Pauses in chest compression and inappropriate shocks: A comparison of manual and semi-automatic defibrillation attempts

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**KEYWORDS**
Automated external defibrillator (AED);
Manual defibrillator;
Out-of-hospital CPR;
In-hospital CPR;
Cardiac arrest

**Summary**

Background: Semi-automatic defibrillation requires pauses in chest compressions during ECG analysis and charging, and prolonged pre-shock compression pauses reduce the chance of a return of spontaneous circulation (ROSC). We hypothesised that pauses are shorter for manual defibrillation by trained rescuers, but with an increased number of inappropriate shocks given for a non-VF/VT rhythm.

Methods: From a prospective study of CPR quality during in- and out-of-hospital cardiac arrest, the duration of pre-shock, inter-shock, and post-shock pauses were compared with Mann–Whitney U-test during manual and AED mode with the same defibrillator, and proportions of inappropriate shocks were compared with Chi-squared tests.

Results: A 635 manual and 530 semi-automatic shocks were studied. Number of shocks per episode was similar for the two groups. All pauses measured in...
seconds (s) were shorter for manual use \((P<0.0001)\); median (25, 75 percentiles); 15 (11, 21) versus 22 (18, 28) pre-shock, 13 (9, 20) versus 23 (22, 26) inter-shock, and 9 (6, 18) versus 20 (11, 31) post-shock, but 163 (26%) manual shocks were inappropriate compared with 30 (6%) AED shocks, odds ratio (OR) 5.7 (95% CI; 3.8–8.7). A 150 (78%) of the inappropriate shocks were delivered for organised rhythms. The proportion of inappropriate manual shocks was higher for resident physicians in-hospital than paramedics out-of-hospital; 77/228 (34%) versus 86/407 (21%), OR 1.9 (1.3–2.7).

Conclusion: Manual defibrillation resulted in shorter pauses in chest compressions, but a higher frequency of inappropriate shocks. A higher formal level of education did not prevent inappropriate shocks.

Trial registration http://www.clinicaltrials.gov/ (NCT00138996 and NCT00228293).

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Introduction

The development of automated external defibrillators (AEDs) has made defibrillation more readily available for patients in cardiac arrest. A number of studies have confirmed the safety and effectiveness of AEDs, and the importance of early defibrillation,\(^1\) but population-based investigations from Seattle and Sweden have shown at best a moderate increase in survival over the years despite a decreased time to defibrillation.\(^2,3\)

Studies have shown that the probability of successful defibrillation and subsequent return of spontaneous circulation (ROSC) deteriorates rapidly with even short pauses in chest compressions.\(^4,5\) The use of AEDs requires time without chest compressions during rhythm analysis and charging, in addition to any further human delays.\(^6\) In many systems, medical personnel trained in advanced life support (ALS) are therefore encouraged to use defibrillators in manual mode to shorten time used for analysis, but for the ability to recognise different ECG-patterns may be more difficult during a stressful clinical situation than during manikin simulation.

We have recently reported on CPR quality in three ambulance services (London, Stockholm, and Akershus)\(^7,8\) and one university hospital (Chicago)\(^9\) using defibrillators modified to enable continuous monitoring of ventilation and chest compression depth and rate. The defibrillators were used in manual mode (Akershus and Chicago), or in AED mode (London and Stockholm). In this pre-planned analysis we hypothesised that manual use of the defibrillator would result in shorter pauses between chest compression and subsequent shock (pre-shock pause), between shocks (inter-shock pause), and from last shock in a series to the resumption of chest compressions (post-shock pause), but more frequent shocks for non-VF/VT rhythms (i.e., inappropriate shocks).

Materials and methods

Methods, especially regarding CPR-sensing technology and subject enrolment, have been presented in detail previously.\(^7–9\) The present description of study methods highlights concepts particular to this analysis of defibrillation and compression pauses.

Study design and recruitment

In this prospective observational study, patients older than 18 years suffering from out-of-hospital cardiac arrests were included between March 2002 and September 2004 (Akershus, Stockholm and London). Patients with in-hospital cardiac arrests were similarly included between December 2002 and December 2005 if the arrest did not occur in the operating theatre or emergency room (Chicago). The study protocol was approved by the regional ethics committees for Akershus (Norway), Stockholm (Sweden) and London (UK), respectively, and the institutional review board at the University of Chicago Hospitals (USA). Informed consent for inclusion in the study was waived as decided by these committees in accordance with paragraph 26 in the Helsinki Declaration.\(^10\) The testing of manual versus AED defibrillation was part of the original research plan. This clinical study was registered at ClinicalTrials.gov as NCT00138996 (out-of-hospital) and NTC00228293 (in-hospital).

