Clinical paper

Impact of city police layperson education and equipment with automatic external defibrillators on patient outcome after out of hospital cardiac arrest

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\textbf{ABSTRACT}

Introduction: Out of hospital cardiac arrest (OHCA) occurs frequently and the outcome is often dismal. Early defibrillation saves lives and brain function in OHCA. The Zurich city police (STAPO) forces were instructed and equipped to provide basic life support (BLS) and to use an AED in 2009.

Methods: Retrospective observational study comparing period 1 (P1) 2004–2009 before equipping and training of the STAPO and period 2 (P2) 2010–2015 after the implementation. Patients suffering from OHCA of cardiac or presumed cardiac origin in the city of Zurich undergoing CPR by EMS in P1 (n = 700) and P2 (n = 684) were included. Intervention periods and outcome were compared between the periods. Outcome variables were adjusted for patient age and gender, witnessed status, and defibrillation by the EMS, STAPO, layperson or no defibrillation.

Results: In P2, CPR was started by the STAPO in a median of 8 (IQR 6–9) minutes after the arrest and thus significantly earlier (median 3 min) than by the EMS (p < 0.001). STAPO performed the first defibrillation in a median of 9 (IQR 8–10) minutes and thus significantly earlier (median 6 min) than the EMS (p < 0.001). Outcome improved significantly in P2: proportion of patients with return of spontaneous circulation (ROSC, P2 35.8%, P1 24.0%, OR 1.8, 95% CI 1.4–2.2, p < 0.001), hospital admission (P2 32.2%, P1 21.4%, OR 1.5, 95% CI 1.1–2.0, p < 0.001) and survival to hospital discharge (P2 13.6%, P1 6.9%, OR 2.1, 95% CI 1.5–3.0, p < 0.001). If the patient was firstly defibrillated by the STAPO, ROSC (STAPO 74.4%, adj. OR 2.6, 95% CI 1.3–5.4, p = 0.010) and hospital admission (STAPO 72.1%, adj. OR 2.8, 95% CI 1.4–5.6, p = 0.005) was higher compared to patients firstly defibrillated by the EMS. Survival to hospital discharge (STAPO 30.2%, adj. OR 1.4, 95% CI 0.7–2.9, p = 0.38) was unchanged.

Conclusion: Dispatching BLS trained and AED equipped police forces results in earlier and more successful resuscitation of OHCA victims, leading to higher proportions of patients with ROSC, hospital admission and survival to hospital discharge.

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Introduction

Out of hospital cardiac arrest (OHCA) occurs frequently and the outcome after resuscitation efforts is often dismal. In 20%–40% of these patients a return of spontaneous circulation (ROSC) can be restored, but only 2%–19% of patients with OHCA are discharged alive from the hospital [1,2] Neuronal damage as a result of global cerebral ischemia during cardiac arrest is the main cause of death during the post resuscitation period [3]. In addition, a considerable proportion of surviving patients suffer from permanent impairment of cognitive functions in domains such as attention, memory and executive functioning [4]. The 2015 European Resuscitation Guidelines for Resuscitation highlighted the importance of the initial resuscitation management with focus on the reduction of the time delay from cardiac arrest to start of cardiopulmonary resuscita-

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tation (CPR) and early defibrillation in case of ventricular fibrillation [5].

Since early defibrillation within 3–5 min of collapse saves lives (and brain) in OHCA [5,7], current national and supranational health authorities aim at (lay) persons on scene to carry out basic life support (BLS) and to use automated external defibrillators (AED) prior to emergency medical service (EMS) arrival.

Based on the expectation that the Zurich city police (STypo) reaches the scene faster than the emergency medical service (EMS), the STypo forces were instructed to provide basic life support (BLS) and every patrol car was equipped with an AED and a semi-automatic respirator in 2009. In addition, the closest STypo patrol received an alert in parallel to the EMS by the emergency medical dispatcher (EMD), if a presumed cardia pulmonary arrest was reported.

