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Clinical paper

Defibrillation success during different phases of the mechanical chest compression cycle☆

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ABSTRACT

Introduction: Animal studies indicate higher termination of VF/VT (TOF) rates after shocks delivered during the decompression phase of the compression cycle for manual and mechanical CPR. We investigated TOF for shocks delivered in different compression cycle phases during load distributing band (LDB) mechanical CPR in the CIRC trial.

Methods: Shocks were retrospectively categorized as delivered during the compression, decompression, or relaxation phase of LDB compressions using transthoracic impedance data. Shocks delivered when the LDB device was paused, were used as controls. The first shock and the first up-to-three shocks (first shocks plus shocks two and three if given) from patients with initial VF/VT and LDB CPR prior to shock were grouped according to compression cycle phase. TOF rates for these groups versus the control group were analyzed using logistic regression for first shocks and the general estimating equations (GEE) model for the up-to-three shocks. Adjustments were made for bystander CPR, witnessed arrest, defibrillator shock energy and transthoracic impedance.

Results: Among 244 first shocks and 685 up-to-three shocks TOF success rates were lower ($p < 0.05$ and $p < 0.02$) for shocks given during the compression phase (72% and 71% respectively) than for control shocks given during compression pauses (86% and 82% respectively). Decompression and relaxation phase shocks had TOF rates not different from the controls.

Conclusion: Shocks delivered in the compression phase of LDB chest compressions had lower TOF rates than shocks delivered while pausing the LDB device. More research is needed to see how defibrillation during chest compressions affect ROSC and survival.

Introduction

Early cardiopulmonary resuscitation (CPR) and defibrillation are considered the most important factors for survival after sudden cardiac arrest. The interplay between chest compressions and defibrillation attempts in patients with shockable rhythms is probably important. The 2010 CPR guidelines of European Resuscitation Council (ERC) and American Heart Association (AHA) emphasize reducing chest compression interruptions as much as possible[1,2] based on studies showing negative effects of such

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pauses.[3–6] Avoiding pre-shock pauses altogether could potentially increase the defibrillation success rate even further. This may be achieved with compressions given by a mechanical device or manually with appropriate safety gloves.[7]

Li et al. found higher termination of VF/VT 5 s post-shock (TOF) rate for shocks delivered during the decompression phase of the chest compression cycle compared with shocks delivered after a 2 s pre-shock chest compression pause for both manual and mechanical chest compressions in pigs.[8,9] Three large randomized trials, the LINC, CIRC and PARAMEDIC trials, have evaluated two mechanical chest compression devices with defibrillation during ongoing chest compressions in the mechanical chest compression group (AutoPulse® Load Distributing Band [LDB], ZOLL Medical, Chelmsford, MA and LUCAS®, Physio-Control, Redmond, WA). All three studies failed to show improved survival.[10–12]

Olsen et al. recently reported that TOF was lower with defibrillation during continuous LDB compressions for the first shock based on retrospective data from the CIRC trial.[13] In an accompanying editorial Deakin pointed out that “defibrillation may be more successful in the relaxation phase of each compression cycle”.[14] The same was pointed out by Carron and Yersin regarding the LINC trial.[15] Olsen et al. had not differentiated between compression cycle phases. We have now been able to define in what phases of the compression cycle the various shocks were given in the CIRC trial, and have therefore investigated the relation between TOF and shocks delivered in different LDB compression cycle phases on data from the CIRC trial.[10]

Methods

Study population

This is a retrospective study on electronical data from the CIRC trial. The multicentre CIRC trial was carried out in Houston TX, Hillsborough County FL and Fox Valley WY in the USA, in Nijmegen, the Netherlands, and in Vienna, Austria between March 5, 2009 and January 11, 2011. It was designed to compare manual chest compressions with integrated use of mechanical LDB-CPR in respect to survival to hospital discharge.[10,16] CIRC followed international CPR Guidelines with the exception that the CPR cycle was 3 min.[17] In the current paper shocks from CIRC patients with initial VF/VT and LDB-CPR prior to defibrillation were included for further investigation.

