# Comparison of Naive Sixth-Grade Children With Trained Professionals in the Use of an Automated External Defibrillator

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***Background*****—**Survival after out-of-hospital cardiac arrest (OHCA) is strongly influenced by time to defibrillation. Wider availability of automated external defibrillators (AEDs) may decrease response times but only with increased lay use. Consequently, this study endeavored to improve our understanding of AED use in naive users by measuring times to shock and appropriateness of pad location. We chose sixth-grade students to simulate an extreme circumstance of unfamiliarity with the problem of OHCA and defibrillation. The children's AED use was then compared with that of professionals.

***Methods and Results*****—**With the use of a mock cardiac arrest scenario, AED use by 15 children was compared with that of 22 emergency medical technicians (EMTs) or paramedics. The primary end point was time from entry onto the cardiac arrest scene to delivery of the shock into simulated ventricular fibrillation. The secondary end point was appropriateness of pad placement. All subject performances were videotaped to assess safety of use and compliance with AED prompts to remain clear of the mannequin during shock delivery. Mean time to defibrillation was 90±14 seconds (range, 69 to 111 seconds) for the children and 67±10 seconds (range, 50 to 87 seconds) for the EMTs/paramedics ($P<0.0001$). Electrode pad placement was appropriate for all subjects. All remained clear of the "patient" during shock delivery.

***Conclusions*****—**During mock cardiac arrest, the speed of AED use by untrained children is only modestly slower than that of professionals. The difference between the groups is surprisingly small, considering the naïveté of the children as untutored first-time users. These findings suggest that widespread use of AEDs will require only modest training. **(*Circulation*. 1999;100:1703-1707.)**

**Key Words:** defibrillation ■ fibrillation ■ death, sudden ■ cardiopulmonary resuscitation



Sudden cardiac death (SCD) is the leading cause of death in the United States, accounting for >350 000 cases annually.[1] The vast majority of SCD cases are due to ventricular fibrillation (VF).[2] Survival to hospital discharge after out-of-hospital cardiac arrest (OHCA) remains poor, generally only in the 5% to 20% range, from the best of emergency response centers.[3] The most effective intervention for VF is rapid defibrillation. This intervention is significantly more important to survival than cardiopulmonary resuscitation[4] and is the reason that American Heart Association guidelines were rewritten to support the use of defibrillatory shocks before basic life support in a cardiac arrest.[5] In certain environments, survival rates can approach 80% to 100% when defibrillation is achieved within the first few minutes of a cardiac arrest.[6,7] Despite efforts to bolster emergency medical care by broadening training in defibrillation to include, in addition to paramedics, emergency medical technicians, response times for OHCA remain unacceptably long.

The development of automated external defibrillators (AEDs) in the early 1980s made possible the use of defibrillation by individuals other than paramedics and hospital personnel.[8] Further technological developments in the 1990s have made these devices more portable and simpler to use. With these improvements and the recognition of time to defibrillation as 1 of the most critical, if not the most important, factors in clinical outcome, AED use by laypersons has developed widespread support.[9] More widespread use of AEDs may significantly affect response times for OHCA and therefore survival. In large measure, wider availability of AEDs means that lay users will increase in number. Consequently, this study endeavored to improve our understanding of how well lay users will use AEDs by measuring use times and appropriateness of pad location in a controlled fashion. Naive users, sixth-grade students, were chosen to simulate an extreme circumstance for purposes of comparison with trained professional users.

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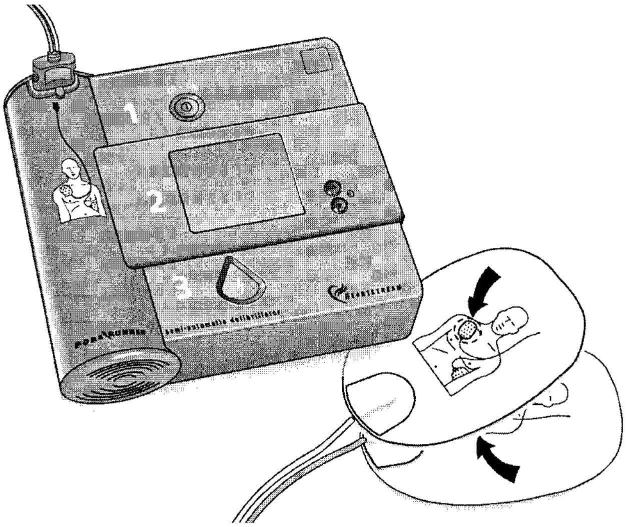

**Figure 1.** AED with electrode pads and connector.

**Steps**

1 " Apply pads to patient's bare chest."
2 " Plug in pads connector next to flashing light."
3 " Apply pads."
4 " Plug in connector."