In this study, the five-year periods before and after the implementation of the STypo as first responders are investigated regarding the proportion of patients with ROSC, hospital admission and survival of OHCA patients in the city of Zurich.

Methods

Ethics

The study was approved by the local ethics committee (KEK ZH 2014-06665) and registered online at ClinicalTrials.gov (NCT02473679). An expert committee of the Federal Department of Home Affairs granted permission to review the patient’s history, if an informed patient consent could not or no longer be obtained.

Data handling was in accordance with the Good Clinical Practise Guidelines and the Declaration of Helsinki for biomedical research. Methods and data analysis adhere to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [8,9].

Setting

The EMS system of the city of Zurich (Schutz und Rettung Zurich, SRZ) is the largest civil emergency service in Switzerland. It operates an average of 35,000 medical emergency missions per year and covers an overall area of 240 km², whereas the City of Zurich has a territory of 92 km². Depending on the time of day, a maximum of 18 teams are on call. The teams consist of two registered paramedics that accomplished a 3-year advanced federal diploma of higher education, in some cases, one of them is a trainee. In the case of a life-threatening emergency, e.g. presumed cardiac arrest, a designated emergency physician, skilled in advanced airway management is brought to the pre-hospital scene in parallel by a separate ambulance car, driven by a senior paramedic, who has several years of experience and functions as the teamleader. The resuscitation is performed according to the advanced life support (ALS) guidelines by the European Resuscitation Council (ERC) [5]. If the patient can be resuscitated and stabilized for transport, the individual is brought to one of the study hospitals with 24 h/7 capability of percutaneous coronary intervention (PCI) and an intensive care unit for further treatment (University Hospital Zurich (USZ) or the Triemli City Hospital).

In December 2009, all forces of the Zurich city police (STypo) on patrol were equipped with AED (FRED Easy, Schiller Medizintechnik, Feldkirchen, Germany) and automated ventilation equipment (Oxylator FR 300, CPR Medical Devices, Markham, Canada) to act as first responders within the EMS system [10]. During the day, 15 teams patrol through the city of Zurich, at least 1 patrol of the Zurich city sea police operates on the water. All individuals were repeatedly taught to provide basic life support and to apply automated external defibrillation per the project “AED Zurich City Police 2009”. Since then, the STypo is dispatched by the EMD in parallel to the EMS as part of the standardised response system, if a cardiac arrest is reported. STypo always starts CPR if indicated and if they reach the patient earlier than the EMS.

Training and costs

All STypo policemen received a 6-h basic life support training to perform chest compressions and ventilation (ratio 30:2) according to the ERC guidelines. Until completion of the study period, a total of 1554 STypo members including 420 new policemen at police school were trained to act as first responders. All police members need to obtain an internal 2-h recertification within a period of two years (theoretical and practical). A total of 2466 re-certifications were granted within the study period. Total costs including equipment and training within the study period amounted 320,000 Swiss Francs (347,000 US$). Annual costs for training and re-certifications in subsequent years add up to 37,000 Swiss Francs (approximately 37,000 US $, taken the currency exchange rate into consideration).

Study design and participants

This is a retrospective observational study. Two five year periods were compared in the study: Period 1 (P1) from May 2004 to December 2009 before equipping and training of the STypo as first responder system and period 2 (P2) from July 2010 to July 2015 after the successful implementation of the process. The STypo implementation phase from January to June 2010 was excluded from data analysis. All patients suffering from OHCA in the city of Zurich, resuscitated by SRZ with OHCA of cardiac or presumed cardiac origin (exclusion if known or likely to have been caused by trauma, submersion, drug overdose, asphyxia, exsanguination, or any other non-cardiac cause as best determined by rescuers), >18 years of age were included to the study. Patients were excluded if the cardiac arrest occurred in the presence of EMS. Moreover, patients who denied the use of their data for scientific reasons and patients with incomplete datasets were not included for data analysis (Fig. 1).

