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Effects of a mandatory basic life support training programme on the no-flow fraction during in-hospital cardiac resuscitation: An observational study☆

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1. Introduction

The reported incidence rates of in-hospital cardiac arrest range from 0.66 to 3.8/1000 hospital admissions.[1,2] Although modern approaches to preventing cardiac arrest during hospital stays have been quite successful,[1] a considerable number of patients still require cardiac resuscitation. To provide optimal care for these patients, guidelines for cardiac resuscitation based on the current scientific evidence are available and updated every five years.[3] However, the proportion of patients who achieve return of spontaneous circulation (ROSC) ranges between 49% and 67%, and the hospital discharge rate is still poor (15–39%).[4,5]

The guidelines for cardiac resuscitation published in 2005 clearly focused on high-quality chest compressions with minimal interruptions.[6] The updated guidelines emphasize these chest compressions even more strongly.[3] However, several studies have reported a high proportion of time without chest compressions during the period without spontaneous circulation (i.e., a high no-flow fraction) during resuscitation. During out-of-hospital cardiac arrest, the reported no-flow fractions during resuscitation by

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paramedics were 0.6 in an ambulance system in the US[7] and 0.48 in a system in Sweden[8]. For in-hospital cardiac arrest, one study investigated the no-flow fraction during life support provided by a cardiac arrest team and observed a result of 0.24.[9] However, in that study, a sensor was placed above the sternum to evaluate the quality of the compressions, which might have produced a lower no-flow fraction because the cardiac arrest team was aware of the assessment. To our knowledge, no previous studies have investigated the no-flow fraction during in-hospital resuscitation provided by standard care nursing teams. Furthermore, we do not know whether basic life support (BLS) training influences the no-flow fraction.

We established a mandatory BLS curriculum that focused on high-quality chest compressions for all employees of a large university hospital. The aim of the study was to evaluate whether a standardized mandatory BLS training programme reduced the no-flow fraction during in-hospital cardiac resuscitation provided by the staff members in standard care wards and which outcomes were affected.

2. Methods

The study protocol and patient enrolment procedure were approved by the institutional review board (IRB) at the University Hospital Dresden (EK 145042011). Informed consent was waived by the IRB.

2.1. Hospital

The study was performed at a 1100 bed university hospital, which provides full complement of services. 60,000 inpatients are admitted annually.

2.2. Teaching intervention

All nurses and physicians at our university hospital receive compulsory BLS training that adheres to the current guidelines of the European Resuscitation Council (ERC). An intensive care nurse who is also trained as a paramedic and an instructor for the ERC's Advanced Life Support (ALS) course teaches the training courses. The 90-min training is provided for groups of five to nine attendees and includes an opportunity to handle and operate the automated external defibrillator (AED, LifePak 1000, Physio-Control, Redmond, Washington, USA) that is used hospital-wide. All participants perform BLS according to the current algorithm for in-hospital BLS, including defibrillation with the AED, on an ALS manikin. The participants are continuously assessed, and the training is considered successful when the attendee is able to perform BLS, including safe defibrillation with the AED according to the ERC standards. The training programme has been repeated annually since 2008, the first year in which all nursing personnel in the hospital were trained.

2.3. Emergency management infrastructure

Seventy AEDs have been distributed throughout the university hospital campus in the years 2006 and 2007. All manual defibrillators have been replaced by AEDs except for operating rooms, intermediate/intensive care wards, post-anaesthesia care units, the emergency department, and the emergency team. From any location on campus, an AED can be accessed within 60–90 s. Cardiac arrest flow charts, which contain information on the location of the closest accessible AED and emergency box, were placed in every ward office.