*Steps 3 and 4 repeat every 15 seconds until completed.*

5 "Analyzing heart rhythm. Do not touch the patient."

*5 second pause.*

6 " Shock advised. Charging. Stay clear of patient."
7 " Deliver shock now. Press the orange button now."

*Step 7 repeated every 6 seconds until completed.*

8 " Shock delivered. Analyzing heart rhythm. Do not touch the patient."

*5 second pause.*

9 " Analyzing heart rhythm."

*3 second pause.*

10 " No shock advised. It is safe to touch the patient. Check airway, check breathing, check pulse. If needed begin CPR."

**Figure 2.** Sequence of AED voice prompts during mock cardiac arrest.



# Methods

## Subject Recruitment and Selection

The study was approved by the University of Washington Human Subjects Review Committee. Informed consent was obtained from each subject before the test was conducted (parental permission was obtained for the schoolchildren). Subjects were recruited by obtaining permission first from their respective training supervisors/teacher. They were required to have at least a sixth-grade reading level and no physical limitations (eg, visual or hearing handicaps or relative immobility) that would preclude the efficient use of an AED.

The 15 sixth-grade schoolchildren were selected from a single class at St Joseph Catholic School (Seattle, Wash). The entire class was recruited, but only 15 children received parental consent to participate. None of them had prior basic life support training or experience with an AED. None of the children was prompted or prepared in any way by the investigators before the study. The 22 emergency medical technicians (EMTs) or paramedics were chosen from the Kitsap County Fire Department (Bremerton, Wash). Each EMT or paramedic had extensive clinical training and experience managing a wide array of medical emergencies, including cardiac arrest. Every 6 months, each EMT or paramedic had been given a 2 1/2-hour formal workshop on AED use and its application to clinical scenarios.

## Equipment

### *AED*

The AED (Hewlett-Packard Heartstream ForeRunner AED) delivers 150-J biphasic truncated exponential waveform shocks that adjust wave shape according to chest impedance. The device measures 6×22×20 cm and weighs 2 kg. Disposable, self-adhesive defibrillation pads with integrated cable and connector are supplied with the device. Diagrams on the pads illustrate placement in an anterior-anterior (lead II) position (Figure 1). Optional PC cards include the training card TC1, which places the AED in a scenario-based training mode and disables the energy delivery system. Each subject was assured of this safety feature before beginning the test. After the device was turned on and the pads were properly positioned and connected to the device, an internal protocol evaluated the patient's ECG and signal quality to determine whether a shock was appropriate. Connection impedance for proper defibrillation pad contact was also evaluated. Voice prompts guided the user through the necessary steps (Figure 2), and abbreviated text prompts were displayed on the screen.

### *Mannequin*

The mannequin (Laerdal ResusciAnne) is widely used by the AHA for instructional purposes during advanced cardiac life support (ACLS) courses. The mannequin was fully dressed to better portray a cardiac arrest situation and to provide a natural barrier to the placement of electrode pads. Copper stripping was arranged in a grid on this mannequin to allow the AED to calculate patient impedance when electrode pads were placed during a training scenario. Voice prompts then told the subject if pads were making appropriate skin contact.

### *Video and Photography Materials*

A Sony portable video recorder and videotape of sufficient quantity to record 5 minutes documented each subject's performance. A Polaroid instant camera photographed electrode pad applications and position.

## Protocol

The subjects were informed that their performance would be evaluated in a mock cardiac arrest resuscitation on a mannequin. As part of this evaluation, the subjects were told they would be videotaped. Each subject was tested individually and could not view another's performance. The importance of speed was emphasized to each subject before the test. The only instruction given to the schoolchildren was verbal directions as to the identity of the electrode pads and the necessity of peeling them from their packaging and placing them on the mannequin's chest. (In earlier tests, lay users proved unfamiliar with the word "pads" and how to peel the cover off.) The EMTs/paramedics were not given any such instruction about the electrode pads.

