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Simulation and education

Comparative performance assessment of commercially available automatic external defibrillators: A simulation and real-life measurement study of hands-off time☆

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ABSTRACT

Q3 *Purpose:* Early and good quality cardiopulmonary resuscitation (CPR) and the use of automated external defibrillators (AEDs) are key factors to improve the outcome in patients with cardiac arrest. However, AED peri- and post-shock ECG analysis pauses may prolong hands-off time and reduce CPR effectiveness.
Methods: This study consisted of 2 independent parts. In the first part, the time performance of 12 different commercially available AEDs was tested in a manikin based scenario; in the second one, the AEDs recordings following the clinical use (same manufacturers as in the benchmark testing) in 2 different regions (Pavia, Italy, and Ticino, Switzerland) were retrieved and analyzed to evaluate the analysis time and post-shock time.
Results: Manikin based study. For shockable rhythms, none of the tested AEDs was able to complete the analysis and to charge the capacitors in less than ten seconds. The mean analysis time was 9.7 ± 1.5 s; the mean charging time was 6.9 ± 3.8 s; the mean post-shock pause was 6.7 ± 2.4 s. For non-shockable rhythms, the mean analysis time was (10.3 ± 2 s) and the mean post-analysis time was 6.2 ± 2.2 s.

Clinical use. A total of 154 AED records [Emergency Medical Service (EMS) rescuers: 104 records; lay rescuers: 50 records] were analyzed. The post-shock pauses were significantly shorter than the post-analysis pauses [3.1 s (95%CI 2.6–3.7) vs 5.4 s (95%CI 5–5.7) p < 0.001] and EMS rescuers were faster in resuming CPR as compared to lay rescuers [5.3 s (95%CI 5–5.7) vs 8.6 s (95%CI 7.3–10) p < 0.001].

EMS rescuers' post-shock and post-analysis pauses were considerably shorter than the ones suggested by AEDs [2.8 s (95%CI 2.4–3.3) vs 6.6 s (95%CI 6.2–6.9) p < 0.001, and 5.6 s (95%CI 5.4–5.9) vs 6.6 s (95%CI 6.5–6.8) p < 0.001, respectively]. On the contrary lay rescuers' post-shock and post-analysis pauses were in line with the pauses suggested by the AED [7.3 s (95%CI 5–9.6) vs 6.3 s (95%CI 2.5–10.1) p = 0.62, and 8.9 s (95%CI 7.3–10.5) vs 7.6 s (95%CI 6.8–8.4) p = 0.14 respectively].
Conclusions: AEDs have different performances that may negatively affect the quality of CPR mostly for those rescuers who follow AED vocal instructions. Both technological improvements and better lay Q4 rescuer training might be needed.

Introduction

Automated external defibrillators (AEDs) have a key role in out-of-hospital cardiopulmonary resuscitation (CPR). Convincing data supporting the relationship between the widespread use of AEDs and the increase of survival of out-of hospital cardiac arrest victims

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have been recently published.[1,2] Non-professional first responders or lay rescuers are guided in their hands-off/on time by automatic messaging given by AED. However interruption of chest compression over a substantial period of time is often observed, in order to allow the AED shock advisory system to analyze the patient's rhythm for artifact free electrocardiogram (ECG). This processing results in an accurate indication for shock or immediate chest compression resumption and, during discharge time prevent rescuer from electrocution.[3–5] Decreasing the duration of pre-shock and immediate post-shock analysis would help to minimize interruptions in chest compression. Indeed, it is well known that pre-shock and peri-shock pauses are independently associated with a decrease in defibrillation success,[6] with a lower probability of return-to spontaneous circulation (ROSC)[7] and ultimately, with survival.[8,9] Variations of even a few seconds produce large effects on survival outcome.[8] As such, current clinical practice guidelines recommend to reduce as much as possible the hands-off time to less than ten seconds per cycle.[10,11]

In 2004, Snyder and Morgan[12] showed that various AEDs models impose wide variations in the hands-off interval, due to differences in AED voice prompting, ECG analysis capabilities, and defibrillator charge times. They concluded that protocol guidance offered by modern AED models varies considerably in ways that may offset the benefits of substantial gains in defibrillation efficacy. They also demonstrated that out of seven different tested models of commercially available AEDs, only one achieved an interruption interval of <10 s. Also, previous studies using AED recordings have shown a median time from last compression until attempted defibrillation, and from shock delivery until resumed chest compression of 20 s and 38 s, respectively.[13,14] However, current guidelines neither prescribe nor recommend maximum ECG analysis time and capacitor charging time in AEDs to maintain hands-off time within the recommended 10 s time.[10]

