Simulation and education

Effects of AED device features on performance by untrained laypersons

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Objective: Our study evaluates the impact of features of automated external defibrillators (AEDs) on the performance and speed of untrained laypersons to deliver a shock and initiate CPR after a shock.

Methods: This was a randomized trial of volunteer laypersons without AED or advanced medical training. Subjects were assigned to use one of six different models of AEDs on a manikin in simulated cardiac arrest. No instructions on AED operation were provided. Primary endpoints were shock delivery and elapsed time from start to shock. Secondary endpoints included time to power-on, initiation of CPR, adequacy of pad placement and subjects’ ratings of ease of use (1 = very easy, 5 = very difficult).

Results: Most subjects (109/120; 91%) were able to deliver a shock. Median time from start of scenario to shock delivery was 79 s (IQR: 67–99). Of the 11 participants who did not deliver shock, eight never powered on the device. Time to power-on was shorter in devices with open lid (median 12 s, IQR 8–27 s) and pull handle (17 s, IQR 9–20 s) mechanisms than with a push button (37 s, IQR 18–69 s; p = 0.000). Pad position on the manikin was judged adequate for 86 (77%) of the 111 subjects who placed pads. Devices which gave more detailed voice instruction for pad placement had higher rates of adequate pad position (38/39 (97%) versus 50/73 (68%); p = 0.001). With AEDs that provided step-by-step CPR instruction, 49/58 (84%) subjects began CPR compared to 26/51 (51%) with AEDs that only prompted to start CPR (p = 0.01). Participants rated all the models easy to use (overall mean 1.48; individual device means 1.28–1.71).

Conclusions: Most untrained laypersons were successful in delivering a shock. Device features had the most impact on these functions: ability and time to power-on device, adequacy of pad position and initiation of CPR.

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1. Introduction

Sudden cardiac arrest (SCA) is the leading cause of death among adults in the United States, striking as many as 325,000 individuals per year.1 A common cardiac rhythm disturbance associated with sudden cardiac arrest is ventricular fibrillation (VF), for which the only effective treatment is rapid defibrillation.

New simplified automated external defibrillators (AEDs) enable untrained laypersons to deliver shocks to victims of cardiac arrest. A simulation study showed that sixth graders can deliver a rescue shock only 30 s slower than an experienced emergency medical technician or paramedic.2 Another study showed that a 30 min course in CPR and AED use was equivalent to the traditional full length course even after 6 months had passed, and that the AED was applied 93% of the time.3 Additionally, a recent study using three distinct methods of instruction to teach AED application and CPR showed that all three methods were highly effective at instructing participants on AED use.4

There are many AED models available and these models have been shown to have varying success rates when used by laypersons. These models have similar functions, but features that affect the ease and speed of use vary among the devices. Simulation studies have shown marked variation in layperson operation.5–9 Since rapid defibrillation is of paramount importance in the treatment of SCA, it is important to identify what makes a device easy to use.

The majority of studies involving layperson AED use focus on the operation of the overall device and how quickly a shock can be delivered.5–10 One study looked at pad placement and successful shock delivery,4 and another study looked at the time from first shock to the initiation of CPR.8 This study focuses on specific ergonomic features of AEDs and how they affect the ease and speed with which a shock can be delivered, and how quickly after a shock CPR is initiated. We
hypothesized that successful device operation is based on the ability to rapidly perform these main steps: turning the device on, placing the pads, delivering a shock, and starting CPR.

2. Methods

This was a prospective, randomized, observational evaluation of features of selected trainer AEDs in a controlled simulation environment. Volunteer subjects were assigned to one of the devices using a computer generated randomization table (Microsoft Excel). Cross-over design was not used due to concern for learning effect. The study was conducted at a university-affiliated sports medicine clinic and at a university event center.

A “trainer AED” was defined for this study as a training device designed to not deliver an electrical current while simulating shock or a clinical device with the shock function modified to prevent actual shock delivery. The devices were otherwise similar to the actual clinical devices.

The model of AED for each manufacturer was selected and provided by the manufacturer as the model that would be easiest for use by untrained lay persons. Device features were categorized a priori by the authors as shown in Table 1. Voice instruction for pad placement was categorized as simple or detailed. Simple instruction was voice prompt stating only to place pads on chest; detailed included more step-by-step instruction such as to remove backing from pads and more specific location description. All AEDs were programmed according to The American Heart Association 2000 Guidelines.

Volunteer subjects were recruited by flyers and direct contact with the investigators. The only exclusion criteria were prior training or experience in the use of an AED. Subjects received a five dollar gift card for use at the on-site coffee shop.

The study protocol was as follows: after agreeing to participate, subjects were screened for prior AED training and/or use and informed consent was obtained. The subject was given an instruction card that read, “In the adjacent area you will find a manikin and a projected card that read, “In the adjacent area you will find a manikin and a gift card for use at the on-site coffee shop.”

