CPREzy^{TM}: an evaluation during simulated cardiac arrest on a hospital bed[☆]

Gavin D Perkins*, Colette Augré, Helen Rogers, Michael Allan, David R Thickett

Division of Medical Sciences, University of Birmingham, Birmingham B152TT, UK

Abstract

CPREzy^{TM} is a new adjunct designed to improve the application of manual external chest compressions (ECC) during cardiopulmonary resuscitation (CPR). The aim of this study was to determine the effect of using the CPREzy^{TM} device compared to standard CPR during the simulated resuscitation of a patient on a hospital bed. Twenty medical student volunteers were randomised using a cross over trial design to perform 3 min of continuous ECC using CPREzy^{TM} and standard CPR. There was a significant improvement in ECC depth with CPREzy^{TM} compared to standard CPR 42.9 (4.4) mm versus 34.2 (7.6): mm, $P = 0.001$; 95% CI d.f. 4.4–12.9 mm. This translated to a reduction in the percentage of shallow compressions (<38 mm) with CPREzy^{TM} 16 (23)% compared to standard CPR 59 (44)%, $P = 0.003$. There was a small increase in the percentage of compression regarded excessive (>51 mm): CPREzy^{TM} 6.5 (19)% versus standard CPR 0 (0.1)%. $P = 0.012$). There was no difference in compression rate or duty cycle between techniques. Equal numbers of participants (40% in each group) performed one of more incorrectly placed chest compression. However the total number of incorrect compressions was higher for the CPREzy^{TM} group (26% versus 3.9% standard CPR, $P < 0.001$). This was due to a higher number of low compressions (26% of total compressions for CPREzy^{TM} versus 1% for standard CPR, $P < 0.001$). In conclusion, CPREzy^{TM} was associated with significant improvements in ECC performance. Further animal and clinical studies are required to validate this finding in vivo and to see if it translates to an improvement in outcome in human victims of cardiac arrest.
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Keywords: Basic life support; Cardiac massage; Chest compression; Cardiopulmonary resuscitation

1. Background

The performance and quality of basic life support are important determinants of outcome in cardiac arrest victims [1]. Most in-hospital arrests occur while the victim is on a hospital bed [2]. We have demonstrated previously that external chest compressions (ECC) performed on a hospital bed are inferior to those undertaken with the victim on the floor [3]. Furthermore, performance is not enhanced by emergency deflation of air filled mattresses [4]; by using a back-board; by kneeling on the bed next to the victim or by altering bed height [5].

CPREzy^{TM} is a portable device designed to improve the efficacy of manual chest compressions during cardiopulmonary resuscitation (CPR). Early evaluations of this device reported improvements in compression rate, the number of correct compressions and a reduction in the deterioration of CPR performance over time [6]. The aim of this study was to evaluate the effectiveness of the CPREzy^{TM} device to improve chest compression efficacy in a cardiac arrest model simulating a patient in cardiac arrest on a hospital bed.

2. Methods

2.1. CPREzy^{TM} device

The CPREzy^{TM} device is a portable adjunct for use during external chest compressions (Fig. 1). It has a series of lights

