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Techniques and Procedures

ANALYZING THE EFFECTIVENESS OF DIFFERENT FORMS OF CARDIOPULMONARY RESUSCITATION

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☐ **Abstract—Background: In order to simulate a heartbeat in a cardiac arrest patient, cardiopulmonary resuscitation (CPR) requires that chest compressions be delivered with a force of at least 560 N at a rate >100 compressions/min. Many new learners initially use CPR forms that may not meet these parameters sufficiently. We examined three forms of CPR: the form recommended by the American Heart Association (AHA) and two forms that are common among new learners but that are considered incorrect, using a CPR manikin placed on a force plate. Four trained CPR users tested the different methods. Discussion: AHA-recommended CPR is the most effective, delivering a force of 737.2 ± 5.3 N at a rate of 103.2 ± 1.2 compressions/min. Compressions using a bent arms method delivered compressions with a force of 511.8 ± 4.1 N at a rate of 112.8 ± 3.0 compressions/min. Compressions using a different hand position from that recommended by the AHA delivered compressions with a force of 433.3 ± 3.2 N at a rate of 115.2 ± 1.2 compressions/min. Conclusions: AHA-recommended CPR more effectively compresses a patient's heart than the bent-arms method or the alternate hand–position method, and, of the three methods, only the AHA-recommended form can reliably simulate a patient's heartbeat.** © 2018 Elsevier Inc. All rights reserved.

☐ **Keywords—CPR; resuscitation; cardiopulmonary resuscitation; Emergency Medicine training; education; instruction**

INTRODUCTION

Cardiopulmonary resuscitation (CPR) is a tested and proven emergency rescue technique that can maintain brain function even when a patient's heart is not beating. According to American Heart Association (AHA) statistics from 2016, only about 12% of out-of-hospital cardiac arrest patients in the United States survive a cardiac arrest without CPR, while those receiving properly executed CPR survive the initial cardiac arrest in 46.1% of cases (1–3). Unfortunately, only about 30% of U.S. residents are trained in CPR and know the proper procedure (4,5). Poorly executed CPR can not only prevent the procedure from being successful, but can also actively harm a patient (6,7). This experiment compares the effectiveness of different forms of CPR: the primary method recommended by the AHA and two variations that are common with new learners of CPR. This paper analyzes the data collected regarding the average amount of force delivered with each type of compression, as well as the frequency of the compressions delivered during the same period to determine whether the different methods constitute effective CPR.

DESIGNS AND METHODS

The AHA is the leading body in the United States studying and advising on cardiac life support, and its recommendations are standard in CPR curricula across the United States. CPR technique has varied throughout the years as new data arise and inform on the effectiveness of various methods. To simulate a cardiac arrest patient's heartbeat, a patient's chest must be compressed 1.5–2

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inches in depth (8–10). Such a compression depth requires a rescuer to deliver a force of 560 N to the patient's chest (11). Furthermore, the AHA recommends a continuous compression rate of 100 chest compressions/min, which is an appropriate speed to circulate blood without fatiguing the rescuer (8,10).

When CPR is performed according to the AHA's current recommendations, the rescuer kneels on one side of the patient and places his or her hands over the patient's chest (8). One hand is flat on the center of the sternum, and the other hand is flat over the first. When the rescuer delivers a compression, the rescuer moves his or her entire body downward in one motion, with arms locked. The rescuer proceeds in this motion for as long as CPR continues, usually 2 min if other rescuers are nearby.

Hand and arm positions play major roles in determining the effectiveness of applied CPR. Previous research supports the AHA-recommended form by demonstrating that stacked-hand, straight-arm CPR delivers more effective chest compressions than some common alternate forms, including rescuer hands side-by-side or hand placement further away from the heart (12,13). Further research validates that CPR is most effective when the rescuer's dominant hand is placed on top of the non-dominant hand when performing compressions (14). Most CPR classes in the United States teach the currently recommended form of CPR. However, as new learners initially try the technique, they frequently perform it with incorrect techniques. Specifically, they often employ the forms mentioned, as well as two forms that are similar to AHA-recommended form but are considered incorrect, using a different arm compression form or a different hand placement.

