Original Article

New method of chest compression for infants in a single rescuer situation: thumb-index finger technique

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We introduce a new method of external chest compression (ECC), an essential part of cardiopulmonary resuscitation, using a thumb and index finger method (TIFM) on infants, and compares, this with two standard methods of the two finger method (TFM) and the two-thumb encircling hands method (TTEM).

Sixty trained PALS (Pediatric Advanced Life Support) providers were randomly assigned into three groups and provided one-rescuer ECC for a period of five continuous minutes. Results without coaching or feedback were recorded on a recording CPR simulator (Laerdal, Inc). ECC was performed according to the BLS recommendations of the International Liaison Committee on Resuscitation (ILCOR).

The quality of ECC in the TFM group deviated considerably from guideline recommendations. The same parameters in the TTEM and new TIFM groups during this study were in accordance with the parameters recommended by the guidelines.

Thus, our new TIFM technique of chest compression, in infants was shown to be better than the currently TFM, especially for achieving adequate compression depth and avoiding fatigue, and is equally as effective as the TTEM. We propose this new method (TIFM) should be considered as the method of choice in single rescuer situations.

Key words: cardiopulmonary resuscitation (CPR); basic life support (BLS); external chest compression (ECC); chest compression quality; fatigue

Introduction

Training programs for cardiopulmonary resuscitation (CPR) have been implemented worldwide over the last 50 years, and are based on guidelines established by the European Resuscitation Council (ERC) and the American Heart Association (AHA), which are based on recent international consensus [1]. These programs specify course content, management, and guidelines for CPR practice and testing, including criteria for the correct performance of CPR. However, survival rates from cardiac arrest remain poor despite the development of both CPR and electrical defibrillation as treatment modalities over the past 50 years. In an effort to improve cardiac arrest outcomes, recent investigations have focused on the timing and quality of CPR [2, 3, 4].

Tests immediately after a traditional instructor CPR course with lectures, demonstrations, training, and evaluation have demonstrated poor skills performance [5, 6]. It has been discussed whether this is caused by the course content, the instructor, the training technique or something else. Multiple studies have demonstrated that rescuer fatigue can affect chest compression quality, and that the rescuer does not recognize when fatigue affects CPR performance [3, 5, 7].

Current AHA guidelines recommend the “two-thumb” method (TTEM) for two rescuers and the “two finger” chest compression method (TFM) for the lone rescuer. It is known, however, that TTEM is better than TFM, as
TFM is prone to fatigue. A better technique for a single rescuer is needed. We have been carrying out a comparative analysis of infant chest compression during CPR and we believe we have found a better alternative to existing standard methods of chest compression during CPR in infants.

Materials and methods

The study protocol was approved by the institutional clinical investigation review board and informed consent was obtained prior to the study from the volunteers who participated.

Subjects

Sixty trained PALS providers (18 female, 42 male, 27.8 ± 2.1 years) were randomly assigned to provide one-rescuer CPR for a period of five continuous minutes using three different methods (TFM, TTEM, or TIFM). This prospective study was carried out with a modified CPR simulator (Resusci-Anne with the PC Skill Reporting System, Ver. 2.2.1; Laerdal). This basic life support (BLS) simulator was equipped with functions that can continuously record the rate of compressions, the actual number of compressions per minute, the actual depth and location of compressions, recoil decompression (hand release), and interruption of CPR.

Description of the new method

A fist is made with the pad of the thumb pressed tightly against the side of the middle phalanx of the index finger. The tip half of the pad of the thumb and the dorsum of the middle phalanx are placed on the front of the sternum, with the thumb placed in the direction of the jugular notch (Figure 1). All other requirements for ECC are the same. Chest compression is applied over the lower part of the sternum at a rate of 100 per minute. Compression and relaxation should take an equal amount of time and compression depth should be 1/3 the anterior-posterior diameter of the chest. Pressure should be released without losing contact.

Study protocol

Sixty participants were enrolled and randomly divided into three groups. At the beginning of each session, investigators informed participants of the method of chest compression, ratio and depth chosen. Each participant provided one-rescuer CPR over a period of five consecutive minutes. Results were recorded from time 0 to 1 minute (first interval), from 2 to 3 minutes (second interval), and from 4 to 5 minutes (third interval) over a period of five consecutive minutes. Participants were not told the intermediary results. This study was carried out at the National Center for Child Health and Development (NCCHD), Tokyo, and all participants were volunteers who were recruited from new residents who had just completed a BLS and pediatric advanced life support (PALS) provider course at the institution.