The hospital switchboard is available via a campus-wide emergency telephone number. As part of the project, a digital alarm and a communications server (DACS, Siemens, Germany) has been installed to call the emergency team. When an emergency call is received, the time is documented, and a voice message is generated by the DACS system. The DACS calls the emergency team doctor and nurse on their cellular phones. As each team member answers the call, he or she receives the voice message with details regarding the location of the emergency. After receiving the message, the respondent confirms the alarm by pressing "1", thereby generating another time stamp in the system. When the team member is unavailable (for example, because of another emergency), the call can be rejected by pressing "0". In this case, the DACS system sends the alarm to a second-line team member. Four anaesthesiologists and three nurses are on call concurrently and are theoretically available to respond to emergencies. If none of the on-call personnel are able to respond to the call, it is forwarded to the intensive care unit. The system clocks for the alarm server and all AEDs are synchronized to ensure that the time between the emergency call and the first rhythm/first shock can be calculated.

2.4. Patient enrolment

All emergency calls for in-hospital cardiac arrest that occurred in standard care wards between January 1, 2008 and December 31, 2012 were included in the study. Cardiac arrests that occurred in intermediate/intensive care wards, in the emergency department, or in the operating room were excluded because ALS-trained personnel are usually available in those areas. Furthermore, the departments of internal medicine and paediatrics were also excluded because they have their own cardiac arrest teams.

2.5. Data acquisition

After each emergency call and DACS alarm, the hospital switchboard personnel sent an email to the resuscitation training officer, who was also responsible for collecting the data. In addition to the patient's data (i.e., age, gender, initial cardiac rhythm), the training officer documented AED use and recorded the data (time stamps, duration of use). The time period between the emergency call and the registration of the first rhythm and the time period between the emergency call and the time to the first shock (if indicated) were calculated.

In addition, the quality of BLS was evaluated by determining the chest compression rate (CCR) and the no-flow fraction (NFF) during the first 5 min of the arrest. The chest compressions were identified using thoracic impedance data (Code-Stat software, version 8.0, Physio-Control, Redmond, WA, USA). The AED produces a vertical bar each time a chest compression is identified (Fig. 1). We defined episodes as "no-flow time" when no chest compressions were performed for 1.5 s or more. The NFF was calculated by dividing the no-flow time by the total time without spontaneous circulation. To ensure that every time interval during which no chest compressions were given was considered as no-flow time, the investigators did not rely on the calculation by the software. The investigators determined each time span (consisting of chest compressions or no chest compressions) manually. For each case, the mean chest compression rate was calculated.

2.6. Statistical analysis

Descriptive statistics were calculated using SPSS (Version 20.0, IBM Corporation, Armonk, New York, USA). The NFF data are presented as median and 25‰/75‰. All other data are presented as means ± standard deviations (SD). To calculate the differences in the parameter outcomes, we clustered the data from each year

Table 1
Data for the use of an AED, demographic – and outcome data for patients with cardiac arrest given as ROSC and discharge from hospital.

Year	2008	2009	2010	2011	2012
Cardiac arrests	20	21	17	36	25
Female	4 (20%)[a]	7 (33%)	5 (29%)	13 (36%)	9 (36%)
Age	67 ± 19	71 ± 12	68 ± 10	72 ± 12	67 ± 15
AED attached	9 (45%)	9 (43%)	10 (59%)	23 (64%)	14 (56%)
Average CCR per minute	111 ± 18	121 ± 16	116 ± 24	117 ± 28	115 ± 19
ROSC	8 (40%)[a]	12 (57%)	8 (47%)	26 (72%)	18 (72%)
Discharge	2 (10%)[a]	6 (29%)	3 (18%)	15 (42%)	6 (24%)[a]
ROSC[‡]	28 (48%)[a]			44 (72%)	
Discharge	11 (19%)[a]			21 (35%)[a]	

[a] Missing values for age and gender (8 patients), for ROSC (4 patients), and for hospital discharge (3 patients) in 2008. Discharge (one patient) in 2012.
[‡] *P*-value < 0.05.

