Resuscitation 120 (2017) 63–70

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Quality of bystander cardiopulmonary resuscitation during real-life out-of-hospital cardiac arrest☆

Tore Gyllenborg[a,*], Asger Granfeldt[b], Freddy Lippert[c], Ingunn Skogstad Riddervold[d], Fredrik Folke[c,e]

[a] Department of Medicine, Nykøbing Falster Hospital, Nykøbing Falster, Denmark
[b] Department of Anaesthesiology, Aarhus University Hospital, Aarhus, Denmark
[c] Emergency Medical Services Copenhagen, University of Copenhagen, Denmark
[d] Prehospital Emergency Medical Services: Central Region Denmark, Denmark
[e] Department of Cardiology, Copenhagen University Hospital, Gentofte, Denmark

ARTICLE INFO

Article history:
Received 1 July 2017
Received in revised form 27 August 2017
Accepted 9 September 2017

Keywords:
Cardiac arrest
Cardiopulmonary resuscitation
Bystander
Quality

ABSTRACT

Background: Cardiopulmonary resuscitation (CPR) can increase survival in out-of-hospital cardiac arrest (OHCA). However, little is known about bystander CPR quality in real-life OHCA.
Aim: To describe bystander CPR quality based on automated external defibrillator (AED) CPR process data during OHCA and compare it with the European Resuscitation Council 2010 and 2015 Guidelines.
Methods: We included OHCA cases from the Capital Region, Denmark, (2012–2016) where a Zoll AED was used before ambulance arrival. For cases with at least one minute of continuous data, the initial 10 min of CPR data were analysed for compression rate, depth, fraction and compressions delivered for each minute of CPR. Data are presented as median [25th;75th percentile].
Results: We included 136 cases. Bystander median compression rate was 101 min^{-1} [94;113], compression depth was 4.8 cm [3.9;5.8] and compressions per minute were 62 [48;73]. Of all cases, the median compression rate was 100–120 min^{-1} in 42%, compression depth was 5–6 cm in 26%, compression fraction ≥ 60% in 51% and compressions delivered per minute exceeded 60 in 54%. In a minute-to-minute analysis, we found no evidence of deterioration in CPR quality over time.

The median peri-shock pause was 27 s [23;31] and the pre-shock pause was 19 s [17;22].
Conclusions: The median CPR performed by bystanders using AEDs with audio-feedback in OHCA was within guideline recommendations without deterioration over time. Compression depth had poorer quality compared with other parameters. To improve bystander CPR quality, focus should be on proper compression depth and minimizing pauses.

Introduction

Out-of-hospital cardiac arrest (OHCA) is a leading cause of death in Europe. Early cardiopulmonary resuscitation (CPR) to increase survival is emphasized in international resuscitation guidelines [1–3]. Although early initiation of bystander CPR before arrival of the emergency medical services (EMS) increases both short- and long-term OHCA survival [4–6], the effect depends on the CPR quality [7,8].

Studies based on EMS treated OHCAs have demonstrated that few interruptions, compression rates of 100–120 min^{-1} and compression depths of 5–6 cm are associated with improved survival; this is endorsed by the 2010 and 2015 European Resuscitation Council (ERC) Guidelines [2,9–14]. Several studies on EMS CPR quality report varying CPR performances often not adhering to guidelines [10,12,15–19]. Bystander CPR quality is difficult to study in real-life OHCAs; hence the lack of studies on this subject [13,20–23]. Moreover, the studies published on this topic are small, include only trained laypersons, or lack data on chest compression depth [13,20–23]. The introduction of public automated external defibrillators (AEDs) for bystander use gives a novel opportunity of objectively quantifying bystander CPR quality, including compression depth [24,25].

☆ A Spanish translated version of the abstract of this article appears as Appendix in the final online version at http://dx.doi.org/10.1016/j.resuscitation.2017.09.006.

* Corresponding author at: Department of Medicine, Nykøbing Falster Hospital, Fjordvej 15, 4800 Nykøbing Falster, Denmark.
E-mail address: toregyllenborg@hotmail.dk (T. Gyllenborg).

http://dx.doi.org/10.1016/j.resuscitation.2017.09.006
0300-9572/

The aim of this study was to describe the quality of bystander CPR based on AED information from real-time CPR process data during OHCA and compare it with the 2010 and 2015 ERC guidelines.

Methods

Study design, setting and AEDs

This observational study was undertaken in the Capital Region of Denmark (Population 1.8 million area 2561 km^2, rural and urban) during 1 January 2012–1 May 2016.

In 2007, a network of public AEDs was established in Denmark by the Danish foundation TrygFonden. The network requires voluntary registration of public AEDs on a webpage accessible to laypersons [26]. From 2012 to May 2016 the registered AEDs nationwide rose from 5431 to 13,702 [26].