CPR was performed according to the BLS recommendations proposed by the International Liaison Committee on Resuscitation (ILCOR) with the following

Figure 1: New method of external chest compression

Figure presents the new method of external chest compression.
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requirements: compression is applied over the lower part of the sternum, compression and relaxation should take an equal amount of time, compression depth should be 1/3 the anterior-posterior diameter of the chest, and the pressure should be released without losing contact. We chose, an ECC duration of five minutes, because this duration has been used in the literature [2, 8, 9]. The quality of chest compressions was evaluated according to international recommendations [1, 10]. In previous studies, the quality was assessed on the basis of rate, correct location of hands and adequate compression depth during a period of five minutes of CPR. The quality of CPR was assessed with additional CPR indices including incomplete recoil, excess depth, suitable and unsuitable ECC, and no error ECC, in percentages. Suitable compression depth has been defined as depth from 38-51 mm. Attempt level was defined as the minimum depth to detect a compression and has been set as 10 mm. Incomplete recoil is detected if compression is not released above the attempt level. Unsuitable compression depth is defined as depth more than the attempt level, but less than 38 mm. Excessive compression depth was defined as depth more than 51 mm (Resusci-Anne with the PC Skill Reporting System, Ver. 2.2.1; Laerdal) [11].

Data acquisition
We modified a standard CPR infant manikin to visually monitor and record chest compression quality including depth and timing. Trained CPR providers performed chest compressions targeting 1/3 of chest diameter for five minutes continuously using the “two-thumb” (TTEM), “two finger” (TFM), and “new method” (TIFM) (n=20, n=20, n=20 respectively) without looking at the monitor display. The only exception was in the TFM group. The depth of chest compression was initially too shallow, so we had to give feedback after the first interval to let participants briefly see the compression process on the computer display. This feedback was not given in the other two groups.

Statistical Analysis
A spreadsheet application (Excel 2008; Microsoft) was used to calculate mean values and their standard deviations. Differences in CPR parameters for outcome evaluation between three groups were assessed using the analysis of Variance (ANOVA). Additionally, differences in CPR parameters between TTEM and TIFM groups were assessed using a t-Student test. A p value below 0.05 (p<0.05) was considered as statistically significant.

Results
Sixty participants (18 females, 42 males) were enrolled. The mean age was 27.8 ± 2.1 years.
No significant deviation of chest compression location was observed in any of the three study groups. The rates of chest compression achieved were quite different among the study groups, with a mean of 112.4 ± 12 per minute in TFM, 101.6 ± 9.5 per minute in TTEM and 98.7 ± 6.4 per minute in new TIFM. The difference in ECC rate between the TFM and TTEM groups during the study was statistically significant (p<0.05), whereas the average ECC rates shown in the TTEM and TIFM groups were similar.

The depth of compression in the three groups is shown in Figure 2. The depth of chest compression in the TFM group was initially extremely shallow (28.4 mm, 27.1 mm, and 26.6 mm at the first, second and third intervals, respectively) and we had to give feedback. The depth of compression initially improved, but the depth of ECC decayed significantly over five minutes (33.3 mm, 30.7 mm, 28.8 mm at the 3 intervals, respectively). The tendency for compression depth to become shallower in this group over time was obvious. Statistically, the difference between depth in the first and the second intervals and between the second and the third was not significant.

Chest compression depth changes in TTEM (33.3 mm, 32.9 mm, and 33.0 mm at the 3 intervals, respectively) were not statistically significant.

Statistically significant differences in ECC depth between TFM and TTEM were observed (p<0.05). No statistically significant differences in chest compression depth over the time course in the TIFM group (33.4 mm, 33.4 mm, and 33.1 mm at the 3 intervals, respectively) were observed. No statistically significant differences in ECC depth were found between the TIFM and TTEM groups over the same time course (Figure 2).

A small percentage of incomplete chest decompression was observed in TFM (3.8%, 9.2%, 8.1% at the first, second and third intervals, respectively) (Figure 3). The proportion of incomplete recoil was greatest in TTEM at 50.3%, 57.3%, and 50.5%, at the 3 intervals, respectively. In contrast, the percentage of incomplete recoil progressively declined during the 5 minute study period in TIFM. It averaged 23% at the end of the first interval, 14.5% at the end of the second interval, and was 9% at the end of the third interval, however these changes were not statistically significant. There was
a statistically significant difference in the proportion of incomplete recoil between TIFM and TTEM (p<0.05) (Figure 3).

Unsuitable chest compression percentage average in TTEM and TIFM groups was the 11.6 ± 25.2% and 7.2 ± 12.4% respectively. In case of TFM group, the unsuitable chest compression percentage increased from 7 ± 16.1% in first minute to 50.1 ± 33.9% in second, till 81.2 ± 28.4% in finish of CPR (Figure 4).

