Resuscitation 83 (2012) 1319–1323

Contents lists available at SciVerse ScienceDirect

Resuscitation

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

Clinical paper

Excessive chest compression rate is associated with insufficient compression depth in prehospital cardiac arrest[☆]

Koenraad G. Monsieurs[a,b,*], Melissa De Regge[c], Kristof Vansteelandt[d], Jeroen De Smet[e], Emmanuel Annaert[e], Sabine Lemoyne[e], Alain F. Kalmar[f], Paul A. Calle[b]

[a] *Emergency Department, Antwerp University Hospital, Wilrijkstraat 10, B-2650 Edegem, Belgium*
[b] *Faculty of Medicine and Health Sciences, Ghent University, Sint-Pietersnieuwstraat 25, B-9000 Ghent, Belgium*
[c] *Department of Management, Innovation and Entrepreneurship, Ghent University, Tweekerkenstraat 2, B-9000 Ghent, Belgium*
[d] *University Psychiatric Centre, Catholic University Leuven–Campus Kortenberg, Leuvensesteenweg 517, B-3070 Kortenberg, Belgium*
[e] *Emergency Department, Ghent University Hospital, De Pintelaan 185, B-9000 Ghent, Belgium*
[f] *Department of Anaesthesia, University of Groningen, University Medical Centre Groningen, Hanzeplein 1, Postbus 30 001, 9700 RB Groningen, The Netherlands*

ARTICLE INFO

Article history:
Received 14 February 2012
Received in revised form 28 June 2012
Accepted 14 July 2012

Keywords:
Cardiac arrest
Cardiopulmonary resuscitation (CPR)
Chest compressions
Compression depth
Compression rate
Prehospital

ABSTRACT

Background and goal of study: The relationship between chest compression rate and compression depth is unknown. In order to characterise this relationship, we performed an observational study in prehospital cardiac arrest patients. We hypothesised that faster compressions are associated with decreased depth.
Materials and methods: In patients undergoing prehospital cardiopulmonary resuscitation by health care professionals, chest compression rate and depth were recorded using an accelerometer (E-series monitor-defibrillator, Zoll, USA). Compression depth was compared for rates <80/min, 80–120/min and >120/min. A difference in compression depth ≥0.5 cm was considered clinically significant. Mixed models with repeated measurements of chest compression depth and rate (level 1) nested within patients (level 2) were used with compression rate as a continuous and as a categorical predictor of depth. Results are reported as means and standard error (SE).
Results and discussion: One hundred and thirty-three consecutive patients were analysed (213,409 compressions). Of all compressions 2% were <80/min, 62% between 80 and 120/min and 36% >120/min, 36% were <4 cm deep, 45% between 4 and 5 cm, 19% >5 cm. In 77 out of 133 (58%) patients a statistically significant lower depth was observed for rates >120/min compared to rates 80–120/min, in 40 out of 133 (30%) this difference was also clinically significant. The mixed models predicted that the deepest compression (4.5 cm) occurred at a rate of 86/min, with progressively lower compression depths at higher rates. Rates >145/min would result in a depth <4 cm. Predicted compression depth for rates 80–120/min was on average 4.5 cm (SE 0.06) compared to 4.1 cm (SE 0.06) for compressions >120/min (mean difference 0.4 cm, $P < 0.001$). Age and sex of the patient had no additional effect on depth.
Conclusions: This study showed an association between higher compression rates and lower compression depths. Avoiding excessive compression rates may lead to more compressions of sufficient depth.

1. Introduction

Following the International Consensus on Science and Treatment Recommendations on Resuscitation, the European Resuscitation Council (ERC) 2010 Guidelines for Cardiopulmonary Resuscitation (CPR) recommend for rescuers to compress the sternum of an adult victim of cardiac arrest "at least 5 cm (but not more than 6 cm)" at a rate of "at least 100/min (but not more than 120/min)".[1,2] The previous ERC Guidelines (2005) recommended to compress the sternum "4 to 5 cm" at a rate of "about 100/min".[3] The main reason for this change in guidelines are studies showing that deeper compression depth is associated with higher success of defibrillation and a higher chance of admission to hospital.[4,5] Therefore, sufficient compression depth is key to survival. Professional rescuers, however, often do not deliver high quality CPR regarding compression rate and depth.[6–8] The reasons for this are not fully known. Recently, Field et al. found that compression depth decreased from 4.0 cm at 80/min to 3.5 cm at 160/min when health care professionals performed continuous compressions on a manikin.[9] Their results suggest an inverse relationship between compression rate and depth. The latest Consensus on Science and

☆ A Spanish translated version of the summary of this article appears as Appendix in the final online version at http://dx.doi.org/10.1016/j.resuscitation.2012.07.015.

* Corresponding author at: Emergency Department, Antwerp University Hospital, Wilrijkstraat 10, B-2650 Edegem, Belgium. Tel.: +32 38215679.
E-mail address: koen.monsieurs@uza.be (K.G. Monsieurs).

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http://dx.doi.org/10.1016/j.resuscitation.2012.07.015

Treatment Recommendations on Cardiopulmonary Resuscitation (2010) recognised the knowledge gaps in the relationship between compression rate and depth.[1] In order to characterise the relationship between compression rate and depth, we performed an observational study in prehospital cardiac arrest patients.