* Corresponding author. Fax: +44 121 443 2494.
  E-mail address: gavin.perkins@virgin.net (G.D. Perkins).
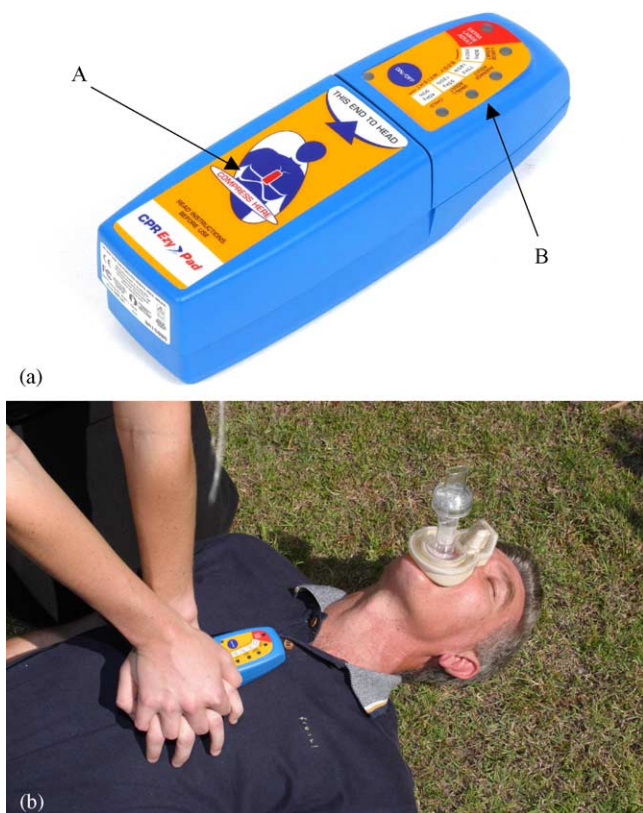
Fig. 1. (a) CPREzy^{TM} device: (A) compression pad, (B) light indicator; (b) the CPREzy^{TM} device is placed on the sternum during CPR.

on its upper surface that illuminate depending on the amount of pressure generated by each chest compression. Activation pressures for the lights are quoted as: 1 light (child) 23 kg; 2 lights (small adult) 32 kg, 3 lights (average adult) 41 kg, 4 lights (large adult) 50 kg, 5 lights (caution) 54 kg [6]. When compression pressure is released the lights switch off. In addition to the description of patient size next to the lights (i.e. child to large adult), the approximate weight of the patient is also identified. This is not the same as the activation pressure for the lights. The device contains an audible tone that bleeps at a rate of 100 times per minute. It is designed to be placed on the sternum during chest compression in order to improve the accuracy of CPR. A diagram on the front of the device shows where it should be placed on the patient when performing CPR.

2.2. Pilot study

The pressure indicators on the CPREzy^{TM} device are calibrated for use with a victim lying on a firm, non-compressible surface. However, a greater force is required when performing compressions with a victim on a hospital bed to overcome the additional effect of mattress compression. In order to determine the optimal compression force required to achieve a compression depth of 40–50 mm, six volunteers performed 1 min of chest compressions aiming to illuminate 1, 2, 3, 4 or all 5 lights.

2.3. Principle study design

The study was approved by the Executive Dean at the Medical school, University of Birmingham. Students gave verbal informed consent to participate in the study. The study was a randomised controlled cross-over trial. Medical student volunteers, trained as European Resuscitation Council BLS/AED Instructors as part of our peer led resuscitation training initiative were recruited [7,8]. Students performed, in a random order, CPR using the CPREzy^{TM} device and standard CPR. Randomisation was performed using odd-even allocation from a list of random numbers generated using SPSS (SPSSinc, IL, USA). Each phase of testing was separated by a period of 7 days.

Participants received 2 min instruction on the use of the CPREzy^{TM} device at the start of the study and were allowed a short 1 min period of familiarisation/revision with CPREzy^{TM}/standard CPR. Participants were instructed to illuminate four lights when using the CPREzy^{TM} device. The study required participants to perform 3 min of continuous ECC (with and without CPREzy^{TM}) on a Laerdal Resusci Anne manikin placed on a hospital bed and Softform^{TM} mattress. A 3-min sequence of continuous compressions was chosen to reflect one cycle of the non-VF/VT treatment algorithm in the intubated patient. The bed was adjusted to its lowest position, which was 45 cm above the ground.

Data on compression performance were collected using the VAM system software (version 1.30.19 Beta) and downloaded to a laptop computer (Dell Latitude D600, Dell, UK) as previously described [4]. The VAM system was used for data collection only and the feedback facility was deactivated. Data for each participant were exported to a Microsoft Excel 2000 spreadsheet. The VAM system measures the following compression variables (depth, duty cycle, rate, hand position). Hand positioning is recorded as correct if pressure is exerted on the lower third of the sternum only. The proportion of incorrect compressions that are low (below the simulated xiphoid process) are also recorded.