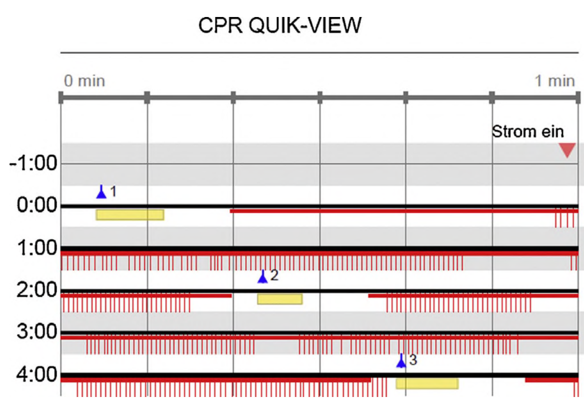

Fig. 1. Automated external defibrillator (AED) protocol printout (Code-Stat 8.0 software) depicting a five-min period. Each vertical bar represents one chest compression. “Strom ein” indicates when the AED was switched on, and the yellow horizontal bars illustrate the rhythm analysis. The numbers on the left side represent the minutes after switching on the defibrillator.

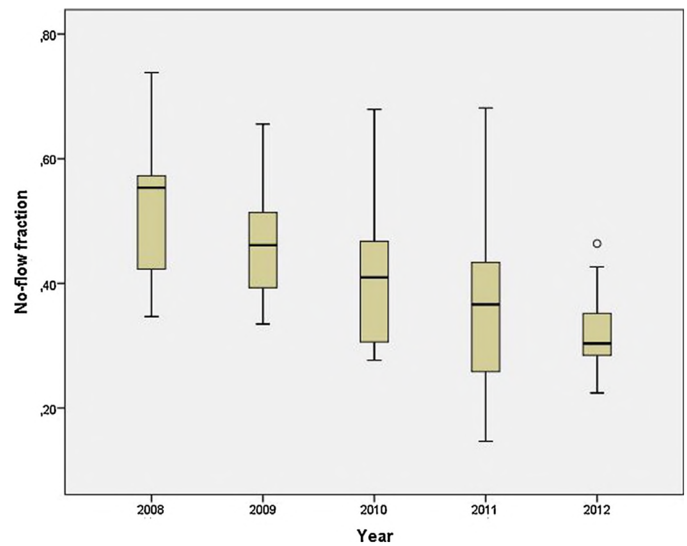

Fig. 2. No-flow fraction during the five year study period, $P = 0.003$.

in the study period. The data for each year were compared using a single-factor analysis of variance (ANOVA). For better depiction of the development of quartiles over time, a boxplot was considered most appropriate. Proportions of independent samples (ROSC and survival rates before and after the implementation of the 2010 guidelines; ROSC/survival for cases with and without the use of an AED) were compared using the chi-squared test. The results were considered statistically significant at $P < 0.05$.

3. Results

Between January 1, 2008 and December 31, 2012, the emergency team responded to 119 calls related to cardiac arrest. The incidence of cardiac arrest was 0.68 per 1000 hospital admissions. The majority of patients who experienced in-hospital cardiac arrest were male and between the ages of 66 and 72 years. The ROSC rate was 40% (8 out of 20) in 2008 and 72% (26 out of 36) in 2012. However, the annual increase did not reach statistical significance. In addition, the hospital discharge rate did not change from year to year during the study period (Table 1). However, by combining the cases of cardiac arrest before and after the introduction of the new guidelines (at the end of 2010), the ROSC rate increased, but the hospital discharge rate did not (Table 1).

For each year of the study period (2008, 2009, 2010, 2011, and 2012), a total of 1454, 1466, 1487, 1432, and 1388 participants, respectively, participated in the training.

An AED was attached to 65 patients of the 119 patients with cardiac arrest.

Of those 65 patients, 57 patients were in cardiac arrest for >1 min, and the AED data were available for analysis. The initial rhythm was shockable in 12% of the patients. While the CCR and the range of CCR remained stable over the study period (Table 1), the NFF decreased over the years (Fig. 2).

The ROSC rate and the proportion of patients who were discharged did not differ significantly between the group of patients who had been attached to an AED and those who had not (Table 2).