Equipment

Prototype defibrillators were deployed in six ambulances at each site and one defibrillator was used by the in-hospital resuscitation team at the University of Chicago. These investigational devices were based on a standard Heartstart 4000 biphasic defibrillator (Philips Medical Systems, Andover, MA, USA) with the addition of an extra chest sensor designed for placement on the lower part of the sternum with double adhesive tape. This chest pad was out-
fitted with an accelerometer (ADXL202e, Analog Devices, USA) and a pressure sensor (22PCCFB66, Honeywell, USA), so that both chest compression rate and depth could be assessed and recorded.11 Trans-thoracic impedance was measured by applying a near constant sinusoidal current across the standard defibrillation pads and both accelerometer and impedance signals were stored on a data card fitted in the defibrillators. The programming of voice prompts and automatic rhythm analysis algorithms were unaltered by the modification process and the default start-up mode (manual or AED) was pre-programmed at each site.

Automated feedback on quality of CPR was provided from October 2003 to December 2004 for out-of-hospital and in-hospital rescuers, respectively. The feedback consisted of tracings on an LCD display of chest compression depth and rate, ventilations, and duration of periods without chest compressions, as well as verbal prompts in the national language if measured quality was outside predefined limits.7 The system gave a tonal prompt after 15 s without chest compressions, and verbal prompts to resume CPR after 30, 45, and 60 s.

Training and treatment protocol

All ambulances were staffed with paramedics trained and tested in the use of this modified defibrillator, as well as annual ALS certification according to the 2000 international guidelines,12 coincident with the start of the study period. Stockholm had a two-tiered system with a nurse anaesthetist in the second ambulance attending cardiac arrests, but the modified defibrillators were dispatched with the first response vehicle at all sites. In Akershus there was one modification in that patients with ventricular fibrillation (VF) or pulseless ventricular tachycardia (VT) received three minutes of CPR before the first DC shock and between unsuccessful series of three DC shocks.13 In-hospital arrests in Chicago were managed by a resuscitation team where all users were certified in either basic life support (medical students and nurses), advanced cardiovascular life support (all physicians), or both. The same type of defibrillators was used in manual mode in Akershus and Chicago and as AEDs in semi-automatic mode in Stockholm and London.

Data collection and processing

Data from each episode included scanned patient report forms and locally adapted Utstein style forms,14 ECG-signals, time stamps, resuscitation events, accelerometer signals, and trans-thoracic impedance were collected from defibrillator data cards. Data from each case were viewed and annotated with custom software designed for this study (Sister Studio, Laerdal Medical, Stavanger, Norway). Compressions were calculated from the accelerometer signal. Ventilations were automatically detected by changes in thoracic impedance corrected for compression and blood flow related signals. Return of spontaneous circulation (ROSC) was annotated based on times noted in the ambulance journal and/or QRS-related changes in the trans-thoracic impedance signals.15 Annotations were scrutinised and corrected manually if needed by consensus of one of the authors and one engineer with in-depth knowledge of the sampling technology. A number of collected episodes were not available for annotation and CPR quality evaluation. The reasons for exclusion have been described in detail previously.7—9 Each defibrillation attempt was identified and ECG rhythm immediately before and 5 s after each attempt was recorded. Pre-shock, inter-shock, and post-shock pauses in chest compressions were recorded. A stack of shocks was defined as two or more subsequent shocks separated by fewer than 10 chest compressions or less than 1 min without any chest compressions.

To determine the human delay component of these pause times, the time necessary for analysis, charging and reanalysis was determined for every shock, using the time stamps from the defibrillator. If there was an organised rhythm following a defibrillation, a maximum of 10 s was allowed for pulse check. For the manual mode, rescuers were allowed 5 s for rhythm analysis. The total pause time minus this "necessary" time constitutes the potential for improvement in these systems with this particular defibrillator. An example of the intervals is illustrated in Figure 1.

