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Clinical paper

Minimizing pre-shock chest compression pauses in a cardiopulmonary resuscitation cycle by performing an earlier rhythm analysis☆

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ABSTRACT

Background: Guidelines recommend 2 min of CPR after defibrillation attempts followed by ECG analysis during chest compression pause. This pause may reduce the likelihood of return of spontaneous circulation (ROSC) and survival. We have evaluated the possibility of analysing the rhythm earlier in the CPR cycle in an attempt to replace immediate pre-shock rhythm analysis.

Methods and results: The randomized Circulation Improving Resuscitation Care (CIRC) trial included patients with out of hospital cardiac arrest of presumed cardiac aetiology. Defibrillator data were used to categorize ECG rhythms as shockable or non-shockable 1 min post-shock and immediately before next shock. ROSC was determined from end-tidal CO_2, transthoracic impedance (TTI), and patient records. TTI was used to identify chest compressions. Artefact free ECGs were categorized during periods without chest compressions. Episodes without ECG or TTI data or with undeterminable ECG rhythm were excluded. Data were analyzed using descriptive statistics.

Of 1657 patients who received 3409 analysable shocks, the rhythm was shockable in 1529 (44.9%) cases 1 min post-shock, 13 (0.9%) of which were no longer shockable immediately prior to next possible shock. Of these, three had converted to asystole, seven to PEA and three to ROSC.

Conclusion: While a shockable rhythm 1 min post-shock was present also immediately before next possible defibrillation attempt in most cases, three patients had ROSC. Studies are needed to document if moving the pre-shock rhythm analysis will increase shocks delivered to organized rhythms, and if it will increase shock success and survival.

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1. Introduction

In patients with cardiac arrest European Resuscitation Council (ERC) 2010 guidelines recommend two-minute cycles of cardiopulmonary resuscitation (CPR) followed by ECG rhythm analysis immediately prior to possible defibrillation attempts.[1,2] This requires a pause in chest compressions to avoid corrupting the ECG signals by compression artefacts. Studies indicate that pauses immediately before defibrillation attempts may affect termination of fibrillation, return of spontaneous circulation (ROSC) and survival.[3–8] Chest compression fraction (time with compressions as fraction of total CPR time) has also been reported to affect survival,[9,10] but compression pauses immediately pre-shock have been reported to affect survival independent of the compression fraction.[7] Guidelines therefore emphasize minimizing immediate pre-shock compression pauses as such, not only reducing pauses in chest compressions in general.[1,2] Pre-shock pauses can be reduced to a few seconds if the defibrillator software allows chest compressions during defibrillator charging.[2] An additional approach independent of the type of defibrillator would be if the pause for ECG analysis could be moved earlier in the CPR cycle. This approach would require that the analysis has sufficient predictive accuracy for the rhythm at the time of the next possible defibrillation attempt.

The Circulation Improving Resuscitation Care (CIRC) trial compared manual and mechanical CPR in out-of-hospital cardiac arrest (OHCA) patients in US and Europe, and has a large database with continuous ECG recordings.[11] 2005 ERC and AHA guidelines were followed with the exemption of a 3 min CPR cycle with rhythm analysis 1 min after defibrillation attempts according to Norwegian CPR guidelines.[1,2,12] If the rhythm is shockable at this point, chest compressions are continued for another 2 min before a second rhythm analysis is carried out immediately before a possible defibrillation attempt.[12] The CIRC study therefore gives the unique opportunity to evaluate an artefact free ECG at two points during a CPR cycle and thereby assess the stability of a shockable rhythm during chest compressions.

We hypothesize that a shockable rhythm 1 min post-shock stays shockable after 2 min of CPR, until next defibrillation attempt. This knowledge may be useful for CPR guideline processes, both for two- and three-minute CPR cycles.