At the conclusion of each test, participants were asked to complete a visual analogue scale to measure their perceptions of efficacy and fatigue [9]. (Statements—(i) the CPR I performed was efficacious and (ii) I was fatigued at the end of the test.) In addition, feedback was sought on comfort associated with using the CPREzy^{TM} device.

2.4. Statistical analysis

From a previous study [3] we calculated that we would need 20 participants to demonstrate a 10% difference in chest compression depth at a significance level of 0.05 and 90% power.

Date were analysed using SPSS 10.0 for Windows (SPSSinc, IL, USA). Data were tested for normality using Sharpiro Wilks test. For normally distributed data repeated measurements over time were analysed by two-factor repeated measure ANOVA, the two factors being compression variable

and time. Huynh–Feldt epsilon was used when spherecity conditions were not met. Paired *t*-tests were used to compare overall data for the two groups. These results are presented as mean (standard deviation) and 95% confidence intervals of the difference between groups (95% CI d.f.). Non-normally distributed data were analysed using Friedmans test and Wilcoxon signed rank test and were presented as median (interquartile range). Pearsons correlation coefficient was used to assess linear associations. Nominal data were compared using McNemar's test. A *P*-value of <0.05 was considered statistically significant.

3. Results

3.1. Pilot study

There was a significant linear relationship between compression depth and force (indicated by the number of lights illuminated on the CPREzy[TM] device), $r = 0.998$, $P = 0.002$. Optimal chest compression depth (40–50 mm) was achieved when four lights were illuminated (Fig. 2).

3.2. Principle study

Twenty medical students were recruited to the main study. Due to logistic problems, three participants from the first phase of the study had to be replaced by volunteers matched for age, sex, height and weight during the second phase. The participants age, sex, height and weight are displayed in Table 1.
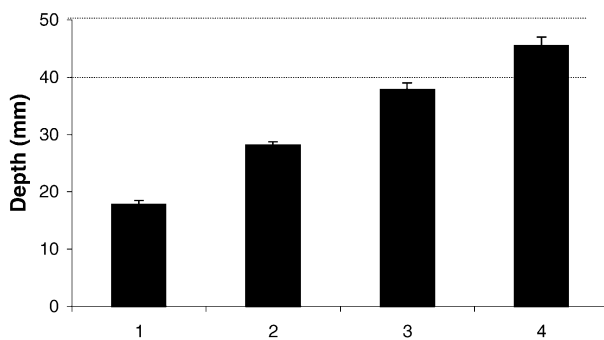

Fig. 2. Pilot study results—chest compression depth corresponding to the number of lights illuminated on the CPREzy[TM] device. Optimal chest compression depth (40–50 mm: dashed lines) was achieved when four lights were illuminated. Data presented are the mean (standard error) from six subjects.

Table 1
Demographics of study participants

	Female	Male
Number	10	10
Age (years)	20.3	20.8
Height (m)	165.8 (5.6)	178.7 (7.1)
Weight (kg)	62.6 (10.3)	74.3 (8.5)

Data are mean (standard deviation).

There was a significant improvement in chest compression depth with CPREzy[TM] compared to standard CPR 42.9 mm (4.4) versus 34.2 mm (7.6), $P = 0.001$; 95% CI d.f. 4.4–12.9 mm. This effect was maintained throughout the 3-min test (Fig. 3A). This translated to a reduction in the percentage of shallow compressions (<38 mm) with CPREzy[TM] 16 (23)% compared to standard CPR 59 (44)%, $P = 0.003$. There was a small increase in the percentage of compression regarded to be excessive (>51 mm): CPREzy[TM] 6.5 (19)% versus standard CPR 0 (0.1)%, $P = 0.012$.