The test began when the subject was handed the AED with instructions that in an adjoining room a mannequin was lying on the floor, representing an unresponsive, pulseless person. The AED was packaged in a soft case with the zipper shut. The device was kept in its usual standby mode at the beginning of the test, ie, battery inserted. Present in the testing room was a physician certified in ACLS and AED use. The physician's role was to observe the performance of the subject and give feedback after the resuscitation test was completed. A fully dressed mannequin lay supine on the floor. A video camera and operator stood at 1 corner of the room. The steps observed in performing resuscitation to first shock included (1) opening the soft case, (2) turning on the AED with a press of a single button, (3) attaching the electrode pad connector to AED, (4) applying the electrode pads to the patient, (5) safely staying clear of the mannequin while charging, and (6) administering the shock (press of a single button) when instructed by the AED.

**Time From Start of Resuscitation Scenario to AED Shock**

| Subject | EMTs/Paramedics, s | Sixth Graders, s |
|---|---|---|
| 1 | 72 | 93 |
| 2 | 70 | 69 |
| 3 | 59 | 111 |
| 4 | 52 | 88 |
| 5 | 69 | 81 |
| 6 | 59 | 69 |
| 7 | 74 | 85 |
| 8 | 74 | 105 |
| 9 | 65 | 82 |
| 10 | 50 | 109 |
| 11 | 56 | 77 |
| 12 | 72 | 98 |
| 13 | 63 | 98 |
| 14 | 77 | 103 |
| 15 | 56 | 75 |
| 16 | 58 | |
| 17 | 87 | |
| 18 | 77 | |
| 19 | 59 | |
| 20 | 65 | |
| 21 | 79 | |
| 22 | 80 | |
| Mean±SD (range) | 67±10 (50–87) | 90±14 (69–111) |
| 95% CI | 62–71 | 82–97 |
| *P* | <0.0001 | |
| 95% CI of difference | 15–31 | |

The subjects were not permitted to ask questions during the test, and no guidance or clues were provided by the researchers. After each subject's completion of the test, the physician-observer took a photograph of the electrode pad positioning. This physician then reviewed the videotape material to determine the time from beginning the test to delivering a shock. (The AED is designed to give an audible sound when the shock is delivered during the cardiac arrest scenario.) A separate physician, also certified in ACLS and AED use, independently reviewed the videotape of each mock resuscitation. This physician was not present during the training or testing process. Proper completion of each step was verified and recorded by the reviewer.

Performance of the step involving the application of pads to the patient received particular attention. Evaluation of this step was based primarily on the application of pads that would achieve an effective current vector through the left ventricle.[10–13] For practical purposes, this involves placement in an anterior-apical position (right infraclavicular–left lateral chest wall) as diagrammed on the electrode pads provided in the AED package and shown in Figure 1. An accepted range for pad positioning was diagrammed on a custom-made plastic sheet designed to consistently fit the mannequin chest wall. Subject pad application (as determined from the photograph) was compared with this range as part of the performance evaluation. The relation between subject pad positioning and the accepted range was recorded by the physician-observer (see the Data Analysis section). The accepted range for the right infraclavicular pad involves the following: cephalad border, 3 cm above the clavicle; lateral border, midaxillary line; medial border, 3 cm left of the midsternum; and caudal border, costal margin. The accepted range for the apical pad involves the following: cephalad border, top of the axilla; lateral border, midaxillary line; medial border, 2 cm right of the midsternum; and caudal border, 4 cm below the costal margin. Admittedly, these border designations are somewhat arbitrary. They are created, however, in accordance with the idea of achieving an effective current vector. Subjects were graded in a pass/fail format for this step. Criteria for passing were for all the following to be met: (1) clothing separated from mannequin chest wall before pad placement, (2) each pad placed within the accepted range (as defined above), (3) pads separated by ≥2 cm from each other, and (4) each pad interfaced by ≥50% with the mannequin chest wall.