The protocol included time and event data were collected using simulation training software (SimMan, Laerdal Corporation) and transferred to Microsoft Excel. Times for the following actions were recorded: start of scenario, AED power-on, pads placed, shock delivered, and start of CPR. The manikin’s chest was photographed at the end of the scenario. Using the photos, a paramedic and a nurse not associated with the study independently evaluated the adequacy of pad placement for every scenario. They were instructed to judge each case as “adequate” or “not adequate” based on pad location and placement on bare skin to deliver successful shock. In the event they were unable to agree, an EMS physician not involved in the study was consulted to make the final determination.

Primary endpoints were shock delivery and elapsed time from start of scenario to shock. Sample size determination was calculated based on power of 0.8 to detect 25% absolute difference from 90% of subjects performing shock delivery with alpha at 0.05; this yielded need for 102 subjects. Secondary endpoints included time to power-on, time from second rhythm analysis to initiation of CPR, adequacy of pad placement and subject survey responses. Dichotomous data were compared with Chi-square or Fisher’s exact test and continuous data with ANOVA. We compared performance differences among ergonomic features using survival analysis. Subjects rated the ease of use on a 5-point Likert scale (1 = very easy, 5 = very difficult). Data were analyzed using Microsoft Excel and STATA. We compared elapsed time differences using the Kaplan–Meier log-rank and Kruskal–Wallis tests. Only subjects who completed the specific task were included in time analyses.

This study was approved by the university Institutional Review Board.

3. Results

One hundred and twenty persons participated in the study. All but one completed high school and 45% had obtained a bachelor
Table 2
Participant characteristics.

<table>
<thead>
<tr>
<th>Device</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Language</th>
<th>Education</th>
<th>Medical training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median (range)</td>
<td>Male (%)</td>
<td>English (%)</td>
<td>Bachelor (%)</td>
<td>None (%)</td>
</tr>
<tr>
<td>Cardiac science (20)</td>
<td>21.5 (18–59)</td>
<td>9</td>
<td>18</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Heartsine (20)</td>
<td>25.5 (19–61)</td>
<td>13</td>
<td>19</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Medtronic (20)</td>
<td>23.0 (18–66)</td>
<td>9</td>
<td>19</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>Phillips (20)</td>
<td>27.0 (18–77)</td>
<td>9</td>
<td>19</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Welch Allyn (20)</td>
<td>24.5 (18–60)</td>
<td>9</td>
<td>19</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Zoll (20)</td>
<td>32.0 (18–64)</td>
<td>9</td>
<td>19</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>All models (120)</td>
<td>25.0 (18–77)</td>
<td>9</td>
<td>19</td>
<td>8</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 3
Subject performance of individual steps by device model.

<table>
<thead>
<tr>
<th>Device</th>
<th>Powered on, N (%)</th>
<th>Pads placed on chest, N (%)</th>
<th>Adequate pad location, N (%)</th>
<th>Shock delivered, N (%)</th>
<th>CPR started, N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac science (20)</td>
<td>19 (95)</td>
<td>18 (90)</td>
<td>16 (89)</td>
<td>18 (90)</td>
<td>16 (80)</td>
</tr>
<tr>
<td>Heartsine (20)</td>
<td>16 (80)</td>
<td>17 (85)</td>
<td>11 (65)</td>
<td>16 (80)</td>
<td>9 (45)</td>
</tr>
<tr>
<td>Medtronic (20)</td>
<td>20 (100)</td>
<td>20 (100)</td>
<td>17 (85)</td>
<td>20 (100)</td>
<td>15 (75)</td>
</tr>
<tr>
<td>Phillips (20)</td>
<td>20 (100)</td>
<td>20 (100)</td>
<td>20 (100)</td>
<td>20 (100)</td>
<td>18 (90)</td>
</tr>
<tr>
<td>Welch Allyn (20)</td>
<td>19 (95)</td>
<td>17 (85)</td>
<td>12 (70)</td>
<td>17 (85)</td>
<td>8 (40)</td>
</tr>
<tr>
<td>Zoll (20)</td>
<td>18 (90)</td>
<td>19 (85)</td>
<td>10 (53)</td>
<td>18 (90)</td>
<td>9 (45)</td>
</tr>
<tr>
<td>All models (120)</td>
<td>112 (93)</td>
<td>111 (92)</td>
<td>86 (77)</td>
<td>109 (91)</td>
<td>75 (62)</td>
</tr>
</tbody>
</table>

Table 4
Comparison of individual step time intervals by device model (median times (s (IQR))).