A very common mistake when untrained rescuers perform CPR is for the rescuer to compress the patient's chest using the rescuer's arms primarily. The AHA recommends that the rescuer lock his or her arms and move with his or her entire body when compressing the patient's chest. However, new rescuers will often compress exclusively with their arms, not utilizing more of their body weight to augment the applied force. Furthermore, the AHA is specific with its recommended hand placement: both palms flat on the patient's chest and one on top of the other. Nevertheless, many students initially tend to use other placements of their hands before receiving instruction on the proper position. One common alternate form is a hand position similar to that used in the Heimlich maneuver, with one hand in a fist directly on the patient's chest and the other placed over it.

We examined the quality of these three types of CPR—the AHA-recommended form, the different arm position form, and the different hand position form—to compare them and determined whether each meets the thresholds for effective CPR: 560 N applied force at a rate of 100 compressions/min (8). A CPR manikin was placed on a Vernier force plate (Vernier, Beaverton, OR), and CPR was performed in various forms; first in the manner recommended by the AHA, then with two mistakes—poor compression form and poor hand placement. Amplitude and frequency of compressions were measured using a Vernier Lab Pro connected to a computer running Logger Pro (Vernier). The plate was calibrated to the force of the manikin resting on top, so the only force measured by the plate was that applied through CPR. Four trained and currently certified CPR rescuers applied each of the three techniques with rest and hydration between each test. Figure 1 displays each form of CPR, with Figures 1A and 1B depicting the AHA-recommended arm and hand placements, Figure 1C depicting the poor hand placement, and Figure 1D depicting poor arm placement.

RESULTS

Figure 2 displays an example of the compression force-per-time step, along with the force threshold for effective AHA-recommended CPR.

The mean force applied in each compression of AHA-recommended CPR is 737.2 $\pm$ 5.3 N, compared with a mean force of 511.8 $\pm$ 4.1 N for different arm–position CPR and 433.3 $\pm$ 3.2 N for different hand–position CPR. The amplitude of each force spike recorded is displayed in the histogram in Figure 3, compared to the 560 N threshold required for effective CPR.

AHA-recommend CPR was delivered at an average compression rate of 103.2 $\pm$ 1.2 compressions/min, compared to 112.8 $\pm$ 3.0 compressions/min for different arm position and 115.2 $\pm$ 1.2 compressions/min for different hand position.

DISCUSSION

The most important metric for assessing CPR quality is compression force (10). Strong compressions at a low frequency can still circulate blood, but compressions below the force threshold cannot be relied upon to compress the heart adequately. The data indicate that CPR performed to AHA recommendations applies an average force of 737.2 N, regularly achieving a force not only above the threshold force value of 560 N for effective CPR, but also at a significantly higher force than either other type of CPR. Neither the different arm–position form (with an average force of 511.8 N) nor the different hand position–form (with an average force of 433.3 N) regularly delivers compressions at a force > 560 N. The disparity in compression forces suggests that compressing with the entire body, not merely with the arms, delivers a much greater force at less effort to the rescuer,