Data collection and variables

The data was collected according to the Utstein criteria [11] for uniform reporting of data from OHCA and entered into the designated research database secuTrial (Interactive Systems GmbH, Berlin, Germany). Patient epidemiologic data (date of birth, gender) was collected from the EMS protocol and patient age was calculated. Location and address of the cardiac arrest was documented to include the cases within the City of Zurich only. Initial cardiac rhythm was documented and classified as shockable and non-shockable. Information about bystander CPR (includes STypo), witnessed arrest, EMS field treatment and presumed origin of arrest was extracted from the mission protocol and the Utstein database. The EMD, EMS and STypo forces utilize the same radio-controlled time measurement throughout the organization. The chronometers of the medical equipment are regularly synchronized to this radio controlled and unified chronometry. Exact time of emergency call and time of arrival on scene (STypo and EMS) were extracted from the automated database of the EMD center. Start time of CPR and time of first defibrillation was extracted from the AED devices, the mission protocol or the Utstein database. All interval times (time to CPR, time to first defibrillation) after EMD alert were calculated. Per the Utstein criteria, return of spontaneous circulation (ROSC) and/or termination of pre-hospital CPR were encoded to the database. ROSC was defined as at least a brief (>30 s) restoration of a spontaneous perfusing rhythm, that provides evidence of more than an occasional gasp, fleeting palpated pulse or arte-
rial waveform according to the Utstein criteria [12]. Only patients with sustained ROSC were transported to the hospital, otherwise CPR was terminated in the field. Data in the Utstein database was prospectively collected and periodically cross checked for validity and integrity. All patients were followed up to determine survival at hospital discharge.

Endpoints

Primary: Proportion of patients with return of spontaneous circulation, of hospital admission and of survival to hospital discharge of all included patients with OHCA.

Secondary: Time intervals from emergency call to first CPR and defibrillation.

Bias

All pre-hospital resuscitations performed by SRZ were filed per the Utstein criteria directly after every mission. Multiple cross checks have been performed to ensure the data quality. The Utstein database entries were mandatory for all missions with a national advisory committee for aeronautics (NACA) score of VI and VII and had to be performed directly after the mission which limits the influence of recall and selection bias.

Statistical methods

A sample size was determined based on estimations of sample sizes in other investigations. A statistical power analysis was performed on an improvement of the survival rate (hospital discharge) from 8.2 to 12% for first response treated patients. A statistically significant result (alpha of 0.05, power of 80%) was expected by inclusion of approximately 1000 patients in each period. Upon this estimation, the number of years in the two periods necessary to include this patient number were calculated and the maximum number of years available in this before and after design was defined.

Categorical data was reported as frequency and percent, whereas numeric data was presented as median and 25th and 75th percentile (IQR). The chi-square and Fisher’s exact test were used to compare categorical data. The Mann-Whitney test was used to compare numerical data. Multiple logistic regression analyses were performed for ROSC, hospital admission and survival to discharge. Explanatory variables were the two periods, patient age and gender, bystander witnessed status, and defibrillation by the EMS, STAP, layperson or no defibrillation. Odds ratios (OR), 95% confidence intervals (CI) and p-values were calculated. The model fit was assessed using the Hosmer-Lemeshow test. All statistical analyses were performed by IBM SPSS Statistics 22 (IBM Corp., Armonk, NY, USA). A p-value of ≤0.01 was considered statistically significant due to the large number of statistical tests in this analysis.

Results

In total 1393 patients suffering from OHCA of cardiac or presumed cardiac origin, treated in the City of Zurich in P1 (n = 709) and P2 (n = 684) were included into this analysis (Fig. 1). Patient age, gender and proportion of witnessed arrest were not different.
Table 1
Patient and mission characteristics comparing period 1 (P1: 2004–2009) and period 2 (P2: 2010–2015). Data is presented as absolute numbers and %, or median and quartiles. Bystander CPR includes STAPAO. CPR: cardiopulmonary resuscitation; EMS: emergency medical services; STAPAO: Zurich city police.

