10 minutes for the control group ($p = 0.05$).

In the intervention group, 83.5% (66/79) of the patients were connected to a defibrillator and it was ready to use before arrival of the MET and 82% (14/17) of the defibrillated patients were already defibrillated when the

Table 3. Defibrillation.

	Control (n = 47)	Intervention (n = 79)	*P*-value
Defibrillated* total	14.9% (n = 7)	25.3% (n = 20)	0.17
Defibrillated with complete times registered in NRCR**	**Control (n = 7)**	**Intervention (n = 17)**	***P*-value**
Defibrillated < 3 min	0% (n = 0)	64.7% (n = 11)	0.02
Defibrillated < 1 min	0% (n = 0)	29.4% (n = 5)	0.21
Defibrillated Prior to MET	N/A	82.4% (n = 14)	0.002

*Patients that weren't defibrillated in our material never presented a shockable rhythm during the resuscitation event; **NRCR = Swedish national registry of cardiopulmonary resuscitation.

Table 4. Outcome.

Outcome	Control (n = 47)	Intervention (n = 79)	*P*-value
ROSC* (%)	55.3 (n = 26)	49.4 (n = 39)	0.52
Alive after event (%)	40.4 (n = 19)	41.8 (n = 33)	0.88
Discharged alive (%)	10.6 (n = 5)	16.5 (n = 13)	0.37
	Control n = 7	Intervention n = 20	*P*-value
Defibrillated discharged alive (%)	14.3 (n = 1)	35.0 (n = 7)	0.30

*ROSC = Return of spontaneous defibrillation.

MET arrived on scene.

Ambient sound recordings gave at hand that the AEDs electrodes were applied and AED ready to deliver a shock 96 seconds (range 14 - 427 s) before the arrival of the MET.

Nurses were the dominating staff category that defibrillated prior to arrival of MET in 15 of the 20 cases (75%).

The patients in the material that weren't defibrillated never presented a shockable rhythm during the resuscitation event.

3.4. Outcome (Table 4)

49% (39/79) of the patients in the intervention group received return of spontaneous circulation (ROSC) versus 55% (26/47) in the control group ($p = 0.52$).

42% (33/79) of the patients in the intervention group were alive after the CPR event versus 40% (19/47) in the control group ($p = 0.88$).

16% (13/79) of the patients in the intervention group were discharged alive versus 11% (5/47) in the control group (NS).

Amongst the defibrillated patients in the intervention group 35% (7/20) were discharged alive versus 14% (1/7) in the control group (NS).

4. Discussion

As expected due to the presence of AEDs rhythm assessment is carried out earlier and this makes it is possible to defibrillate before arrival of the MET. And when ambient recording of the AEDs use were assessed we found that the AEDs were ready to be used *i.e.* electrodes applied and AED ready to deliver shock, more than 1.5 minutes, in mean, before the arrival of MET. In our material defibrillation occurred before MET arrival in over 80 % of all cases in the AED equipped intervention group. Furthermore, in the interventions group 65% of all patients in shockable rhythm were defibrillated within 3 minutes compare to none in the standard care group. As seen in **Table 4** there was no significant difference in survival to discharge between the two groups but a clearly visible trend 35% in the intervention group vs. 14.3 in the control group and this, we think, is not only explained by ah slightly larger number of patients included in the intervention group.

As shown in **Table 3** only 27 patients in total were defibrillated at any stage, 7 in control group and 20 in intervention group, the rest of the patients presented asystole or PEA as rhythms throughout the entire resuscitation process. It is known that VT/VF decrease by time from the onset of cardiac arrest [2] and this could partly explain the differences between the two groups.

Since the wards not were randomly distributed in our material, the two groups were not identical; therefore patient's previous medical history differs somewhat between the two groups. However there was no significant difference with regards to age or sex between the two groups. The hospitals three cardiology wards were included in the intervention group due to ethical and practical reasons; this is a possible explanation to the larger number of IHCA in the intervention group. This subgroup consists of patients with elevated risk for CA not only due to their previous medical history of ischemic heart disease but also due to the fact that a cardiac reason for admittance is associated to a higher risk of IHCA [5].