## Data Analysis

### *Primary End Point*

The primary end point in this study, time to first shock from entry into the room of the mock cardiac arrest scenario, was chosen to represent the most crucial factor in determining survival in a cardiac arrest victim. Previous studies have suggested that a large benefit in survival from OHCA is achieved with a reduction in time to defibrillation rates of >3 minutes. A much smaller survival benefit is seen when response times differ by just 1 minute.[14] Differences in time to defibrillation rates of ≤15 seconds have not been proven to result in significant differences in survival. By use of a *t* test and 95% CIs, the mean response time of the children was compared with that achieved by the EMT/paramedic group. The sample size was selected to show a 15-second difference in AED use times ($P=0.05$, power=0.80), assuming that the AED use time for the EMT/paramedic group would be 80±15 seconds (from preliminary tests). This design required ≥15 subjects for each group.

### *Secondary End Points*

Secondary end points were chosen to assess the effectiveness of the resuscitation effort. Proper pad positioning (as outlined above) was determined in a pass/fail format and compared in a proportional manner between groups. Procedure safety was assessed by observing whether the subject stayed clear of the mannequin when instructed, ie, during device charging and shock delivery.

# Results

## Time to Defibrillation

Time from beginning the scenario to delivering the AED shock is summarized in the Table. Mean time to defibrillation was 90±14 seconds (range, 69 to 111 seconds) for the sixth-grade schoolchildren and 67±10 seconds (range, 50 to 87 seconds) for the EMT/paramedics ($P<0.0001$). The difference in mean values between the children and EMT/paramedics was 23 seconds, with a 95% CI of the difference from 15 to 31 seconds.

## Electrode Pad Positioning and Safety

Electrode pad positioning was determined to be adequate for all schoolchildren and all EMT/paramedics. All subjects in each group stayed effectively clear of the mannequin during the process of device charging and shock delivery.

# Discussion

## Technological Developments in AEDs

AEDs were first developed in the late 1970s[8] and became available for clinical use in the early 1980s.[15] The AED identifies VF in cardiac arrest victims and provides the means to deliver defibrillation shocks. The operator is neither required to make judgments regarding the cardiac rhythm nor required to acknowledge the need for defibrillatory shocks. Recent advances have enhanced the ease of use of AEDs, including instructional verbal prompts, simplified displays, and icons to help in proper pad placement. An emphasis on human-factors design has simplified the steps that the user must perform. In addition, application of more effective low-energy biphasic waveforms to these devices as a means of energy delivery has significantly reduced their size and enhanced their portable nature. The clinical utility of biphasic waveform use in victims of OHCA has been well demonstrated.[16–18] More efficient use of energy by biphasic waveform AEDs leads to smaller capacitors and batteries. This contributes to the significantly smaller overall size of the newest AEDs.

The impetus for support of the broader use of AEDs derives from observations that the single most important factor determining outcome from cardiac arrest is time to defibrillation. Providing defibrillation to a cardiac arrest victim improves survival by ≈10%/min during the first 10 minutes of the arrest.[14] Use of AEDs by trained EMTs has shown to improve survival from OHCA.[9] Likewise, use of AEDs in OHCA by police officers has significantly improved response times and yielded survival rates as high as 58%.[4] The successful use of AEDs by persons with minimal training or by nonprofessionals has now been applied also to the casino and airline industries.[7,16,17,19]

Undoubtedly, many public arenas exist in which response times by trained medical personnel may be unacceptably long. The AHA estimates that broader use of AEDs by first-line responders could avert 20 000 to 100 000 deaths per year.[20] Economic analysis has suggested that the cost per life saved from OHCA by emergency medical systems that provide EMTs with defibrillation training may be less than $5000, a value well below that addressing other major causes of death.[21]

## Previous Studies Examining AED Use With Trained Laypersons

Unfortunately, few studies have addressed the training needs or requirements surrounding the use of these devices by lay individuals or non-EMT/paramedic personnel. One study examined the use of AEDs on mannequins by family members of cardiac arrest survivors.[22] All but 2 of 34 individuals were trained to deliver the first defibrillatory shock within 2 minutes in a mock cardiac arrest situation. Significant worsening of speed and quality of performance was observed on retesting after 6 weeks. The variable most highly correlated with skill decline was age. Decreases in performance may have related to the protocol used in the study, which preceded current guidelines for cardiopulmonary resuscitation (CPR); subjects were required to perform CPR before the first defibrillatory shock and between each successive shock. Furthermore, the device used for the study (Heart Aid, model 80, Cardiac Resuscitator Corp) was significantly larger than the most recent AEDs and lacks verbal prompts and simplified visual displays. In another study, volunteers were trained in a 2-hour class to operate an AED and perform CPR.[23] Retesting at 1 year showed that the volunteers were satisfactorily able to remember how to operate the device although the time required to deliver a shock was greater.