There was no difference in chest compression rate (median[IQR]): CPREzy[TM] 102[101–104] min^{-1} versus standard CPR 98[90.5–107], $P = 0.407$. This did not change over time $P = 0.861$ (Fig. 3B). There was no difference in average duty cycle CPREzy[TM] 47.7(3.4)% versus standard CPR 48.1(5.5)%, $P = 0.845$. This did not change over time $P = 0.789$ (Fig. 3C).

Equal numbers of participants (40% in each group) performed one or more incorrectly placed chest compression. However, there were no grossly misplaced compressions. The total number of incorrectly placed compressions was higher for the CPREzy[TM] group (26% versus 3.9% standard CPR, $P < 0.001$.). This was due to a higher number of low compressions (26% of total compressions for CPREzy[TM] versus 1% for standard CPR, $P < 0.001$).

3.3. Participant feedback

There was no difference in participants perceptions of achieving adequate depth of compression between techniques: CPREzy[TM] 49 (S.D. 30) versus standard CPR 60 (S.D. 22) $P = 0.149$. Participants found using the CPREzy[TM] device caused greater fatigue than standard CPR 75 (S.D. 22) versus 60 (S.D. 25), 95% CI d.f. 4.5–26.4, $P = 0.008$. Ninety-five percent of participants reported discomfort in the heels of their hands and wrists in association with the CPREzy[TM] device. One participant sustained a soft tissue injury when the skin covering the fifth metacarpal became trapped between moving compression pad (Fig. 1, part A) and fixed lights section (Fig. 1, part B) of the device (Fig. 4 shows injury). The bruising settled within 2 weeks and there were no long lasting sequelae from this injury.

4. Discussion

The principle finding of this study was that the CPREzy[TM] device was associated with a significant (average 8.7 mm) improvement in chest compression depth during simulated resuscitation of a patient on a hospital bed. This was associated with a substantial reduction in the number of "shallow" (<38 mm) compressions and only a slight increase in the number of "excessive" compressions (>51 mm). This is an important finding since it is to our knowledge the first intervention shown to improve the efficacy of external
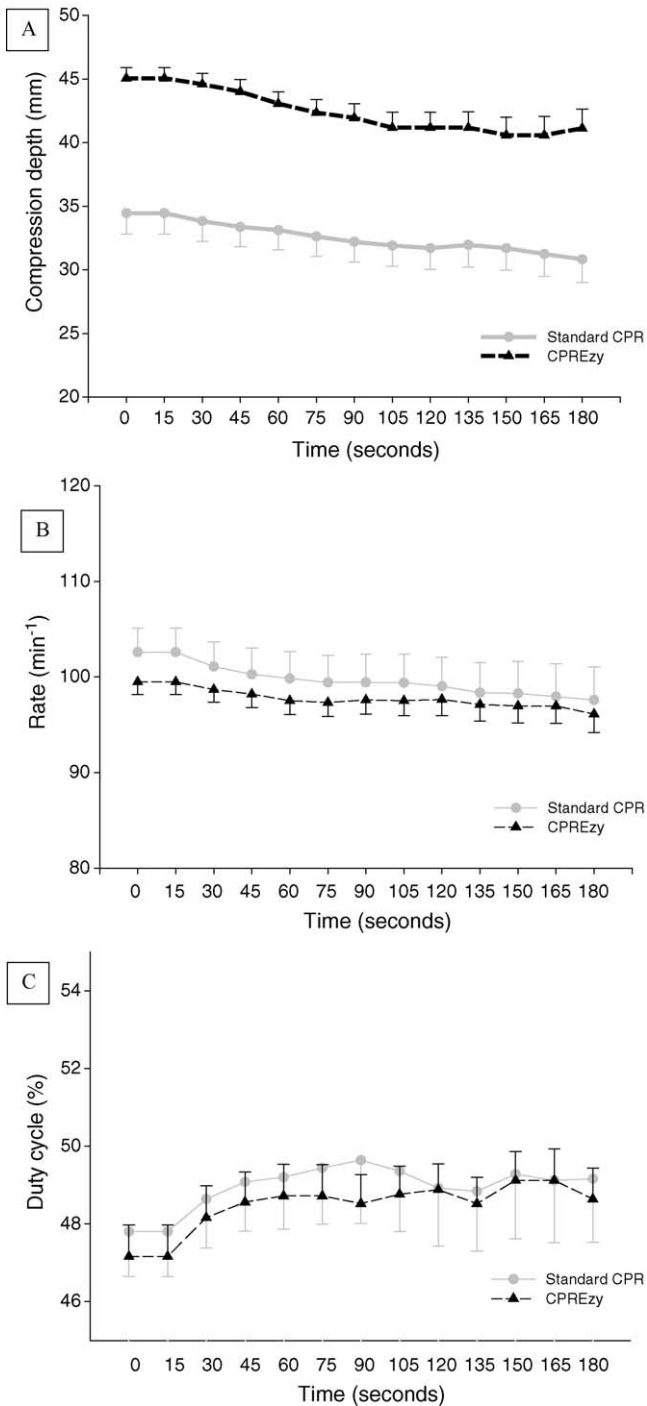
Fig. 4. Photograph showing soft tissue injury over outer aspect of fifth metacarpal after the hand became trapped between the mobile CPREzy[TM] compression plate and fixed light indicator box.

