Clinical Paper

Beyond the pre-shock pause: the effect of prehospital defibrillation mode on CPR interruptions and return of spontaneous circulation

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A B S T R A C T

Aims: The pattern of interruptions to chest compressions in pre-hospital cardiac arrests in Wellington, New Zealand, was examined prospectively to determine whether the mode of defibrillation chosen by paramedics influenced interruptions, shock success and the return of spontaneous circulation (ROSC).

Methods: A prospective observational cohort study of 44 adult cardiac arrests in which 203 shocks were administered by Wellington Free Ambulance (WFA) paramedics was undertaken to compare Code-stat® electronic records from Medtronic® Lifepak 12 and Lifepak 15 defibrillators used in semi-automated (AED) or manual mode. Interruptions during the 30 s prior to shock delivery as well as pre-shock and post-shock pauses were calculated. Shock success and ROSC were the outcome measures.

Results: Pre-shock pauses were shorter in manual mode (median 3 s, IQR 2–5) versus AED mode (median 4 s, IQR 3–6; p = 0.003). Interruptions of CPR in the 30 s prior to shock delivery were also shorter in manual mode (median 6 s, IQR 4–11) versus AED mode (median 14 s, IQR 12–16; p < 0.001). Shock success rates and post-shock pauses were not statistically different between modes. ROSC was significantly higher in manual mode (18.4%) versus AED mode (8.3%; p = 0.042).

Conclusion: When paramedics used the defibrillator in manual mode as compared to AED mode, interruptions to CPR during the 30 s prior to shock delivery were significantly reduced and pre-shock pauses were also shorter. This was associated with increased ROSC. Manual defibrillation should be the preferred option for appropriately trained paramedics. Training in this locality has been changed accordingly.

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1. Introduction

In many emergency services, defibrillators can be used either in semi-automated (AED) or manual mode but in Wellington Free Ambulance (WFA), the default function is AED. This mode is often preferred, even by senior paramedics, as it allows other resuscitation needs (such as immediate chest compressions, ventilation, equipment preparation and cannulation) to be addressed simultaneously. In AED mode, the defibrillator directs the paramedic to perform a further 15–17 s of chest compressions after hands-off rhythm analysis and during charging. (Fig. 1) In manual mode, the duration of the hands-off rhythm analysis is determined by the operator but is brief and normally part of the pre-shock pause (Fig. 2). Although AED rhythm analysis does not contribute to the pre-shock pause, it does fall within the 30 s period preceding shock delivery. We have found no studies that specifically examine pauses during this 30 s period.

Interruptions to cardiopulmonary resuscitation (CPR) such as pre-shock and post-shock pauses have been shown to adversely affect the return of spontaneous circulation (ROSC) and survival in CPR registry, compression-only CPR, and animal studies. 1-4 The pre-shock pause can be reduced by continuing chest compressions during charging and this carries minimal risk if rubber gloves are worn. 5, 6 (The defibrillators used in this study allow the rescuer to charge during CPR.) In AED mode, prehospital studies have shown a reduced time to the first shock 7 but more interruptions associated with hands-off rhythm analysis and voice prompts. 7, 9

The aim of this observational cohort study was to prospectively determine the effect of defibrillation mode on CPR interruptions, as well as ROSC (primary outcome measure) and shock success (secondary outcome measure) at pre-hospital cardiac arrests in Wellington.

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2. Methods

WFA is the sole ambulance provider for the capital city and Greater Wellington region which is a mixed urban and rural environment with a population of approximately 500,000. It responds to approximately 170 adult cardiac arrests a year, excluding paramedic-witnessed arrests. Basic paramedics use AED mode whilst intermediate and advanced level paramedics have a choice of AED or manual mode. All paramedics apply standard CPR at a ratio of 30 compressions to two ventilations until the airway is secured, when ventilations and compressions are given independently.

This prospective study compared CPR Code-stat® electronic records obtained from Medtronic® Lifepak 12 and Lifepak 15 defibrillators used either in AED or manual mode at 360 joules. Initially, a target of 50 shockable arrests was selected. Defibrillators were equipped with Code-stat® equipment, staff training was undertaken, and Code-stat® Reviewer software was installed between 17th January and the end of June 2011. The majority of the data was therefore obtained during the period 1st July 2011 to 17th March 2012. The printouts for each patient were analysed using Code-stat® Reviewer software and were correlated with clinical information documented by paramedics on Patient Report Forms (PRFs). Call and response times were obtained from the Emergency Ambulance Communications Centre.

Patient inclusion criteria were age over 16 and the administration of at least one defibrillatory shock. Patients who were not initially in a shockable cardiac rhythm but developed one during the cardiac arrest were also included.

Patients excluded were those who suffered interruptions in resuscitation of greater than 60 s resulting from external factors (e.g. rescue difficulty) and those who were shocked by first responders using other brands of defibrillator. Patients who received shocks for rhythms other than ventricular fibrillation (VF) or ventricular tachycardia (VT), as determined by consensus between

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**Fig. 1.** An AED Code-stat® report. The black line is the ECG and the green represents chest impedance and compressions. Coloured arrows mark chest compressions in red and ventilations in blue. The black markers above the strips record the time in seconds (each line is 11 s in duration). This report shows chest compressions interrupted by (a) rhythm analysis (top line) and (b) pre-shock pause, followed by a shock (bottom line).