2. Methods

2.1. Aim of the study

The aim of the study was to quantify the relationship between compression rate and compression depth during prehospital cardiac arrest by professional rescuers. Our hypothesis was that higher compression rate is associated with lower compression depth.

2.2. Procedure

This observational study was conducted in the Ghent area with a population of approximately 150,000 inhabitants. From March 2009 until October 2010 all prehospital resuscitation events attended by the physician-staffed second tier ambulance of Ghent University Hospital were registered with a Zoll E-series defibrillator and CPR-D Padz® (Zoll, Chelmsford, USA) The ambulance was staffed by an emergency medical technician, a nurse specialised in emergency medicine and a resident or consultant in emergency medicine or anaesthesiology. ERC Guidelines 2005 were followed. All patients were resuscitated on a solid surface. In most cases, a first tier ambulance staffed with two emergency medical technicians would also be at the scene, ensuring chest compression during advanced life support. The Ethics Committee of Ghent University Hospital approved the study and allowed deferred consent.

2.3. Materials

Immediately after arrival of the second tier ambulance, CPR-D Padz® were placed on the victim's chest according to the manufacturer's instructions. The CPR-D Padz® incorporate an accelerometer measuring displacement of the chest during compressions. The defibrillator provided real-time audible and visual feedback of compression quality (rate and depth). A sliding window of five compressions was analysed. If the recorded depth failed to achieve 4 cm in three of the five compressions, the unit periodically generated a voice prompt saying, "push harder" When the four cm threshold was achieved in two of three compressions, the "good compression" voice prompt was played. According to the manufacturer, the accuracy of the compression depth measurement was ±0.6 cm 95% of the time.[10] Compression rates below 80/min resulted in the automatic activation of a metronome sounding at a rate of 100/min. In addition to the audible feedback, visual feedback was provided consisting of a display showing a vertical bar for every compression indicating depth, plus a horizontal bar indicating overall good compression depth and rate when full. As an inherent feature of the Zoll software, potentially excessive compression depth or rate was not corrected.

2.4. Data collection

For every compression, the defibrillator automatically stored depth, rate and a time stamp on a memory card that was uploaded after the event with RescueNet™ Code Review, Enterprise Edition version 5.12 (Zoll, Chelmsford, USA). The resulting files were exported in a text format and imported into Excel for Windows. For each compression the rate was then calculated using the time interval to its preceding compression. Therefore the first compression of a series of compressions was not taken into account. Data on sex of the patient, age, presenting rhythm and return of spontaneous circulation were extracted from the ambulance run sheets.

Table 1
Demographics. SD: standard deviation; VF: ventricular fibrillation; VT: ventricular tachycardia; PEA: pulseless electrical activity; ROSC: return of spontaneous circulation. Values as mean (SD) or count (percentage).

	Included patients $n = 133$ (83%)	Excluded patients $n = 28$ (17%)	*P*-values
Age (years)	67 (16)	61 (18)	0.13
Female	41 (31%)	6 (21%)	0.32
Initial rhythm			0.32
Asystole	93 (70%)	17 (61%)	
VF/VT	18 (14%)	4 (14%)	
PEA	22 (16%)	7 (25%)	
ROSC	56 (42%)	15 (53%)	0.27

2.5. Inclusion and exclusion criteria

Inclusion criteria for analysis were: presence of informed consent and age of 18 years or more. Exclusion criteria for analysis were the absence of a data file (accelerometer not applied or a technical problem), an incomplete data file or resuscitation performed in a driving ambulance generating random compression data.

2.6. Statistical analysis

To examine the relationship between chest compression depth and rate, a mixed model was used with repeated measurements of chest compression depth and rate (level 1) nested within patients (level 2). Multilevel models have several advantages: they use all available data, can properly account for correlation between repeated measurements on the same subject, can handle missing data adequately, and have great flexibility to model time effects.[11–13] Different specifications of the variance-covariance structure were considered and model selection was based on the procedures described in Verbeke and Molenberghs,[11] information criteria (Akaike Information Criterion, Bayes Information Criterion) and interpretability of the results. First, a mixed model was estimated with chest compression depth as criterion, fixed linear and quadratic effects for chest compression rate as time-varying predictors, age and sex as time-invariant covariates, and random intercepts and random linear (subject-specific) slopes as random effects. For inference on the fixed effects, the Kenward–Roger denominator degrees of freedom method was used. This model (without the terms that were not significant) was used to make compression depth estimates (and 95% confidence intervals) at particular values of compression rate. In addition, a similar mixed model was estimated but with compression rates divided into a categorical variable comprised of three categories: <80/min, 80–120/min, and >120/min. *P*-Values are reported as two-tailed. A $P \leq 0.05$ was considered significant. Statistical analysis was performed using Statistical Analysis Software (SAS) (version 9.2, Cary, NC, USA).

3. Results

3.1. Demographics

Demographic data are shown in Table 1.

3.2. Compression data

Out of the 161 eligible patients, 133 patients could be analysed. Each subject had on average 1605 (SD 1068, min 86, max 5108)