Some technical improvements have been developed to mostly shorten the pre-shock pauses with promising results: an algorithm that recognizes chest compression interruption allows for faster rhythm analysis.[15] Also, modification in the capacitors charging algorithm during the rhythm analysis could result in shorter hands-off time.[16] However, shortening of post-shock pauses has not been improved. Consequently, our aim was to conduct a comparative performance assessment of 12 modern commercially available AEDs in a manikin model and to compare the bench data with analysis of AED recordings, with particular emphasis to post shock-pauses. Q5

Materials and methods

This study consists of 2 independent parts: the former performed on a manikin, where 12 different commercially available AEDs were tested against the same rhythm scenario; the latter consisted in the analysis of AEDs recordings following the clinical use of the AED (same manufacturers as in the benchmark testing) to evaluate the post-shock and the post-analysis pauses in both lay rescuers and EMS rescuers. The post-shock pause was the time from the delivery of the shock to the first chest compression after the shock. The post analysis pause was the time from the end of rhythm analysis to the first chest compression after the analysis.

AEDs tested

Twelve commercially available AEDs were tested: Rescue SAM and Rescue life AED (Progetti, Turin, Italy); FR2, FR3 and Heartstart (Philips, Eindhoven, Netherlands); 3G Plus (Cardiac Science, Bohtell, WA, USA); FRED Easy and FRED Easyport (Schiller AG, Baar, Switzerland); Lifeline AED (Defibtech, Guilford, CT, USA); Heartsave AD (Primedic, Rottweil, Germany); i-PAD (CU Medical System, Korea); and finally, BeneHeart D1 (Mindray Medical, China). Every AED was equipped with a new battery before the beginning of the study, and the initial automated test was successfully passed. Each AED was updated with the 2015 guidelines. For comparative assessment goals, the benchmark analysis was limited to those AEDs that are mostly used by the local rescue vehicles or that are freely accessible on the territory.

Manikin preparation

An ALS trainer (Laerdal Medical, Norway) was utilized: the manikin was equipped with a rhythm simulator capable of reproducing the following rhythms: ventricular fibrillation (VF), asystole, normal sinus rhythm at 60 bpm, slow monomorphic ventricular tachycardia (Slow VT) at 125 bpm and fast monomorphic ventricular tachycardia (Fast VT) at 225 bpm. For each AED, a set of pads was used and prepared to be connected to the cable of the manikin using clip connectors. The rhythm was selected and turned on before attaching the AED pads.

Time performance

According to the guidelines, after turning on the AED, the cables were connected to the manikin and the performance for both shockable and non-shockable rhythm was tested. VF, slow VT and fast VT were considered as shockable rhythms, while asystole and normal sinus rhythm were considered as non-shockable rhythms. Moreover, the AED ability to discriminate between shockable vs non-shockable rhythm just before shock delivery was tested. To do so, at the end of the analysis once the shock was indicated, a sudden rhythm change (from VF to normal sinus rhythm) was introduced.

For each of the 3 shockable rhythms (VF, fast VT and slow VT), the analysis time (the time from the cable connection to the message "shock needed" or "not needed"), the charging time (from the message "shock needed" to the lighting of the shock button), the post-shock pause (the time elapsing from the shock delivery to the instruction to resume CPR) and the pads to CPR time (the time from pads connection to the instruction to resume CPR) were recorded.

For non-shockable rhythms, the analysis time (the time from cable connection to the message "shock needed" or "not needed"), the post-analysis pause (the time passing from the end of the analysis to the instruction to resume CPR) and the pads to CPR time (the time from the pads connection to the instruction to resume CPR) were computed.

Each evaluation was repeated three times and the mean performance was then considered for statistical analysis. All the tests were filmed and the time analysis was performed by 2 independent investigators in a blinded fashion. In case of time discrepancy or difference in interpretation, a third investigator was involved and results were determined by consensus.

Real world use of AED

All the consecutive reports available generated by the use of an AED during out-of-hospital cardiac arrests occurred between October 2014 and December 2015 at 2 different sites (Pavia and Ticino) were analyzed and included in this study. Only reports generated by those AED models included in the bench test were considered for analysis. Post-shock and post-analysis pauses were measured from the shock administration or from the notification of shock not needed to the recovery of chest compression, as assessed by ECG artefacts (Fig. 1), respectively. These time intervals were computed and then compared to those measured during the bench tests.

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