**Fig. 2.** A manual mode Code-stat® report showing chest compressions (green waves) interrupted by a rhythm check during the pre-shock pause (bottom line).
authors WT and MB, were excluded. Any shocks that were given immediately on arrival or with less than 30 s of preceding CPR were not amenable to analysis.

Details recorded were witnessing of the arrest, the call to arrival time, call to start of CPR time, call to first shock time, occurrence of bystander or first-responder CPR (Table 1), initial and subsequent rhythms, and the defibrillation mode (AED or manual).

Code-stat® data was reviewed (Figs. 1 and 2). Interruptions during the 30 s prior to shock delivery, and during the pre-shock and post-shock pauses were calculated.

Shock success was analysed, being defined as the termination of VF or VT 5 s after shock delivery.11-13 ROSC was defined as the presence of a palpable pulse as determined by attending paramedics. Periods of ROSC were identified from the PRFs and matched to appropriate areas on the Code-stat® reports.

Data was recorded on an Excel® spreadsheet (Microsoft, Redmond, WA, USA) and analysed using SPSS 18.0 (IBM, New York, NY, USA). Chi-squared analysis was used for categorical, demographic data (sex, bystander-witnessed arrests and bystander-performed CPR) and the Mann–Whitney U test was employed for the remaining continuous variables. A P-value of less than 0.05 was accepted as statistically significant. The study was approved by the Central Ethics Committee of New Zealand (ref: CEN/11/EXP/049).

3. Results

To meet the deadline for a conference abstract in March 2012, a preliminary analysis of study data was undertaken at that time and it is those results that are reported here. For ethical reasons, the study was discontinued at that point since the difference in ROSC between AED and manual defibrillations reached statistical significance, as evidenced by a P-value of less than 0.05.

Out of a total of 56 patients, one was excluded because the defibrillator failed to record the Code-stat® file and three others because they were treated by firefighters or the public using a different make of defibrillator. Eight patients were excluded because their Code-stat® records started less than 30 s before the first manual shock, or there was no pre-shock CPR. The remaining 44 patients received 203 shocks, 84 from defibrillators in AED mode and 119 in manual mode. Three shocks were inadvertently administered for non-shockable rhythms (one manual and two AED shocks) and these were also excluded.

3.1. Demographics

Demographic details and the data for each shock mode are listed in Table 1. The only significant difference between the two study groups is the small number of AED shocks given to female patients (p = <0.001).

3.2. AED versus manual mode

These results are summarised in Table 2. Pre-shock pauses were shorter in manual mode (median 3 s; IQR 2–5) versus AED mode (median 4 s, IQR 3–6; p = 0.003). Interruptions of CPR in the 30 s prior to shock delivery were also shorter in manual mode (median 7 s, IQR 4–11) versus AED mode (median 14 s, IQR 12–16; p = <0.001). Shock success rates in manual mode of 75.63% versus 70.24% in AED mode were not statistically different. The incidence of prehospital ROSC was higher in manual mode at 18.49% versus 8.33% in AED mode (p = 0.042). There was no difference in the post-shock pause times between the two groups.

Table 3 contains data derived from the first four shocks received by each patient at 82.8% (24/29) of ROSC episodes occurred following one of these four shocks. This dataset again confirms that manual shocks were associated with significantly shorter pre-shock pauses (p = <0.001) and less interruption in the 30 s prior to shock delivery (p = <0.001).

4. Discussion

This prospective observational study demonstrated a statistically significant reduction in both pre-shock pause time (p = 0.003) and interruptions in chest compressions during the 30 s before shock delivery (p = <0.001) when manual defibrillation rather than AED mode was used by paramedics. The study was discontinued for ethical reasons when the manual defibrillation mode was also found to generate a significantly higher ROSC rate than AED mode (p = 0.042).

The greater pre-shock pause in AED mode is attributed to voice prompts which are activated immediately before shock delivery using the Lifepak 12 or 15. Longer pre-shock pauses have been shown to have detrimental effect on defibrillation success,14 as well as on ROSC and patient survival in CPR registry1,2 compression-only CPR,3 and animal4 studies. Ours was a prospective study in a population receiving standard CPR.
Table 3
Data relating to the first four shocks given in each mode.