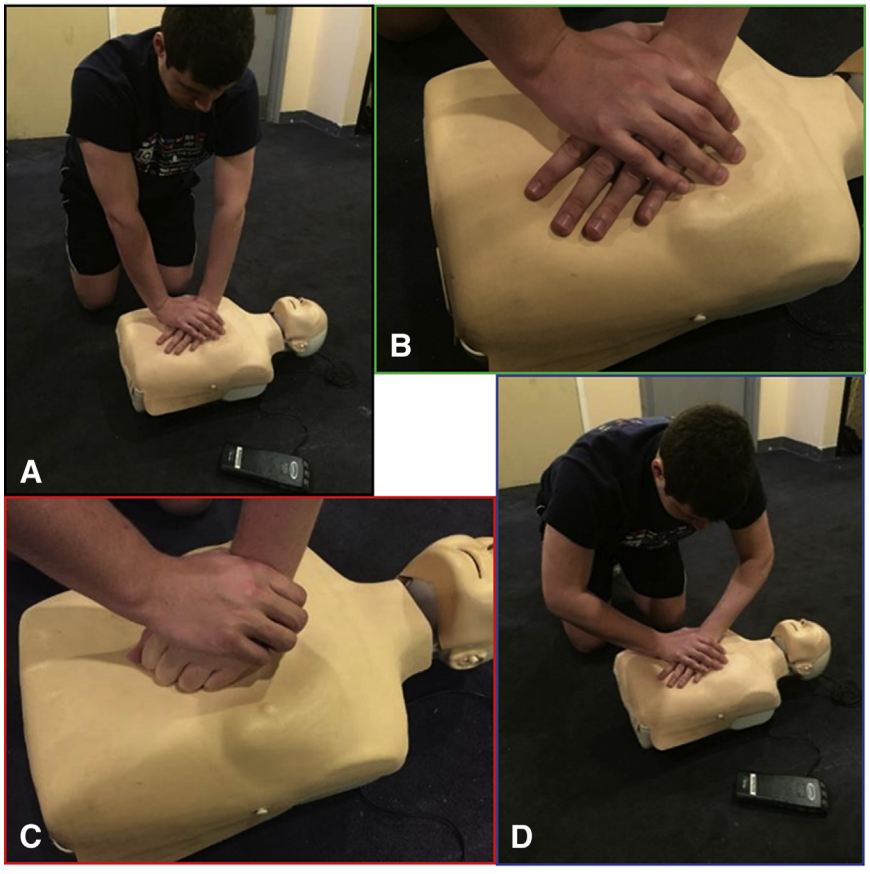

Figure 1. (A) American Heart Association (AHA)–recommended cardiopulmonary resuscitation stance and arm placement. (B) AHA-recommended hand placement. (C) Poor hand placement. (D) Poor arm placement.

allowing the rescuer to maintain the necessary force for effective CPR for a longer amount of time. Furthermore, the different hand–position tested, with hands placed as fists over the CPR manikin, was barely able to deliver CPR at an appropriate force at all, indicating that flat hands can deliver compressions to the chest much more successfully.

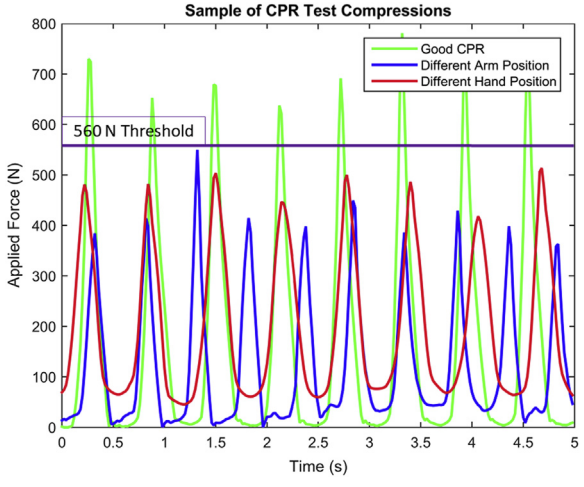

Figure 2. Sample of force-per-time data collected. Each peak compares with the threshold for effective cardiopulmonary resuscitation (CPR), 560 N.

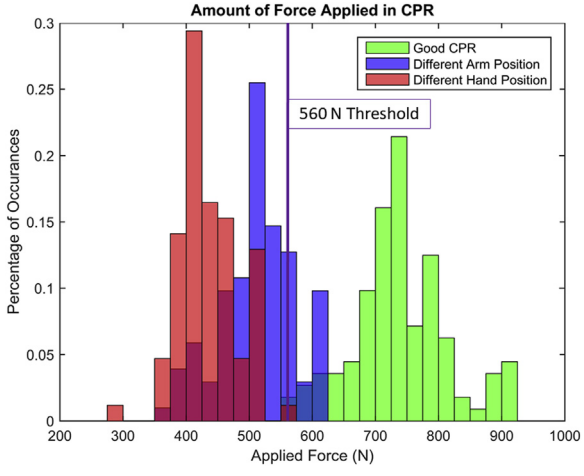

Figure 3. Histogram of force applied in each type of cardiopulmonary resuscitation (CPR) compared to the threshold for effective CPR, 560 N.

The other element that determines the quality of CPR is the rate of compressions. The AHA recommends a compression rate of 100 beats/min to circulate enough blood to the brain so that a patient can be revived without suffering permanent brain damage. All of the forms of CPR tested delivered compressions at a rate greater than that recommended by the AHA. Both of the different forms tested delivered a higher rate of compressions than the AHA-recommended method; although, if the compressions fail to meet the proper force required to compress the chest sufficiently, then they fail to deliver effective lifesaving CPR.

CONCLUSIONS

Of the three methods of CPR examined, only the AHA-recommended form meets both the force and frequency thresholds required for effective CPR. New learners may perform alternate—and ineffective—forms of the procedure, so CPR instructors should correct them and should teach the AHA-recommended form, as it provides the best chance at saving a patient's life during cardiac arrest.

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