The larger proportion of chronic obstructive pulmonary disease patients in the intervention group could also be a reason for the larger number of IHCA patients in the intervention group. However we cannot find this described in any other studies we draw that conclusion based on the fact that in our material where the pulmonary ward alone comprised some 20% of the IHCA in the interventions group. The ultimate study should have randomly distributed both those groups of patients but since this was a single hospital study it was not possible.

As expected a slightly higher number of patients were

defibrillated in the intervention group compared to the control group. This difference was as described earlier expected and predictable due to the historical numbers of cardiac arrests and also since the three cardiology wards were all in the interventions group. But we also think that the larger number of defibrillated patients relate directly to the fact that there were AEDs present to facilitate defibrillation.

Early onset of lifesaving attempts *i.e*. CPR and defibrillation in IHCA all depends on how quick the staff on scene reacts and call for help. In our study all units' staff in both groups started CPR early and did also call for the MET early, well within the guidelines one minute time frame. It is only when it comes to defibrillation within three minutes we could demonstrate any significant differences between the two groups and we think this is a clear example that AED presence facilitates early defibrillation.

It has been debated that AED rhythm analysis might steal valuable time and that this is why AEDs at IHCA might not be associated with increased survival [6,7].

When AEDs, in our study, were present at wards they were associated with earlier application of electrodes and earlier rhythm assessment. In the intervention group with AEDs present at the ward over 80% of the patients had the AED applied and ready to use before arrival of MET. We think this clearly exemplifies the effect of placing AEDs in more strategic locations based mainly on the occurrence of historical episodes of IHCA. This also explains the fact that the number of patients defibrillated within the three-minute time interval stipulated by international guidelines was significantly higher in the intervention group.

Early assessment of heart rhythm is a necessity for early defibrillation and in a larger cohort this could, as Chan *et al*. [8] stated most probably lead to increased survival.

In this study we found out that nurses, acting as a first responder, was the most likely category of personal to defibrillate prior to the MET. This is in accordance to what Gombotz *et al.* found [9] and could be described as by implementing of AEDs at wards, a way of strengthening the chain of survival.

Data from this study suggests that the use of in-hospital AEDs in a more strategic manner significantly shortens the time to defibrillation and early defibrillation is an important key to increase survival. Our survey is too small to state whether this significantly has any effect on mortality. Numerous studies have however showed that in OHCA presence of AEDs and thereby early defibrillation is associated with increased survival [10,11]. The same findings associated with AED present at hospitals have yet to be proved. Chan *et al*. [8] suggested that delay in defibrillation could partly be related to lack of access to defibrillation equipment. In 2010, after a thorough search in the US National Registry of CPR and based on some 11,000 patients Chan *et al*. stated [7] that in-hospital AEDs were not associated with increased survival and they debated that this was due to the time it took to apply the electrodes and assess heart rhythm.

We have however showed that early assessment of heart rhythm facilitates for early defibrillation and this supports the thesis that defibrillation should be able to be performed early, by the first responder, even at hospitals.

5. Limitations

This is a descriptive and non-randomized controlled study performed at a single hospital with limited numbers of patients and only a pilot study aiming for power calculation.

Rhythm analysis and time measurements has been an obvious problem, it was difficult gathering accurate time and data from machines that weren't fully under our control. To carry out a study of this sort a streamlined device would have been to prefer. Data from the MET defibrillators and ward/outclinic-personal time reporting took a lengthy time to gather and still data weren't fully reliable. We also had to exclude some IHCA cases that came to our knowledge but never were entered in to the NRCR and therefore we weren't able to fully evaluate them. This fact has however led to a better system of data handling at the hospital.

6. Conclusion

AEDs implemented at more general hospital, and non-ICU/CCU wards can substantially decrease time to defibrillation in IHCA patients compared to a standard MET response care system. Further and larger studies are however needed to evaluate the impact on the outcome.

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