4. Discussion

This study demonstrated that the NFF in cardiac resuscitation cases decreased over 5 years after a mandatory annual BLS training for healthcare professionals has been established. An AED was used in 55% of patients without impacting the ROSC and the hospital discharge rate. When we compared the cardiac arrest cases that occurred before and after the implementation of the 2010 guidelines in the present study, we found an increase in the ROSC rate in the patients who were resuscitated in accordance with the newer guidelines.

To our knowledge, the present study is the first to report the NFF during BLS provided by a team (mainly nurses) in standard care wards. Nearly 1500 employees at the authors' institution had

Table 2
The ROSC and discharge rates for patients who had received BLS with or without an AED.

	ROSC *n* (%)	Discharge *n* (%)
AED no	32 (62.7%)	17 (33.3%)
AED yes	40 (62.5%)	15 (23.4%)
Total	72 (62.6%)	32 (27.8%)

participated annually in the BLS training over the 5-years observation period. The results clearly show that the NFF decreased over the five-year study period. However, the proportion of patients who survived until discharge did not change significantly. This result might be attributable to the low number of cases in the study. On the other hand, the effect of the reduction of the NFF during the short period before the cardiac arrest team arrives might be too small to influence the survival rate.

Our study was observational in its nature. Factors other than the annual BLS training (e.g., increased awareness about interruptions in chest compressions after reading the actual recommendations, additional training outside the hospital, the implementation of an AED programme that prompts the BLS provider to perform chest compressions) may have lowered the NFF during the 5-year study period. Furthermore, the fact that the resuscitation training officer analyzed the AED data after each code may have increased the awareness regarding the quality of BLS among our staff.

An AED was only attached in 55% of the patients in cardiac arrest by the BLS caregivers, and thus, NFF data could not be obtained for all of the patients. The likelihood of using an AED might be higher in better-trained personnel, producing a lower NFF and biasing the results. However, when a person is alone with a patient in cardiac arrest, fetching an AED instead of providing chest compressions is inappropriate. Therefore, it was not possible to obtain NFF data in the first minutes of BLS for all patients. To increase the proportion of patients in whom the NFF can be monitored even in the first minutes, implementation of a chest compression pad might be helpful.[10] These devices, which also give feedback on chest compression rate, depth, and recoil, should be even more easily available than the AED. In our study, the CCR was too high and remained unchanged over the five years observation period. Furthermore, we could not observe a reduced range of CCR as an effect of the repetitive BLS training. This is in accordance with other studies. Chung et al. found that senior medical students who had previously undergone CPR training performed chest compressions with a CCR of 118.8 ± 14.3 per minute.[11] Beckers and colleagues were able to demonstrate that one week after BLS training only 20% of the participants performed chest compressions with a rate of 90–110 per minute.[12] Our findings underline the necessity to use feedback devices/metronomes during CPR to maintain chest compressions with the recommended rate.

Only few studies have measured the no-flow fraction during real cardiac resuscitation events. Valenzuela investigated the NFF during prehospital resuscitation in cardiac arrests occurring between 1992 and 2001.[7] Another study investigated the NFF in a prehospital ambulance system in Europe.[8] The only study measuring the NFF during in-hospital resuscitation evaluated the cardiac arrest team, not the BLS providers.[9] All three studies investigated NFF data in real patients, but were done before publication of the 2005 guidelines. Our study investigated cardiac arrests being treated according to the guidelines from 2005 to 2010. Since 2005, the guidelines for resuscitation did focus on high quality chest compressions without unnecessary interruptions and were further strengthened in avoiding no-flow time in 2010. In our hospital, devices that give real-time feedback to the provider in addition to measuring interruptions in chest compressions are unavailable. Using such devices can further reduce the NFF.[11] As the NFF data were recorded using impedance data from the AED, we could not evaluate the NFF until an AED was attached to the patient. This limitation affects all studies investigating the NFF. Regardless of which method is used to determine the NFF – an AED or a chest compression sensor – it has to be placed on the patients′ chest.