<table>
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<tr>
<td>Age median years [Q1;Q3]</td>
<td>72 [59-81]</td>
<td>73 [60-82]</td>
<td>0.19</td>
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<tr>
<td>Male gender n (%)</td>
<td>516 (72.8%)</td>
<td>483 (70.6%)</td>
<td>0.37</td>
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<tr>
<td>Witnessed arrest n (%)</td>
<td>460 (64.9%)</td>
<td>452 (66.1%)</td>
<td>0.65</td>
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<tr>
<td>Bystander CPR n (%)</td>
<td>317 (44.7%)</td>
<td>400 (58.8%)</td>
<td>&lt;0.001</td>
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<tr>
<td>CPR by STAPAO n (%)</td>
<td>0%</td>
<td>205 (30.0%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Initial defibrillation n (%)</td>
<td>339 (47.8%)</td>
<td>252 (36.8%)</td>
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<tr>
<td>EMS</td>
<td>0%</td>
<td>43 (6.3%)</td>
<td>0.67</td>
</tr>
<tr>
<td>STAPAO</td>
<td>0%</td>
<td>19 (2.8%)</td>
<td></td>
</tr>
<tr>
<td>Layperson</td>
<td>370 (52.2%)</td>
<td>370 (54.1%)</td>
<td></td>
</tr>
<tr>
<td>Initial cardiac rhythm (%)</td>
<td>518 (73.1%)</td>
<td>402 (71.5%)</td>
<td></td>
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<tr>
<td>Non-Shockable</td>
<td>191 (26.9%)</td>
<td>192 (28.5%)</td>
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Probability of survival to hospital discharge was not significantly increased, if the patient was firstly defibrillated by the STAPAO (30.2%, adj. OR 1.4, 95% CI 0.7–2.9, p = 0.38) compared to patients firstly defibrillated by the EMS (P1 13.0%, P2 19.8%, Table 2C).

Discussion

The implementation of a professional first responder system by means of the Zurich city police (STAPAO) was associated with improved outcome of patients with OHCA. The median times from cardiac arrest to the start of CPR and to the first defibrillation were both significantly reduced due to a significantly earlier intervention by the STAPAO compared to the EMS and resulted in a significantly higher proportion of patients with ROSC, an increased percentage of hospital admission and a significantly better survival to hospital discharge. Apart from the independent effect of STAPAO defibrillation, outcome may have improved in the latter period because of additional or secular effects which are not investigated by the study due to its design (targeted temperature control, percutaneous coronary intervention protocols, advanced life support guidelines and public teaching programmes).

Survival from out of hospital cardiac arrest is critically dependent upon response time [13]. Factors predicting survival after OHCA include witnessed arrest by a bystander, bystander CPR and shockable rhythm [14]. Compared to bystander resuscitation alone, the use of an AED doubles survival after OHCA [15]. In our data analysis the proportion of a shockable rhythms remained unchanged, whereas other studies showed a decline over the last years [16,17]. As a rationale, early CPR and AED use after the collapse by bystanders may prevent the degradation of a rapid ventricular dysrhythmia into an asystole [18], as very early documentation of the cardiac rhythm show shockable rhythms in up to 76% of the patients [7,15]. One minute of delay to defibrillation reduces the probability of survival until hospital discharge without CPR by 10–12% and with CPR by 3–4% per min, which is supported by our study data [19,20]. Multiple approaches including equipment of public places with AEDs, telephone guided resuscitation and education of first responders were initiated over the last decade [21]. AEDs located in public strategic locations are safe and efficacious [22]. However, a large proportion of OHCA does not occur in public locations but at home [23,24]. At home the frequency of bystander CPR is low and patient outcomes is worse compared to public locations [25]. Therefore it is more efficacious to train a professional group on patrol such as the STAPAO to act as first responders.