<table>
<thead>
<tr>
<th>Number of shocks</th>
<th>Median pre-shock pause (IQR)</th>
<th>Median post-shock pause (IQR)</th>
<th>Median interruption in 30 s pre-shock (IQR)</th>
<th>Shock success (n)</th>
<th>ROSC (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual 70</td>
<td>3 (2–5)</td>
<td>4 (3–5)</td>
<td>8 (4–12)**</td>
<td>84.3% (59)</td>
<td>24.3% (17)</td>
</tr>
<tr>
<td>1st shock 15</td>
<td>3 (2–6)</td>
<td>3 (2–4)</td>
<td>11.5 (8.25–16.25)</td>
<td>100% (15)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>2nd shock 23</td>
<td>3 (2–5.75)</td>
<td>3 (3–4.25)</td>
<td>8 (4.75–12)**</td>
<td>73.9% (17)</td>
<td>34.8% (8)</td>
</tr>
<tr>
<td>3rd shock 17</td>
<td>3 (2–5)</td>
<td>4 (3–6)</td>
<td>7 (4–10)†</td>
<td>82.4% (14)</td>
<td>35.3% (6)</td>
</tr>
<tr>
<td>4th shock 15</td>
<td>3 (2.75–4)</td>
<td>4 (3–7)</td>
<td>4 (3–9.5)†</td>
<td>86.7% (13)</td>
<td>20% (3)</td>
</tr>
<tr>
<td>AED 57</td>
<td>5 (3–6)</td>
<td>4 (3–5)</td>
<td>14 (12–16)</td>
<td>80.7% (46)</td>
<td>12.3% (7)</td>
</tr>
<tr>
<td>1st shock 23</td>
<td>5 (3–7)</td>
<td>4 (4–5)</td>
<td>14 (11–16)</td>
<td>82.6% (19)</td>
<td>8.7% (2)</td>
</tr>
<tr>
<td>2nd shock 16</td>
<td>5 (3.25–6)</td>
<td>3 (3–5)</td>
<td>14 (12–16)</td>
<td>81.3% (13)</td>
<td>18.8% (3)</td>
</tr>
<tr>
<td>3rd shock 10</td>
<td>5 (1.75–6)</td>
<td>4 (3–4.25)</td>
<td>15 (14–16.25)</td>
<td>80% (8)</td>
<td>10% (1)</td>
</tr>
<tr>
<td>4th shock 8</td>
<td>4.5 (3.25–8.75)</td>
<td>4 (3.5–5.25)</td>
<td>13.5 (13–18.25)</td>
<td>75% (6/8)</td>
<td>12.5% (1/8)</td>
</tr>
</tbody>
</table>

**p < 0.05.
† p < 0.01.

Increased interruption of CPR during the 30 s before an AED shock is attributed to the hands-off rhythm analysis period of 5.4–8.1 s of the LifePak 12 or 15. The defibrillators were programmed to instruct that 15–17 s of chest compressions should follow analysis, before shock delivery. In manual mode, paramedics wore gloves during charging, the hands were removed for rhythm analysis, and an immediate shock was then given when indicated. CPR interruptions during the 30 s pre-shock have been shown to decrease coronary perfusion pressures and the likelihood of ROSC.4,15 We attribute our higher rates of ROSC in manual mode to shorter CPR pauses in both the pre-shock phase and the 30 s preceding shock delivery.

Compared with AED mode, there was a trend towards earlier CPR and administration of the first shock in manual mode (Table 1). This differs from the finding of Stults7 although the delay to manual defibrillation in his study is attributed to a separate analysis period before the pre-shock pause and the use of paddles and gel pads.

In our study, ROSC was significantly greater for the second, third and fourth manual shocks compared with corresponding AED shocks (p = 0.013; Table 3) A number of first manual shocks had to be excluded from the study because of a lack of pre-shock CPR or the absence of a preceding 30 s record. This may explain the paradox of the 100% cardioversion success rate for the first manual shock but no associated ROSC. Some studies have shown that a lack of CPR prior to the first shock in witnessed arrests decreases ROSC rates,16,17 but there is conflicting research around this topic.18–20

There was no difference in post-shock pause times between the AED (4 s; IQR 3–5) and manual defibrillation groups (4 s; IQR 3–5; p = 0.986) indicating that CPR was resumed promptly in both situations. However, post-shock pause values of less than 2 s are not recorded as the Lifepaks transiently cease monitoring after the shock to protect electrical components.

Limitations associated with this study include the modest number of patients recruited which resulted from discontinuation of the study for ethical reasons when manual defibrillation was found to produce significantly higher ROSC. There were also more males in the AED group but the significance of this is unknown. Three shocks were excluded on the basis that they were administered during periods of non-shockable rhythm, as determined by consensus opinion between WT and MB. It is known that AEDs can occasionally misinterpret non-shockable rhythms.3 Although our basic paramedics are restricted to AED use and cannot choose between the two modes, intermediate and advanced paramedics who do have this option are always deployed either primarily or secondarily to cardiac arrests. A larger study would be required to look at survival to discharge.

5. Conclusion

When paramedics administered CPR for at least 30 s before a shock, manual defibrillation resulted in shorter pre-shock pauses and interruptions to CPR than did AED mode. Manual mode was also associated with a higher ROSC rate. These findings have prompted changes to local prehospital defibrillation protocols and teaching to emphasise that manual defibrillation is the preferred mode amongst appropriately trained paramedics.

Conflicts of interest statement

No conflicts of interest to declare.

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References