In Table 1, we show the percentage of excess compression depth. Excessive compression depth was defined as depth more than 51 mm (Resusci-Anne with the PC Skill Reporting System, Ver. 2.2.1; Laerdal). The biggest excess chest compression depth was observed in TTEM. The average was 7.2 ± 22.7% with 9.7 ± 28.1% in the first interval, 6.5 ± 20.9% in the second interval, and 5.4 ± 19.1% in the third interval. In TFM, the excess depth averaged 6.7 ± 21% with 10.1 ± 21% in the first interval, 4.9 ± 21.5% in the second interval, and 5.1 ± 21.2% in the third interval. TIFM showed the least percent of excess depth and averaged 2.2 ± 8.2% with 1.5 ± 5.4% in the first
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The differences in excess compression depth among the three groups were not statistically significant.

Discussion

Good quality external chest compression (ECC) is of paramount importance in CPR. Good ECC can be defined as chest compression with a good quality of force [8, 9], appropriate rate [12], appropriate compression duration and adequate decompression (recoil) time, without unnecessary interruptions or pauses [13]. This has been confirmed in animal studies [14, 15], experimental swine models [16], and in other laboratory studies [2, 17, 18].

Achieving good quality ECC, however, is not easy. Discrepancy between the performance of healthcare professionals and guideline recommendations, particularly for the rate and the depth of compressions has been reported recently [8, 13]. Abella et al. [3] reported that the correct rate of ECC was found only in 11% of the cases in TFM group.

Figure 4: Unsuitable chest compression percentage
Figure shows low average percentages of unsuitable chest compressions in TIFM and TTEM groups, over the course of the study. In contrast, this index progressively and rapidly increased over time in TFM group.

Table 1: Materials and final results of CPR study
This table summarizes information about chest compressions characteristics, in all groups during study. Information presented as average with standard deviation.
31.4% of the time during in-hospital resuscitation. Aufderheide et al. [6] reported weak compression depth by healthcare professionals during the assessment of different alternative manual chest compression techniques. Wik et al. reported a mean compression depth of 34 mm and only 28% of compressions were within the recommended depth of 38-51 mm in out-of-hospital CPR [5].

It was reported that the quality of chest compression often deviated from guideline recommendations [3] in several important parameters, including chest compression depth, compression recoil, percent of chest compressions without error, and percent of suitable and unsuitable compressions. Specifically, the percentage of suitable chest compression was often less than recommended, and compression depth was often far shallower than the accepted minimum. These reports confirm other recent investigations suggesting that CPR quality may be highly variable in actual practice [4, 19].

We found that the depth of compression in standard TFM tended to become shallower over time. The average depth in TFM was only 27.3 mm at the end of the third interval. The difference in ECC depth between TFM and TTEM over the same time course of the study was statistically significant and TTEM clearly was superior in this aspect (p<0.05) (Figure 2). The reason and explanation for the observed difference, in our view, was the physical tiredness of participants, as well as finger pain in TFM, but further study is needed to confirm these speculations.

Two manikin studies [20, 21], one animal study [22], and case reports of hemodynamic monitoring in infants [23] also showed that TTEM produces higher coronary perfusion pressures, higher systolic and diastolic arterial pressures and more consistent correct depth and force of compression than TFM. In our study, the depth of compression in TTEM was more acceptable than that of TFM and changes in compression depth over time were more stable. The average depth in TTEM was 33.3 mm in the first interval, 32.9 mm in the second interval, and 33.0 mm in the third interval. These are in accordance with the parameters recommended by AHA [1].

Fatigue during experimental CPR performed by healthcare providers was reported by Ashton A. [7]. He studied two consecutive 3-minute periods of continuous compressions separated by a 30-second time interval on a manikin. While the total number of compressions was maintained (100/min) over both periods of CPR, the number of suitable chest compressions performed decreased from 82 in the first minute to only 27 by the fifth minute. Seven subjects were unable to complete a second three minute interval due to fatigue.

The average percentages of suitable chest compressions in TIFM, and TTEM were consistently high at 90.9% and 85.8% respectively. In TFM, this declined progressively over time with 87.6% in the 1st interval, 50.2% in the second interval and 20.1% by the end of the third interval. The differences over time were statistically significant (p<0.05).

Why TIFM technique could avoid fatigue? We supposed that: thumb having a skeleton of phalanges, joined by hinge-like joints is opposable and can provide powerful flexion toward the palm of the hand; has two phalanges, so less flexible, but more powerful; has greater breadth in the proximal phalanx, than in the phalanges in TFM that provide more precise allocation ability on the chest. Index finger is usually the most dexterous and sensitive finger of the hand.

In our view, application thumb and index altogether, provide more fine, precise and powerful compression of chest during CPR.