The AED rhythm-detection algorithms are highly sensitive and specific [26], and AEDs can be safely used by trained individuals from outside the health care sector [27] with a positive correlation of this training with performance during a real resuscitation.


Programs to equip policemen with AEDs have been introduced [29]. In a systematic review on police AED programmes, two studies showed a significant survival benefit [16,30]. Two recent studies showed the significant impact of first responder CPR and defibrillation on ROSC, survival and favourable neurologic outcome [31,32]. Overall proportion of patients with ROSC after the implementation of the police AED program in Zurich is comparable to the data reported by Kitamura and colleagues [32]. Survival to hospital admission in Zurich was higher (32.2%) than reported in a systematic review and meta-analysis by Sisson and colleagues (23.8%) in a collective of more than 140,000 patients with presumed OHCA of cardiac etiology [14]. Proportion of patients surviving to
| Table 2 | Multivariable logistic regression for ROSC, Hospital admission and survival to discharge. Explanatory variables are the two periods, patient age and gender, witnessed status, and defibrillation by the EMS, STAP0, layperson or no defibrillation. Data is presented as univariate and adjusted OR, 95% CI and p-values. ROSC: return of spontaneous circulation, OR: odds ratio, CI: confidence interval, STAP0: Zurich city police, EMS: emergency medical service. |
|---|---|---|---|
| **A: ROSC** | **Univariate** | **Adjusted** |
| | OR (95% CI) | p-value | OR (95% CI) | p-value |
| Period 2 | 1.8 (1.4–2.2) | <0.001 | 1.8 (1.4–2.3) | <0.001 |
| Age (years) | 0.99 (0.98–0.99) | <0.001 | 0.99 (0.98–1.00) | 0.807 |
| Male gender | 1.2 (0.9–1.6) | 0.18 | 0.8 (0.6–1.0) | 0.07 |
| Witnessed arrest | 3.5 (2.6–4.7) | <0.001 | 2.3 (1.7–3.2) | <0.001 |
| Initial defibrillation | | | | |
| EMS | Reference | | Reference | 0.010 |
| STAP0 | 3.9 (1.9–7.9) | <0.001 | 2.8 (1.3–5.4) | 0.008 |
| Layperson | 11.4 (2.6–49.6) | 0.001 | 7.5 (1.7–33.6) | 0.001 |
| No defibrillation | 0.2 (0.2–0.3) | <0.001 | 0.3 (0.2–0.4) | <0.001 |
| **B: Hospital admission** | **Univariate** | **Adjusted** |
| | OR (95% CI) | p-value | OR (95% CI) | p-value |
| Period 2 | 1.7 (1.4–2.2) | <0.001 | 1.7 (1.3–2.2) | <0.001 |
| Age (years) | 0.98 (0.97–0.99) | <0.001 | 0.98 (0.97–0.99) | <0.001 |
| Male gender | 1.4 (1.1–1.8) | 0.02 | 0.9 (0.6–1.2) | 0.39 |
| Witnessed arrest | 4.4 (3.2–6.2) | <0.001 | 3.1 (2.3–4.4) | <0.001 |
| Initial defibrillation | | | | |
| EMS | Reference | | Reference | 0.005 |
| STAP0 | 4.1 (2.1–8.2) | <0.001 | 2.8 (1.4–5.6) | 0.003 |
| Layperson | 13.6 (3.1–59.5) | 0.001 | 9.6 (2.1–43.8) | <0.001 |
| No defibrillation | 0.2 (0.2–0.3) | <0.001 | 0.3 (0.2–0.4) | <0.001 |
| **C: Survival to hospital discharge** | **Univariate** | **Adjusted** |
| | OR (95% CI) | p-value | OR (95% CI) | p-value |
| Period 2 | 2.1 (1.5–3.0) | <0.001 | 2.0 (1.3–2.9) | 0.001 |
| Age (years) | 0.97 (0.96–0.98) | <0.001 | 0.97 (0.96–0.98) | <0.001 |
| Male gender | 2.2 (1.4–3.5) | 0.001 | 1.3 (0.8–2.2) | 0.29 |
| Witnessed arrest | 0.2 (3.3–11.5) | <0.001 | 3.5 (1.8–6.8) | <0.001 |
| Initial defibrillation | | | | |
| EMS | Reference | | Reference | 0.38 |
| STAP0 | 2.3 (1.2–4.6) | 0.018 | 1.4 (0.7–2.9) | 0.001 |
| Layperson | 10.8 (5.4–61.1) | <0.001 | 15.4 (4.6–51.1) | <0.001 |
| No defibrillation | 0.1 (0.1–0.2) | <0.001 | 0.2 (0.1–0.4) | <0.001 |