Outcome and statistical analysis

The primary outcome was length of pauses in chest compressions around defibrillation attempts in manual versus AED mode. We also report the number of shocks applied for rhythms other than VF/VT and rhythm transition tables with defibrillation success rates.

Data were collected and organised using a spreadsheet programme (Microsoft® Excel 2003, Microsoft Corporation, USA) and statistical analysis performed with SPSS for Windows (SPSS for Windows® Version 12.0, Chicago, USA). Results are expressed as medians with 25- and 75-percentiles or as mean ± standard deviation if close to the normal distribution. Continuous data were compared with Mann—Whitney U-test unless otherwise stated, and proportions were compared with Chi-
squared tests with continuity correction. Odds ratios (OR) with 95% confidence levels (95% CI) are provided when appropriate. Adjusted OR were obtained from a logistic regression analysis with post-shock organised rhythm (yes/no) as dependent variable and mode of defibrillation (manual/semi-automatic), time to defibrillation (from the start of the episode), and pre-shock pause as independent variables. Two-sided P-value less than 0.05 were considered significant.

Results

Of the total 560 cases, 481 (86%) had reliable CPR quality registrations. A 223/481 (46%) episodes had at least one defibrillation attempt. The characteristics of these episodes are summarised in Table 1. The in-hospital group had a smaller proportion of episodes with at least one defibrillation and VF/VT as first rhythm, a higher proportion of female patients, and a younger mean patient age. There were no significant differences between the manual and semi-automatic groups in these characteristics. There were 3 (2–6) defibrillation attempts per episode in the manual group and 3.5 (1–9) in the semi-automatic group, P = 0.8.

In the 223 episodes a total of 1187 shocks were delivered. Twenty-two (2%) shocks delivered at the very end of failed resuscitation episodes were excluded from further analysis. The characteristics of the remaining 635 manual and 530 AED shocks are summarised in Tables 2 and 3. There were no differences in the proportions of defibrillation attempts as the first, second, third or subsequent number in a stack of shocks between manual and AED groups (Table 2). Consequently the proportions of pre-, inter-, and post-shock pauses available for analysis were similar (Table 3).

All pauses were significantly shorter during manual defibrillation attempts with a large range (Table 3). In AED mode rhythm analysis resulting in a ‘‘shock advised” message took 7.7 ± 1.4 s with a 3 s defibrillator time-out before charging for 2.5 ± 0.4 s. Charge time was identical in the two groups. This resulted in longer “necessary” pre-shock compression pauses in the AED group; 13.5 ± 2.4 s versus 8.0 ± 1.7 s in the manual group. Interestingly, the human delays (i.e., after correcting for the time required for rhythm analysis and pulse checks if appropriate) were also longer for AED defibrillation attempts (Table 3). Post-shock pause duration depended on the resulting rhythm (Table 4) and this was true for both manual and AED mode (data not shown).

The resulting rhythm for all appropriate shocks is given in Table 2. Manual defibrillation attempts resulted more often in an organised rhythm; unadjusted OR for an organised rhythm after a manual shock 1.8 (1.4–2.4). If the OR was adjusted for time to defibrillation in the episode and length of pre-shock pause in a logistic regression model it was 1.7 (1.2–2.3), P = 0.001. The defibrillation success
Table 1  Patient and episode characteristics in all 481 episodes and in the 223 out-of-hospital (ooh) and in-hospital (ih) episodes with at least one shock that were included in this study

<table>
<thead>
<tr>
<th></th>
<th>Total cohort, $n=481$</th>
<th>At least one shock, $n=223$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akershus (ooh)</td>
<td>102</td>
<td>61 (60%)</td>
</tr>
<tr>
<td>London (ooh)</td>
<td>97</td>
<td>56 (58%)</td>
</tr>
<tr>
<td>Stockholm (ooh)</td>
<td>85</td>
<td>43 (51%)</td>
</tr>
<tr>
<td>Chicago (ih)</td>
<td>197</td>
<td>63 (32%)</td>
</tr>
<tr>
<td>Age, mean ± S.D.</td>
<td>ooh: 68 ± 14; ih: 62 ± 17</td>
<td>ooh: 69 ± 13; ih: 59 ± 17; total: 66 ± 15</td>
</tr>
<tr>
<td>Male sex</td>
<td>ooh: 208 (73%); ih: 104 (54%)</td>
<td>ooh: 120/160 (88%); ih: 36/63 (57%); total: 156/223 (70%)</td>
</tr>
<tr>
<td>VF/VT as initial rhythm</td>
<td>ooh: 111 (39%); ih: 33 (17%)</td>
<td>ooh: 108/160 (68%); ih: 26/63 (41%); total: 134/223 (60%)</td>
</tr>
<tr>
<td>Manual defibrillator mode</td>
<td>ooh: 102 (36%); ih: 197 (100%)</td>
<td>ooh: 61/160 (38%); ih: 63/63 (100%); total: 124/223 (56%)</td>
</tr>
</tbody>
</table>