Survival after in-hospital resuscitation with and without the use of an AED was similar in this study, which is in accordance with other studies.[13–15] This may be due to an increase in hands-off time by the use of the device, as the type of AED influences the time of interruption needed for rhythm analyses.[16] Although the guidelines clearly demand chest compressions during charging the defibrillator, some AED still demand the BLS caregivers to not touching the patient while charging. Even more alarming is the fact that the analysing software provided by some AED manufacturers calculates the NFF by dividing the no-flow time by the time during which chest compressions are prompted by the AED, not by dividing the no-flow time by the total time without spontaneous circulation. This algorithm for analysis of the NFF reveals false low NFF and would furthermore not be able to unmask differences in the NFF when using different AED. Further research is needed to improve the use of an AED without compromising the NFF.

It is well known that minimizing the interruptions in chest compressions during cardiac resuscitation improves survival after cardiac arrest. Kellum and colleagues established the cardiocerebral resuscitation algorithm for treating out-of-hospital cardiac arrest as early as 2004.[17] The protocol is applied to patients with a suspected cardiac cause of arrest and demands uninterrupted high-quality chest compressions and defibrillation, if necessary, until three shocks are delivered or ROSC is observed. To avoid interruptions, the protocol only allows the insertion of an oropharyngeal airway and the application of oxygen via a non-rebreather mask if a second rescuer is present. In an observational study, the proportion of patients who survived until hospital discharge and the proportion of patients who survived the event in good neurologic condition increased after implementing the new algorithm.[18] The emphasis on minimizing interruptions in chest compressions is one of the most important changes in the 2010 guidelines. A simulator-based study has shown that paramedics who followed the new BLS and ALS protocols produced a significantly lower no-flow fraction compared with paramedics in another group who followed the 2005 guidelines.[19] Many hospitals have established BLS courses for their employees. In Sweden, 45% of the hospitals have trained more than 75% of their health care professionals in BLS.[20] It is known that most BLS trainees perform chest compressions with an adequate compression rate, compression depth and release after the course.[21] However, most educational studies about BLS do not evaluate the NFF, despite its importance. The 2005 guidelines recommended measures such as a compression to ventilation ratio of 30:2 to reduce interruptions during cardiac resuscitation. The 2010 guidelines focused even more intently on reducing the NFF. Establishing BLS training for all healthcare providers at a hospital is expensive. Our hospital management team gave us sufficient (human) resources for an annual BLS training of 1.5 h. Regarding the NFF, we recognize that an NFF of 0.55 (2008) is poor, but it is similar to the results of studies that evaluated *pre-hospital* cardiac resuscitation.[7,8,22] In our study, we found that the NFF continuously decreased each year until it reached 0.3 in 2012. Furthermore, the upper quartile (high NFF) of the 2012 boxplot is still below the lower quartile (low NFF) of the 2008 cases. Even the highest NFF found in the 2012 cases is below the median NFF of the 2008 cases. That result implies that repeated BLS training for hospital ward staff has the potential to reduce the NFF to a level that nearly eliminates non-necessary interruptions during in-hospital CPR. Abella reported an excellent NFF (0.24) achieved by an in-hospital cardiac arrest team. The NFF during BLS with AED use can only be reduced below 0.20 by eliminating the hands-off periods required for bag mask ventilation, using monitor-defibrillator devices to analyze the rhythm or by endotracheal intubation.

The NFF is not routinely determined in out-of-hospital and in-hospital cardiac resuscitation. As recommended by Kramer-Johansen et al., this parameter should be part of uniform data reporting when measuring CPR quality.[23] As it is possible to obtain NFF data during resuscitation using defibrillators or chest compression sensors, this parameter should be integrated in large resuscitation registries. This would enable us to study the effects of single interventions or new algorithms on the NFF.

5. Conclusions

A mandatory annual BLS training programme for all healthcare professionals at our university hospital was associated with a reduction of the no-flow fraction during BLS given by standard care nurses.

Conflict of interest statement

None of the authors has to declare any conflict of interest.

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