chest compressions during the resuscitation of a simulated in-hospital cardiac arrest.

External chest compressions yield at best 30% of normal cardiac output [10]. Despite this, the early initiation and quality of CPR have been shown to be important determinants of the success rate of resuscitation from cardiac arrest [1]. Studies in humans and animals in cardiac arrest have demonstrated a linear relationship between compression depth and cardiac output, mean arterial blood pressure and coronary artery perfusion [11,12]. A 10 mm improvement in compression depth was associated with a 50% relative increase in cardiac output and 30% relative increase in mean arterial blood pressure [13,14].

Compared to CPR performed on a manikin placed on the floor, we and others have demonstrated previously that compression depth deteriorates markedly when the manikin is placed on a hospital bed [4,3,15]. One potential explanation for this finding is that when CPR is performed on a hospital bed, the compression force not only causes compression of the sternum, but also of the underlying mattress [16]. It is for this reason that current international guidelines recommend that a back-board is placed underneath the victim [17]. However in our previous studies, neither emergency deflation of an air filled mattress (such that it then becomes a firm, non-compressible surface) [4] nor placing a large back-board beneath the manikin [5] led to any improvement in compression variables. We therefore went on to investigate the role of rescuer body position. In a bench model we found that there was an inverse relationship between maximal compression force and bed height indicating that the physical height of the victim above the floor had an adverse effect on compression performance [4]. However when we subsequently went on to study the effect of kneeling on the bed next to the victim or lowering the height of the bed neither intervention had any significant impact on compression efficacy [18].

One clear theme emerging from this study and our previous studies was the failure of the CPR provider to recognise that their compressions were sub-optimal [3,9]. In the present

Fig. 3. Chest compression depth over time. Black, dashed line represents CPREzy[TM], grey solid line represents standard CPR. Data are presented as mean (triangles/circles) and standard error (bars). Data were analysed by repeated measure ANOVA. Graphs show: (A) depth—there was a significant difference between CPREzy[TM] and standard CPR ($F = 16.2$, $P = 0.001$). There was a significant decline in chest compression depth over time ($F = 10.97$, $P < 0.0001$). (B) Rate—there was no significant difference between CPREzy[TM] and standard CPR ($F = 0.72$, $P = 0.410$). There was a significant decline in chest rate over time ($F = 9.7$, $P = 0.0001$). (C) Duty cycle: there was no significant difference between CPREzy[TM] and standard CPR ($F = 0.904$, $P = 0.904$). There was a significant decline in chest rate over time ($F = 5.3$, $P = 0.0001$).

study, we found no difference in participant's perceptions of the efficacy of their chest compressions between the standard and CPREzy^TM group despite clearly different levels of efficacy. The failure of the CPR provider to recognise suboptimal CPR performance is not a new phenomenon [19], but effective interventions to overcome it have not been studied in detail. The CPREzy^TM device appears to overcome this problem by providing continuous visual and audible feedback on performance.