* $P<0.01$ vs. out-of-hospital group, Student’s $t$-test.
** $P<0.05$ vs. out-of-hospital group, Chi-square test.

Table 2  Characteristics of 1165 shocks with manual and AED use of defibrillators

<table>
<thead>
<tr>
<th></th>
<th>Manual, $n=635$</th>
<th>AED, $n=530$</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of shocks as</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First</td>
<td>430 (69%)</td>
<td>368 (71%)</td>
<td>0.2</td>
</tr>
<tr>
<td>Second</td>
<td>122 (19%)</td>
<td>104 (20%)</td>
<td></td>
</tr>
<tr>
<td>or third in a stack$^a$</td>
<td>76 (12%)</td>
<td>46 (9%)</td>
<td></td>
</tr>
<tr>
<td>Inappropriate shocks (on non-VF/VT rhythm)</td>
<td>163 (26%)</td>
<td>30 (6%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Fraction of inappropriate shocks for an organised rhythm</td>
<td>128/163 (79%)</td>
<td>22/30 (73%)</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Manual, $n=472$  AED, $n=500$  P-value

|                         |                   |              |         |
| Resulting rhythm 5 s after shock on VF/VT |                   |              |         |
| Persistent VF/VT      | 183 (39%)         | 199 (40%)    | 0.8     |
| Asystole               | 117 (25%)         | 183 (37%)    | <0.001  |
| Pulseless electric activity | 139 (29%) | 103 (21%) | 0.002   |
| Pulse generating rhythm | 33 (7%)          | 16 (3%)     | 0.01    |

Two-sided P-value from Chi-squares tests with continuity correction.
$^a$ The number of shocks does not add up as 7 (1%) manual and 11 (2%) AED defibrillation attempts were delivered as fourth, fifth, sixth, or seventh in a stack.

rates for the first shock in a stack, defined as the termination of VF/VT for at least 5 s, were 239/338 (71%) and 242/353 (69%) for manual and AED use, respectively ($P=0.6$).

Table 3  Pauses before, between, and after 472 manual and 500 AED shocks delivered on VF/VT

<table>
<thead>
<tr>
<th></th>
<th>Manual</th>
<th>AED</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-shock pause ($n=338$ and 353)</td>
<td>15 (11, 21), range 1–220</td>
<td>22 (18, 28), range 2–201</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Pre-shock human delay</td>
<td>7 (2, 13), range 0–212</td>
<td>8 (4, 14), range 0–187</td>
<td>0.01</td>
</tr>
<tr>
<td>Inter-shock pause ($n=134$ and 147)</td>
<td>13 (9, 20), range 2–73</td>
<td>23 (22, 26), range 3–66</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Inter-shock human delay</td>
<td>4 (1, 12), range 0–66</td>
<td>9 (8, 11), range 0–52</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Post-shock pause ($n=307$ and 345)</td>
<td>9 (6, 18), range 0–258</td>
<td>20 (11, 31), range 1–374</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Post-shock human delay</td>
<td>3 (0, 9), range 0–243</td>
<td>12 (4, 23), range 0–355</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Times in s, values are medians with 25- and 75-percentiles and ranges. Two sided P-value from Mann–Whitney $U$-test. Human delays represent the pauses corrected for the time required for rhythm analysis, charging, and pulse checks if appropriate, see text and Figure 1 for explanation. The numbers of pre- and post-shock pauses differ as some shocks resulted in ROSC.