Defibrillator data

All participating sites used right subclavian and left apex pad positioning. The stick-on defibrillator pads were placed before the LDB device was deployed, and were in varying degrees covered by the LDB during chest compressions. The defibrillator energy protocol used was either fixed at 360 J for all shocks (one study site) or escalating (first shock 200 J, second 200 J, 300 J or 360 J and third and subsequent 360 J, four study sites). Transthoracic impedance (TTI), ECG signal and defibrillation attempt(s), were continuously recorded and stored by the defibrillators. ECG and TTI data from both LIFEPAK® 12, 15 and 500 (Physio-Control, Redmond, WA, USA) were analyzed using CODE-STAT™ 9.0 software (Physio-Control, Redmond, WA, USA). ECG was analyzed for initial rhythm, pre-shock rhythm and 5 s post-shock rhythm. Pre- and post-shock rhythms were annotated by LW and JO, and 1002 post-shock rhythms (randomly selected by SPSS [Version 22.0, IBM SPSS Inc., Chicago, IL, USA]) were scored by both raters in order to document the inter-rater agreement on rhythm annotations. The rhythm annotation process is described in detail in a recent paper by Olsen et al.[13]

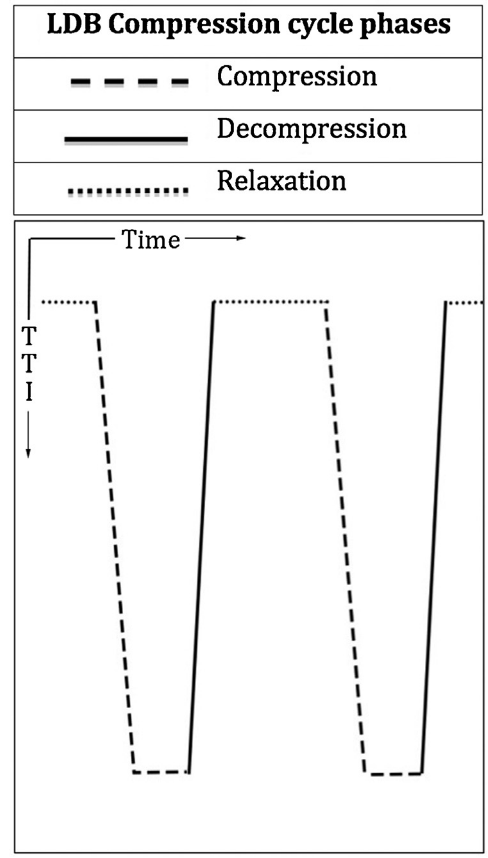

Fig. 1. Sketch of the LDB compression cycle phases defined by changes in transthoracic impedance (TTI). With right subclavian and left apex pads positioning, compression will be illustrated in CODE-STAT™ as a decreasing TTI graph. If the pads are interchanged, the polarity of the TTI signal will change and compressions will be illustrated as an increasing TTI graph.

Annotation of shocks to LDB compression cycle phases

The chest compression–decompression cycle of the LDB-device consists of the following phases (Fig. 1): compression phase (the load-distributing band tightens and holds tight), decompression phase (the load-distributing band loosens, no active decompression) and the relaxation phase (load-distributing band stays loose). The compression phase in our study is similar to what is referred to as the downstroke phase, and the decompression phase is similar to the upstroke phase in the pig studies conducted by Li et al.[8,9] With the LDB-device attached the rescuers should defibrillate during continuous chest compressions according to protocol.

TTI data graphed over time can identify when chest compressions are given.[18] The LDB-device compresses the chest at a constant rate of 80 min^{-1}, producing a TTI graph of distinctive regularity and morphology, which enables identification of the different LDB compression cycle phases. Based on this and data from Zoll Medical on the LDB device work cycle, we made a transparent grid with the LDB work cycle printed on it, and scaled it to the same calibration as CODE-STAT™ – displaying ECG and TTI at 50 mm/s. Physio-Control provided data on the time interval from when the shock is marked as delivered in the CODE-STAT™ software, to when the shock is actually delivered by the different defibrillators. By using these data and aligning the transparent grid to the CODE-STAT™ TTI graph we determined in which part of the LDB compression cycle each shock was delivered (Fig. 2). For each patient the first shock plus shocks 2 and 3 if given, were analyzed. One rater (MS) assigned the phase for all shocks, and