Hospital discharge vary according to the investigated setting and study patient selection, but the absolute numbers presented in this study are in accordance with the most recently published literature [32–34]. As the STAP0 is on patrol, distributed through the city of Zurich, they may be closer to a potential victim of OHCA than the EMS. In general, the EMS starts the mission from three designated starting points and this might explain the longer overall intervention time. After correction for patient age, gender and proportion of witnessed OHCA, there is no evidence for a selection bias in favour of the STAP0 police forces.

The requested intervention period obliged by Swiss authorities is to be below 15 min in 90% of the missions. Although intervention time itself is not shown in the study data, a median start of CPR in 11 min after the arrest, implies that the intervention time is even shorter and well below the requested threshold.

Hospital post-resuscitation care of OHCA patients also changed in the last decade. Therapeutic hypo- or normothermia [35,36] and primary coronary revascularization protocols were implemented with a significant impact on outcome of patients hospitalised after OHCA [5,37]. Therefore the significant higher proportion of patients surviving until hospital discharge may also be partly attributable to in hospital treatment changes [35,36]. However, an absolute prerequisite for such modern treatment pathways to become efficacious is the admission alive of resuscitated patients. Concerning that aspect, our program is particularly efficacious since hospital admittance alive increases from 21.4% to 32.2% in P2 and was exceptionally high in patients firstly defibrillated by the STAP0 (71.4%).

Out of hospital interventions like resuscitation algorithms, chest compression, ventilation ratio and shock delivery sequences have also changed over time and have proven a significant impact on the outcome [5,38]. In the multivariable analysis, these changes might be expressed by the independent significant effect, depicted by the adjusted OR for period 2. However, the significant improvement of patient outcome was not only evident between the two periods but also in patients initially resuscitated and defibrillated by the Zurich City Police prior to arrival of the EMS. These results support the use of a professional group such as the STAP0 as a well-trained first responder on patrol to improve patient outcome after OHCA.

The study has limitations as it was a retrospective analysis. The data quality is high as all patients resuscitated (per the Utstein database) could be included. The data was crosschecked in multiple instances. In addition, the results apply to the area of Zurich but may not be generalised to other cities or terrains. Only associations may be derived from this study design and causal relationships may not be drawn. During the study period, multiple treatment changes occurred which may not be fully rectifiable by statistical models (e.g. hands-only bystander CPR). STAP0 forces were coded as "bystander" according to the Utstein criteria. Consequently bystander CPR could not be implemented in the logistic regression model. Even if non-STAP0 bystander CPR increased the likelihood of a shockable-rhythm as discussed earlier, the independent effect of defibrillation by the STAP0 remains significantly associated with increased probability for ROSC and hospital admission (Table 2). We chose a conservative p-value of 0.01 for statistical
significance due to the high number of statistical tests used in this study.

Conclusion

Training of a police force in BLS and equipping the patrol cars with a AED as a first responder system results in earlier and more successful resuscitation of victims of out of hospital cardiac arrest with a higher proportion of patients with ROSC, an increased percentage of hospital admission and a better survival to hospital discharge.

Conflicts of interest

Philipp Stein, Werner Baulig, Stefan Müller, Burkhardt Seifert and Gabriela H. Spahn have no conflicts of interest.

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