From May 2011, the Capital Region of Denmark had a protocol instructing the emergency medical dispatcher on guiding bystanders calling 1-1-2 in performing CPR in the event of an OHCA. The emergency medical dispatcher also identified accessible AEDs within a radius of 1.5 min of the arrest location. If more than one bystander is present, the dispatcher can guide others to the nearest AED. On EMS arrival, the public AED is replaced with an EMS defibrillator.

In 2011, systematic extraction began of public AED data from OHCAs in the Capital Region of Denmark. If a public AED was applied in an OHCA before EMS arrival, the EMS responders collected the used AED after replacing it with the EMS defibrillator. After delivering the patient to hospital care, the AED was sent by taxi to the Emergency Medical Dispatch Centre, and AED data was downloaded immediately by specially trained personnel. After download, the AED was returned to its owner [27,28].

Study population and data collection

We included all available cases of OHCA in the Capital Region of Denmark where a public Zoll AED Plus and Pro had been used for bystander CPR before EMS arrival.

The Zoll AED Plus and Pro register real-time CPR data (thoracic impedance, delivered compressions, depth, pauses and shock advised) through an accelerometer pad between the rescuer's hand and the patient's sternum and provides real-time audio-prompted CPR feedback [29]. We included all cases with accelerometer waveform deflections indicating chest compressions.

Cases were excluded for the following reasons: 1) no chest compression or electrocardiogram (ECG) data in the AED record, 2) <1 continuous full minute of both accelerometer compression data and continuous ECG waveform data on record, 3) no CPR initiated on record, 4) the duration of resuscitation from first therapeutic intervention (defined below) to last chest compression on record was shorter than one full minute. Excluded cases were reviewed by two investigators (TG and FF) for consensus.

Measurements

Data were analysed using RescueNet™ Code Review 5.71 (Zoll Medical Corp, Chelmsford, MA, USA), which calculates mean compression rate, depth, fraction and number of compressions delivered for each minute of CPR from a manually set starting point, defined as the first therapeutic intervention (first rhythm analysis or chest compression) following AED power on. CPR analysis end was defined as the last chest compression in the CPR recording; however, if the case had a duration over 10 min, only the initial 10 min were analysed.

Data analysis was done according to the uniform reporting of measured CPR quality by Kramer-Johansen et al. and previous studies on CPR quality [11,15,30,31].

Compression rate was defined as the actual compression rate during each set of uninterrupted compressions (≥2 consecutive compressions). Pauses were defined as intervals >2 s without compressions [15]. Compressions too shallow for software detection without a rhythmical pattern of uninterrupted chest compressions were classified as a pause. If compressions were too shallow to be recorded but had rhythmical deflection in thoracic impedance suggesting compressions, compression rate was calculated manually and the compression depth censored.

Compression fraction was defined as the fraction of a period with compressions. Delivered compressions were defined as the actual number of chest compressions delivered within one-minute intervals.

For each case, the overall median for each compression parameter was defined as the median of all compression results for all minutes included in the case. The percentage within ERC range for the case was calculated by dividing the number of minutes with compression parameters within guideline recommendation by the total case length in full minutes. The percentage of OHCA cases within ERC guidelines was calculated for each compression parameter by dividing the number of cases with the compression parameter within guidelines by the total number of cases.

Pre- and post-shock pauses were defined as the interval from the last compression preceding shock until shock delivery and the interval from the shock to the first subsequent compression, respectively. Peri-shock pause was defined as the sum of the pre- and post-shock pause, i.e. the actual interval from the last chest compression before shock delivery to the first chest compression after shock delivery. Prompted peri-shock pauses were defined as the sum of the prompted pre- and post-shock pauses, i.e. the sum of the intervals from AED prompted "Stop CPR" to AED prompted "Press flashing shock button" (prompted pre-shock pause) plus the interval from shock delivery to AED prompted "Start CPR" (prompted post-shock pause) (Fig. 1). Rhythm analysis pauses were divided into shockable and non-shockable rhythms depending on whether a shock was recommended by the AED.

Quality measures

Quality CPR was defined as adherence to 2010 and 2015 ERC Guidelines: compression rate 100–120 min^{-1}, compression depth 5–6 cm, compressions delivered ≥60 per minute and minimizing pauses. Compression fraction was not addressed specifically in the 2010 guidelines; however, a compression fraction ≥60% is recommended in the 2015 guidelines.

Statistics

Statistical calculations were performed for the initial 10 min of registered CPR because of the few cases with data beyond 10 min. For each case, compression rate, compression depth, compression fraction and compressions delivered were calculated as a median over the initial 10 min of resuscitation. Data are presented as median [25;75 percentile].

In six cases, the initial minute consisted of a rhythm analysis followed by a pause. Therefore, compression depth and rate could not be calculated, explaining why only 126 cases were analysed for compression rate and depth in the initial minute (top figures) compared with 132 cases for compression fraction and compressions delivered (bottom figures).

For development over time, data were analysed using mixed model statistics with Kenward-Roger approximation for missing covariates. For compression fraction and compressions delivered,