The average percentages of unsuitable chest compressions in TIFM and TTEM were low over the course of the study at 7.2% and 11.6%, respectively. The differences between these two groups were not statistically significant. In contrast, this index progressively and rapidly increased over time in TFM, with an average of 46%. These changes were statistically significant (p<0.05) (Figure 4).

An analysis of errors in chest compression can be seen in Table 1. The highest percentage of faultless (no-error) compression was obtained in TIFM with an average percentage of 78.9%. In TFM, this index progressively and rapidly decreased over time from 83.6% in the first interval, to 48% in the second interval and 19.1% by the end of the third interval. The average was 50.2%. The high percentage of faultless compression in the first minute of TFM could not be sustained and cumulative fatigue and pain led to a rapid deterioration.

We were surprised to find an unexpectedly low percentage of faultless compression in TTEM with an average of 41.6%. The reason, as it turned out, is that TTEM has the highest percentage of incomplete recoil during the study, an average of 52.7% (Figure 3).

The importance of the decompression phase during CPR is well known. Incomplete chest recoil during cardiopulmonary resuscitation (CPR) in the decompression phase is purported to decrease venous return, and thereby decrease forward blood flow. We
found higher incomplete decompression in TTEM due to the fact that holding the manikin’s thorax with two hands may limit the mobility of joined thumbs. On the other hand, the lowest percentage of incomplete recoil during the ECC was observed in TFM. In our view, this may be due to the desire of the participants to release pressure early to reduce pain sensation upon compression. The average percentage of incomplete decompression during the CPR with TIFM was 15.5%, which is better than TFM and TTEM.

The goal of CPR is to provide adequate blood flow to the brain and heart. Chest compression increases pressure within the thorax, forcing blood out to the heart, brain and other organs, and air out of the lungs. The importance of providing uninterrupted chest compressions is emphasized since every interruption causes a dramatic decrease in coronary perfusion pressure [24]. Compressions should be provided at a rate of 100 per minute and the chest should be compressed 1½ - 2 inches, with half the time spent compressing the chest and the other half spent allowing the chest to fully recoil (decompress). Full chest-wall recoil is also essential [25]. Negative intrathoracic pressure is produced each time the chest is allowed to fully decompress, drawing blood back into the heart and some quantity of air into the lungs [26]. During the chest-recoil phase, blood flows through the coronary arteries, to provide the heart muscle with blood. Performing CPR with uninterrupted compressions and full chest-wall recoil will optimize blood flow to the heart and brain [25, 26].

TTEM produced the highest percentage of excess depth of compression of the chest (Table 1), averaging 7.2%. The percentage of excess compression depth in TFM was 6.7% and slightly lower than TTEM, but it was 2.2% and lowest in TIFM.

Our new “thumb-index finger method” (TIFM) can be considered as a better alternative to the current standard two finger method (TFM).

Several limitations of our study should be discussed. First is the possible existence of the Hawthorne effect, as participants were newly trained resident physicians and knew that there were being studied. This “Hawthorne effect” could have possibly decreased significant deviations from the recommended practice in our study [2, 27]. However, even with the “Hawthorne effect”, the quality of ECC performed by professional healthcare providers showed significant differences among the three methods we studied and does not affect our conclusion. The differences may be greater if we consider applying our results to bystanders.

Second, we studied only 5 consecutive minutes per participant. This can be considered as rather short for a real CPR situation, but we though it is appropriate for our study as nearly 30 % of the participants were female and we did not want the results to be affected by physical stamina. Many previously published CPR studies have adopted the same duration [2, 8, 9]. We found significant differences even with a seemingly short study period.

Third, the manikin we used in our study was an unconscious and pulseless infant model. It is debatable if CPR performance on this manikin in this situation can be converted into real clinical practice. While it is an appropriate concern, the issue has been discussed in several previous studies [4, 8, 19]. Our focus was solely on the ECC function of the manikin and one manikin was used for data acquisition. We used the criteria predetermined by the simulator (Resusci-Anne with the PC Skill Reporting System, Ver. 2.2.1; Laerdal) in assessing the quality of ECC. Those criteria have been used on many previously published papers, and it was felt appropriate for comparing three different methods [6, 8, 9, 20]. While manikins are not human patients, they are used widely in this field.

Further observational and randomized controlled studies will be necessary and desirable to confirm these preliminary observations.

Conclusions

We introduced a new method of chest compression in infants called the thumb-index finger method (TIFM). This method was found to be more useful than the standard two finger method (TFM) as it is less susceptible to fatigue and produced better quality ECC, which is comparable to TTEM used in a two rescuer situation. This new method should be considered as the method of choice in single rescuer situations.

Conflict of interest

The authors declare that Laerdal Medical Corporation, Japan, provided training and recording devices for the investigators of the study. No financial support that could influence the work was granted to any of the listed authors.

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