The numbers of shocks given for incorrect indications were higher for the manual than the AED mode with OR for a manual inappropriate shock 5.7 (3.8–8.7) (Table 2). Most inappropriate shocks
Table 4 Post-shock pauses grouped by resulting rhythm for 652 shocks delivered on VF/VT

<table>
<thead>
<tr>
<th>Post-shock pause</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asystole (n=268)</td>
<td>17 (9, 28)</td>
</tr>
<tr>
<td>VF/VT (n=161)</td>
<td>11 (6, 21)</td>
</tr>
<tr>
<td>PEA (n=184)</td>
<td>19 (9, 34)</td>
</tr>
<tr>
<td>Pulse generating rhythm (n=39)</td>
<td>n.a</td>
</tr>
</tbody>
</table>

Times in s, values are medians (25 and 75 percentiles). Two sided P-value from Mann—Whitney U-test.

(78%) were delivered for an organised rhythm (PEA or pulse generating rhythm) both in manual and AED mode (Table 2). The rhythm changed after 18/163 (11%) manual and 2/30 (7%) semi-automatic inappropriate shocks, and nine shocks (5%) resulted in new VF/VT. Six shocks on organised rhythms (4%) were followed by new VF/VT and six (4%) by asystole. All of these 12 were cases of PEA at the time of the shock with no sign of pulsed blood flow from the impedance measurements.

The proportion of inappropriate shocks in manual mode was higher for resident physicians in-hospital than paramedics out-of-hospital; 77/228 (33%) versus 86/407 (21%) with OR 1.9 (1.3—2.7), P = 0.001.

Return of spontaneous circulation (ROSC) occurred after 112/972 (12%) correctly applied shocks, and ROSC probably occurred without any new chest compressions in more than half of these cases (64/112). The delay to ROSC varied from immediately after shock to 20 min after the shock. Figure 2 shows the temporal distribution of the delay from defibrillation to ROSC for the cases with and without chest compressions between defibrillation and ROSC.

Discussion

In this prospective study peri-shock intervals without chest compressions were shorter with defibrillators in manual mode than in AED mode, but more inappropriate shocks were given in manual mode.

Such intervals without chest compressions have only been studied previously during the use of AEDs,16–19 and the present findings in the AED group are similar to previous findings. Sunde et al found median 20 s pre-shock pauses for ambulance personnel using Heartstart 3000 defibrillators (Laerdal Medical, Stavanger, Norway).16 Valenzuela et al. found median inter-shock pauses to be 27–30 s with the use of Lifepak500 or Lifepak12 defibrillators (Medtronic Emergency Response Systems, Seattle)17 while Rea et al. and Berg et al. recently reported post-shock pauses of median 29 s (several different defibrillators)18 and a range of 15–61 s (Lifepak500)19, respectively. The programmed interruptions due to automated analysis and voice prompts from AEDs have been shown to vary between different manufacturers from 5 to 28 s from the last chest compression to shock delivery.5 Some investigators have advocated manual use of defibrillators to shorten these time intervals, and we have shown that manual use of the same defibrillator could reduce the median length of pauses by 30–55%.

The human delay component of compression pauses was longer in the AED than the manual group. This was true for all time intervals studied and suggests that manual defibrillator mode was associated with a more aggressive approach to CPR and defibrillation. This could be the effect of a higher awareness regarding the importance of CPR quality in the two sites that used defibrillators in manual mode, but when the higher rate of inappropriate shocks is considered it might be argued that the pre-shock pause times in the manual group may have actually been too short.

The consequences of peri-shock pauses have been studied in animal models, in a retrospective analysis of human data,4 and in a sub-analysis of the material presented in the present paper.20 In both porcine2 and rodent21 models, prolonged pre-shock pauses reduced chances for successful defibrillation and survival. Simulating the
difference in pauses between manual and AED defibrillation in a porcine model Berg et al. found that longer pauses without chest compressions resulted in less frequent ROSC and no survival in the AED group.22 In a retrospective analysis of human VF tracings the predicted probability of ROSC after a defibrillation attempt declined during a 20 s chest compression pause.4 In a study of the first shocks in resuscitation episodes, Edelson et al. found termination of VF to be associated with shorter pauses before the shock, as well as deeper chest compressions immediately preceding the shock.20 Pauses after shocks are also detrimental as any pause in chest compressions during CPR reduces blood flow to the heart and brain.23 The effects have not been directly evaluated in an animal model, except in an abstract by Chang et al.24