These findings are consistent with those of other investigators that have studied the effect of feedback during CPR and its effects on performance. Elding et al. investigated the use of a similar device and reported significant improvements in the numbers of correct compressions, improved hand positioning and reduced number of excessive compressions [20]. A more recent advance in the development of on-line feedback during CPR is the Laerdal Voice Advisory Mannikin system. This system analyses CPR performance using a micro-computer and gives verbal instructions to the CPR provider on how to optimise their technique during the resuscitation attempt e.g. "Press a little deeper" etc. Early evaluations of this device have yielded promising results with reported improvements in CPR performance both immediately [21] after training and during testing 6 months later [22]. When this technology was incorporated into an automated-external-defibrillator it led to improvements in ventilation volumes and chest compression depth during simulated CPR performed by nurses [23].

The present study supports and extends the findings by Boyle et al. [6]. Their study evaluated the use of CPREzy^TM during simulated CPR on a resuscitation manikin placed on the floor. The principle findings were a significant improvement in compression rate, the proportion of "effective compressions" (a composite score of correct position, force and release between compressions) and compression positioning. In contrast to their study however, we found that the CPREzy^TM device was associated with an increased *total* number of incorrectly located compressions (mostly too low). However their study reports the number of participants (rather than compressions) that performed low compressions. When considered in these terms, 40% of our subjects performed one or more low compressions, which is comparable to the finding in their control group. What we failed to demonstrate therefore was any improvement with the CPREzy^TM device. Furthermore, the sensor that reports low compressions is very sensitive to small errors in compression placement and as we did not observer any grossly misplaced compressions the relevance, or potential for harm, from this observation is likely to be small. We suggest that to overcome this potential problem, participants are briefed carefully to continually evaluate the position of the device during CPR to avoid misplaced compressions.

It was a concern that 95% of our participants reported discomfort in their hands and wrist whilst using the CPREzy^TM device. This may reflect the additional effort that is required to correctly perform CPR. It may also be due to the hardness or narrowness of the compression plate. Of particular concern was the soft tissue injury sustained by one of our participants whilst using the device. We suggest that users are specifically warned about the potential for injury with the device and take care to avoid placing their hands to close to the moveable compression plate and fixed housing. The manufacturers should also re-visit the design of the devise and take steps to minimise the risk of this recurring.

Although the results of this early evaluation of the CPREzy^TM device are promising, there are several limitations inherent in the study design that requires further consideration. Most importantly, this was a laboratory-based study using a resuscitation manikin rather than a clinical study of patients in cardiac arrest. Our findings, although encouraging, require verification in animal cardiac arrest models before undertaking clinical studies in humans in cardiac arrest. This is particularly topical when one considers the early promise shown by the active-compression-decompression device. Despite evidence of improved CPR efficacy on manikins and improvements in haemodynamics during CPR, large clinical trials failed to demonstrate any consistent improvement in outcome with the device [24,25]. Finally, we used junior medical students recently trained in BLS as the CPR providers rather than qualified healthcare providers. Although at the time of undertaking the study few had first hand experience in performing CPR for real, the quality of CPR appears comparable to that undertaken by healthcare providers in our previous study [4].

5. Conclusions

In conclusion, the CPREzy^TM device was associated with a significant improvement in chest compression depth during simulated resuscitation of a victim in a hospital bed. To our knowledge, this is the first intervention that has been shown to improve the performance of chest compressions when undertaken with the victim on a hospital bed. Further animal and clinical studies are required to validate this finding in vivo and to see if it translates to an improvement in outcome in human victims of cardiac arrest.

6. Conflict of interest statement

Acknowledgements

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