More recently, use of AEDs by student nurses trained in CPR was studied.[24] With a simplified and updated protocol (instructions initially for 3 successive defibrillatory shocks) and use of a somewhat newer-generation AED (Laerdal Heartstart 3000), these individuals were trained to deliver a first shock within 60 seconds. Subtle loss of speed and skill was seen after 1 week and 1 month, but training reinforcement led to a retention of the initial recorded speed and skill after 3 and 6 months. However, this AED did not include the more instructive verbal prompts and visual displays that many modern AEDs use. In another study, lay users were successfully trained to deliver shocks from an AED during an AHA HeartSaver course.[25] Time to first shock increased from 70 to 83 seconds when retention was tested 2 to 4 months later.

## Study Implications

The studies referenced above involved laypersons who were given comprehensive instruction and training before AED use. From a public-access defibrillation standpoint, perhaps a more pertinent issue is whether individuals with minimal or no training can safely and effectively use these devices. No prior study has examined this question, nor has any prior study compared AED use by laypersons to a reference standard, in this case, EMTs and paramedics. This study demonstrated that the speed of AED use by essentially untrained sixth-grade schoolchildren was very good and only modestly slower than that of individuals whose job it is to resuscitate victims from cardiac arrest. Performance quality, specifically electrode pad application, was similar in both groups. All test subjects stayed effectively clear of the mannequin during device charging and shock delivery. In general, these findings suggest that training requirements will not significantly limit more widespread use of AEDs.

The principal obstacle to actual use of the AED appeared to be identifying and understanding the term "pads." Questionnaires distributed after the tests suggest that many laypersons do not have an initial intuitive understanding of electrode pad identity or function. Some children expected paddles as portrayed in movies or on television to be inside the case. This information may be helpful in the design of future equipment in which the identity of the electrode pads is clearly marked and the need to peel them from their packaging is clearly stated.

Despite some of these difficulties, most subjects responding to the posttest questionnaire found the AED to be relatively straightforward to use. Having completed the drill, all children but 1 agreed that they could teach use of this AED to someone else, and all believed that they would use the AED on a family member if the situation arose. For the EMTs/paramedics, 96% found AED use in this drill to be easier than performing CPR.

Finally, despite the very limited instruction, there were no safety concerns. None of the users touched the pads or the mannequin during mock shock delivery. Thus, given appropriate AED commands, modern AEDs can be used safely.

## Study Limitations

The subjects chosen for this study were not selected at random. Therefore, this selection process may introduce some bias. Despite this limitation, they represent an extreme of the uninitiated lay user. Another limitation is subject motivation. It is difficult to imagine the anxiety induced by a real cardiac arrest. A mock cardiac arrest scenario cannot simulate OHCA in all its variations. Nevertheless, the importance of speed was emphasized to each subject before the test. Considering the general premise of this study, it seems intuitive that the group performance would likely remain similar albeit somewhat longer for the children.

## Conclusions

In conclusion, AEDs have developed concurrently with our understanding of time to defibrillation as a crucial factor determining outcome from cardiac arrest. Historically, the complexity and size of AEDs dictated that they could be used only by trained medical professionals. Recent technological developments and emphasis on human-factors design have made these devices much more portable and straightforward to use. These factors have supported the notion of a broader use of AEDs, including laypersons. In this study, statistically significant reductions in defibrillation times were seen with EMTs/paramedics versus untrained lay subjects. The absolute differences between groups, however, were small and may be of little clinical relevance. Furthermore, lay subjects demonstrated proficient electrode placement and safety precautions with the AED system used. These findings suggest that use of this AED by untrained laypersons may be feasible and that complex and time-consuming training programs may not be necessary. The utility of a simplified training program may be in helping a user perform under the pressure and anxiety of an actual emergency rather than learning a complex operational task. One might suggest that even a child can do it.



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