Peri-shock pauses could be shortened by encouraging continued chest compressions after rhythm analysis and as close to the shock as is possible and safe. In some AEDs, confirmatory rhythm analysis is performed right up to the time of the shock, and rhythmic chest compressions can then result in shock abortion. In manual mode, chest compressions can be provided during defibrillator charging, and this could improve shock outcome based on animal studies and retrospective human data.3,4,20,21 In the present study, this was not a part of the curriculum at any of the sites and there were hardly ever any chest compressions from the start of pre-shock analysis until after the post-shock analysis in any group. In our institutions, we now emphasise minimising pauses in chest compressions by this approach during both manual and AED mode. Technological advances such as automatic rhythm analysis during compressions25 and mechanical chest compression devices that can compress continuously during defibrillation attempts can reduce the duration of pauses in chest compressions.

Inappropriate shocks were surprisingly common. Even in the AED group 30/530 (6%) were inappropriate. This is more than expected from the required >95–99% specificity for non-shockable rhythms.26 These ideal numbers are based on noise-free ECG signals. A common feature of many inappropriate AED shocks were noise from movement of leads or chest pads during analysis. As expected the frequency was much higher in the manual group, but it was surprising that 20% of all manual shocks were delivered for an organised rhythm. With each shock, an electrical current passes through the myocardium, and some investigators have found an association between amount of energy delivered and degree of post-resuscitation myocardial dysfunction.27 However, each shock also results in cumulative time without chest compressions, and the cumulative time without chest compressions might also be a determinant of cardiac adverse effects.28 In the case of inappropriate shocks this risk of damage to the myocardium is not balanced by a chance of terminating a non-circulating rhythm. The worst scenario would be a shock terminating spontaneous circulation. Fortunately, there was no evidence of spontaneous circulation from the impedance signals before the 12 inappropriate shocks which converted organised rhythms into VF or asystole, in the present study. All were cases of PEA.

The higher rate of inappropriate manual shocks during in-hospital resuscitation with physicians as team leaders than for paramedics out-of-hospital could be due to the fact that the physicians were internal medicine residents at varying stages of their training programme on a 1 month cardiology rotation. Thus it is possible that their practical experience of resuscitation events was rather low, despite high levels of formal education. The resuscitation team in-hospital consists of more personnel than the typical out-of-hospital team, and organisational issues would seem to be more crucial. The team approach to resuscitation with clearly defined roles and tasks needs to be practised with special attention to decision making and communication.29

We found that nearly half the instances of ROSC after a shock occurred within the first 30 s. This is in contrast to Rea et al. who found that this occurred in only 10%.18 The median post-shock pause was longer in their study, but their criteria for detecting ROSC were different from ours. They only recorded clinically detected pulses, while we also included pulses assessed from QRS-related trans-thoracic impedance changes.15 The manual detection of pulse and pulselessness can be difficult especially at low arterial blood pressures,30 but on the other hand the impedance technique might be too sensitive, recognising forward blood flow that might be clinically unsatisfactory. Using impedance changes as indication of circulation has been partly validated in a clinical resuscitation setting in intensive care patients.31

Our study is limited by the lack of randomisation and the fact that defibrillator mode was site-dependent. The defibrillator mode could therefore be a surrogate for general skills in CPR in that particular service or set of users, and the differences found could then be a combined measure of skills and defibrillator features. Randomisation to different modes would however require training and certifying paramedics in Stockholm and London to enable them to defibrillate manually, which was beyond the scope of this study. A spill-over of manual skills in ECG interpretation could also have influenced the AED users. We cannot exclude the
Manual vs. Semi-automatic defibrillation mode

Manual defibrillation attempts resulted in less time without chest compressions than AED use of identical defibrillators, but a higher proportion of inappropriate shocks. A higher formal level of education did not prevent inappropriate shocks.

Conclusion

Manual defibrillation attempts resulted in less time without chest compressions than AED use of identical defibrillators, but a higher proportion of inappropriate shocks. A higher formal level of education did not prevent inappropriate shocks.

Conflict of interest statements

All authors have received funding and technical support for research projects regarding quality of CPR from Laerdal Medical and Philips Medical Systems. Drs. Abella, Becker, and Edelson have received honoraria from Laerdal Medical and/or Philips Medical Systems. Dr. Wik is on a medical advisory board for Medtronic Medical. Dr. Steen is a board member of Laerdal Medical and The Norwegian Air Ambulance Foundation.

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