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CLINICAL PAPER

Transthoracic impedance used to evaluate performance of cardiopulmonary resuscitation during out of hospital cardiac arrest☆

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Return of spontaneous circulation;
Transthoracic impedance;
Ventilation;
Monitor CPR process

Summary

Introduction: There is a need to measure cardiopulmonary resuscitation (CPR) in order to document whether ambulance personnel follow CPR guidelines. Our goal was to do this using defibrillator technology based on changes in transthoracic impedance (TTI) produced by chest compressions and ventilations.

Methods: 122 incidents of out-of-hospital cardiac arrest between May 2003 and February 2004 were analysed based on data recorded from defibrillators in Oslo EMS. New software was used to analyze chest compressions and ventilations based on changes in thoracic impedance between the defibrillator pads, as well as ECG and other event data.

Results: In total, 25 ± 14% (varying from 76% to 3%) of the time chest compressions were not performed on patients without spontaneous circulation (NFR = No Flow Ratio). When adjusting for time spent on analysis of ECG, pulse check and defibrillation, NFR was 20 ± 13% (varying from 70% to 3%). Mean compressions delivered per minute was 87 ± 16 and the compression rate during active compressions was 117 ± 9 min^{-1}. Individual variation was 31—117 min^{-1} (mean) and 95—144 min^{-1} (active periods). A mean of 14 ± 3 ventilations/min was recorded, varying from 8 to 26 min^{-1}. Compared with the rest of the episode, the first 5 min had a significantly higher proportion of time without chest compressions; 30 ± 17% ($p < 0.001$) and significantly lower mean compression and ventilation rates; 80 ± 19 min^{-1} and 12 ± 4 min^{-1}, respectively ($p < 0.001$ in both cases).

Conclusions: Core CPR values can be measured from TTI signals by using a standard defibrillator and new software. NFR was 25% (20% adjusted) with great rescuer variability.

☆ A Spanish translated version of the summary of this article appears as Appendix in the final online version at doi:10.1016/j.resuscitation.2008.08.007.

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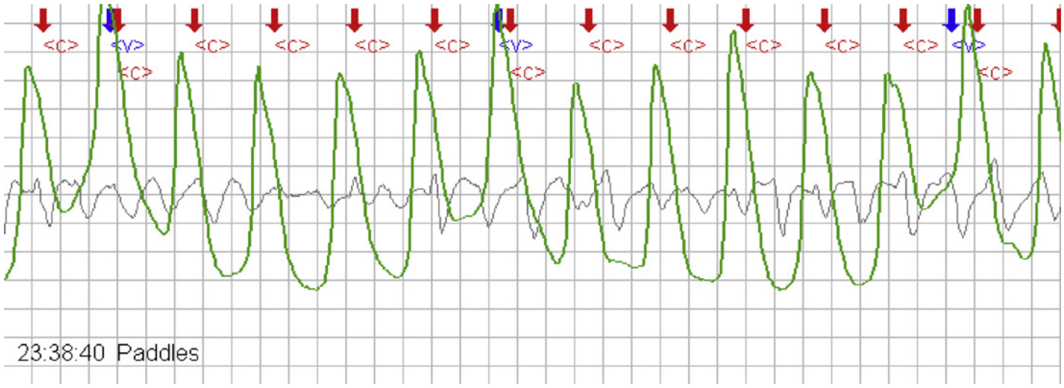

Figure 1 Unfiltered impedance data. ECG signal shows ventricular fibrillation. Impedance signal shows chest compressions ⟨C⟩ and ventilations ⟨V⟩.

Introduction

Evaluation of and feedback on cardiopulmonary resuscitation (CPR) may be an important factor in improving the outcome for cardiac arrest patients. Transthoracic impedance (TTI) has been used in cardiopulmonary research for more than 40 years to measure ventilation, respiration, and cardiac output.[1–6] The signal is available for analysis in many external defibrillators, and most measure TTI by sending a high frequency alternating current between the defibrillation pads. A circuit inside the defibrillator measures the voltage generated when this current flows between the defibrillation pads through the patient's chest. The measured voltage is proportional to the transthoracic impedance between the defibrillator pads. If the flow of current through the chest is unaffected by impedance changes or artefact, the TTI will show a flat line. Inflating the lungs causes a rise in impedance because air is a poor conductor of electric current. When the left ventricle ejects a bolus of blood into the aorta, it causes a temporary, small decrease in impedance because blood is a good conductor. Chest compressions cause both true changes in thoracic impedance and motion artefact in the impedance signal (Figures 1—3).

In this paper, we present data on validation of the TTI signal for detection of chest compressions and results based on measurement of CPR in a series of cases using the TTI signal.

Methods

Validation of the TTI signal for detection of chest compressions

We hypothesized that clinical experts can identify individual chest compressions from TTI and ECG signals recorded by defibrillators with sensitivity and positive predictive value both exceeding 90%. We noted in a series of consecutive cases recorded by LIFEPAK® 500 automated external defibrillators (AEDs) (Physio-Control, Redmond, WA, USA) during resuscitations attempted by emergency medical technicians (EMTs) that audible counting of chest compressions could be heard in the audio track in about half of the recordings, from November 1999 to July 2001 in Contra Costa County Emergency Medical Services (EMS), California, USA. We selected the first 106 cases from the series in which audible counting of compressions were present during the first CPR period prompted by the AED. One clinical expert annotated the chest compressions in the first CPR period in each case by listening to the audio track and using the audible counting to confirm the time location of compressions. Two other clinical experts independently provided the experimental annotations of the same 106 cases with the audio track removed and were asked to annotate chest compressions in the first CPR period based on the TTI and ECG signals and their knowledge of CPR. We measured the sensitivity and positive

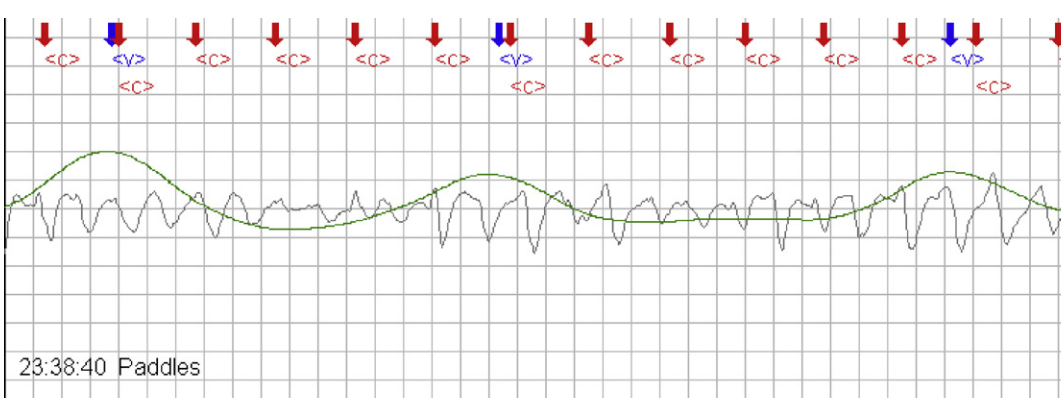

Figure 2 The same time segment as Figure 1. Impedance filtered to preferentially show ventilations. V, ventilations. C, chest compressions.