2. Methods

The multi-centre CIRC trial was carried out in Houston, TX, Fox Valley, WI and Hillsborough County, FL in the US, Vienna in Austria and Nijmegen in the Netherlands. The aim was to compare survival to hospital discharge for OHCA patients randomized to receive either high quality manual chest compressions (M-cc) or integrated (patient receives manual compressions while the mechanical device is deployed) automatic mechanical chest compressions delivered by a Load Distributing Band (LDB-cc) (AutoPuls®, ZOLL Medical, Chelmsford, MA). The CIRC trial was conducted under exception from informed consent for emergency research, and it was approved by the Institutional Review Board (IRB) (US sites) or ethics committee (European sites) for each lead EMS agency and each hospital likely to receive patients. The study protocol is described in detail in a previous methods paper.[13]

Continuous ECG, transthoracic impedance (TTI), defibrillation attempt(s), end-tidal CO_2 ($ETCO_2$), and time intervals were continuously recorded and stored by the defibrillators which were used in both manual and semiautomatic mode. Both LIFEPAK® 12, 15 and 500 (Physio-Control, Redmond, WA, US) and Zoll E Series® and AED Pro® (ZOLL Medical, Chelmsford, MA, US) were used in the trial. These defibrillators do not have filtering technology with the ability to remove real-time ECG artefacts. The data were then downloaded to CIRC central server after each resuscitation attempt.[13] Electronic defibrillator data case files were analyzed using CodeStat 8.0 Data Review Software (Physio-Control, Redmond, WA, US) or RescueNet® Code Review 5.5.3 (ZOLL Medical Corporation, Chelmsford, MA, USA). Software TTI filtering in CodeStat 8.0 allowed us to filter the TTI signal, and thereby more accurately distinguish between the different TTI curves of the compressions and the ventilations. This enabled us to more accurately score the cases.

The use of TTI is a documented method of evaluating performance of CPR and alignment to guidelines or a study protocol.[14] Compressions and ventilations can be determined from TTI waveform analysis.[14] Chest compressions can generate ECG artefacts that may look like VF/VT. ECG evaluation is therefore much more accurate if a parallel TTI graph indicates if chest compressions are given or not. According to CIRC protocol EMS personnel were to stop chest compressions (max 10 s) and determine rhythm by feeling for pulses and evaluate the defibrillator monitor ECG. We analyzed ECG rhythms retrospectively during compression pauses (verified with a flat TTI graph) of minimum 2 s to avoid compression artefacts and interference on the ECG. Only artefact free ECG data was scored. All rhythms were scored by one analyst. Uncertain cases were scored after a discussion with expert analysts, both anaesthesiologist and cardiologist.

For all cardiac arrest episodes we determined initial rhythm as ventricular fibrillation (VF), ventricular tachycardia (VT), asystole, pulseless electric activity (PEA, defined as electrical activity with QRS-waves of any width at an average rate of 10 > beats per minute) or ROSC (determined using ECG, TTI, $ETCO_2$ and notions in the case report forms (based on ambulance records)). Shocks without compression pause for rhythm analysis or with missing ECG or impedance signal at either 1 min and/or 3 min post-shock were excluded. The presence of ICD shocks in-between rhythm analyses or lack of CPR also led to exclusion.

For each defibrillation attempt we determined the rhythm pre-shock, 1 min and 3 min post-shock (immediately before next possible defibrillation attempt). It is difficult for EMS personnel in the field to adhere exactly to guidelines regarding the timing of rhythm analysis. Therefore, the one- and three-minute rhythm analyses were accepted and included for analysis when carried out between 30 and 90 s and between 120 and 240 s post-shock, respectively.

Shocks delivered to a non-shockable rhythm (asystole or an organized rhythm defined as ROSC or PEA) were categorized as inappropriate. We examined the results of inappropriate shocks by determining the rhythm 5 s post-shock.

During resuscitation patients could receive adrenaline, amiodarone, atropine, vasopressin and/or lidocaine depending on local emergency medical service (EMS) drug guidelines. If drugs were administrated it was noted in the ambulance journal, but the timing of drug delivery was not documented.

Descriptive analyses were performed using SPSS version 21.0 (IBM SPSS Inc., Chicago, IL, USA), and presented as proportions or medians with Inter Quartile Ranges (IQR) and 25% and 75% percentiles. Multiple imputations were not considered because shocks are the dependent variable with repeated measurements. Since only descriptive analysis was performed imputed dependent variable contributes no information to the analysis.[15]

3. Results

Of 4231 CIRC patients, 1657 (39.4%) received one or more shocks (totally 5336 shocks). Forty-three patients were excluded due to defibrillator data import failure, missing ECG or TTI data, or undeterminable initial rhythm. The 1614 included patients received