<table>
<thead>
<tr>
<th>Device</th>
<th>Start to on</th>
<th>On to pad placement</th>
<th>Pad placement to shock</th>
<th>Overall time to shock</th>
<th>Shock to CPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac science</td>
<td>8 (5–9)</td>
<td>68 (57–80)</td>
<td>34 (32–35)</td>
<td>101 (90–110)</td>
<td>45 (38–69)</td>
</tr>
<tr>
<td>Heartsine</td>
<td>32 (13–51)</td>
<td>43 (21–44)</td>
<td>23 (21–25)</td>
<td>62 (62–70)</td>
<td>34 (34–45)</td>
</tr>
<tr>
<td>Medtronic</td>
<td>25 (17–38)</td>
<td>48 (40–53)</td>
<td>26 (24–32)</td>
<td>76 (67–86)</td>
<td>44 (35–51)</td>
</tr>
<tr>
<td>Phillips</td>
<td>17 (9–20)</td>
<td>59 (51–65)</td>
<td>25 (25–26)</td>
<td>84 (77–97)</td>
<td>44 (34–55)</td>
</tr>
<tr>
<td>Welch Allyn</td>
<td>37 (19–54)</td>
<td>27 (18–45)</td>
<td>21 (16–28)</td>
<td>56 (36–74)</td>
<td>47 (40–48)</td>
</tr>
<tr>
<td>All models</td>
<td>20 (10–44)</td>
<td>51 (39–67)</td>
<td>25 (23–33)</td>
<td>79 (67–99)</td>
<td>42 (35–53)</td>
</tr>
</tbody>
</table>

4. Discussion

Many cardiac arrest victims who now die can be saved with prompt defibrillation. For this to occur, laypersons must be able to use AEDs quickly and effectively. Our study found that a high per-
The devices with the open lid and pull handle power-on mechanisms had large identifying words or indicators easily noticed by the participants. The start buttons proved to be more difficult to locate and when the device was housed in a zipper case the amount of time it took for the study participant to push the start button increased by doubling their task load. Only two models took users significantly longer than the others to deliver a shock and one of the devices also took subjects longer to power-on by pushing a button. Overall, powering on the device on was the single most rate limiting step as eight participants were unable to accomplish this task.

Proper pad placement is likely affected by multiple variables, including visual and audible instructions, location of pads in device or device case, and ease of backing removal. Pad placement was deemed adequate more often when the device gave more detailed voice instruction. One exception was the Medtronic device, which deemed adequate more often when the device gave more detailed step-by-step instruction. The devices with the open lid and pull handle power-on mechanisms had large identifying words or indicators easily noticed by the participants. The start buttons proved to be more difficult to locate and when the device was housed in a zipper case the amount of time it took for the study participant to push the start button increased by doubling their task load. Only two models took users significantly longer than the others to deliver a shock and one of the devices also took subjects longer to power-on by pushing a button. Overall, powering on the device on was the single most rate limiting step as eight participants were unable to accomplish this task.

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tion, including talking the user through chest compressions, as lay rescuers are more likely to perform CPR with instruction than without, as concluded in another study. The visibility of power-on mechanism, the ease of finding pads, clarity and preciseness of pad placement instructions and step-by-step CPR instruction are ergonomic features that can be modified to assist the lay rescuer in increasing the ease and speed of use of the AED. We suggest that for each step of AED operation, both the clarity and completeness of instructions (aural and visual) and the intrinsic ergonomic attributes of the device should be optimized.

Device features associated with increased performance rate were not always associated with shorter times to shock. This may reflect benefit of more detailed instructions for untrained users. Trained users may be able to deliver shock faster with less intensive verbal instruction.

Our study has a number of important limitations. Performance in a simulated setting may not reflect actions in an actual cardiac arrest. Subjects may not have represented the general US population, as 45% completed college, only 2 were over the age of 65, and none were under the age of 18. We presumed all subjects were truthful, and did not use an AED or have any prior AED training. In six cases English was not the primary language and this may have impeded those subjects’ ability to follow the instructions and prompts correctly. Some photos of pad placement were not labeled properly so we could not determine the number of subjects who both delivered shock and placed pads in adequate position. Features not assessed in this study may also impact device use; we tried to select those that seemed most important.

Future studies could explore the effect of non-standard pad location on shock success, factors that might improve the location of pad placement and the ability of untrained individuals over the age of 65 or under the age of 18 to operate an AED.

5. Conclusion

In a simulated cardiac arrest setting, most untrained AED users were able to deliver a shock within 180 s. Pad placement was often inadequate. Device features were found to have the most impact on time to power-on, accuracy of pad placement and initiation of CPR.

Conflicts of interest

VNM receives compensation for serving as medical director from the Sudden Cardiac Arrest Association, Washington, DC, a non-profit organization which promotes greater awareness and prevention and better treatment of sudden cardiac arrest.

Funding sources

AED devices were loaned and disposable supplies provided by the manufacturers of the six devices used in the study. The final study design and manuscript were solely determined by the authors. Manufacturers did not have access to the study database.

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References
