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ORIGINAL RESEARCH

Two-Thumb Technique Is Superior to Two-Finger Technique in Cardiopulmonary Resuscitation of Simulated Out-of-Hospital Cardiac Arrest in Infants

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BACKGROUND: To compare the 2-finger and 2-thumb chest compression techniques on infant manikins in an out-of-hospital setting regarding efficiency of compressions, ventilation, and rescuer pain and fatigue.

METHODS AND RESULTS: In a randomized crossover design, 78 medical students performed 2 minutes of cardiopulmonary resuscitation with mouth-to-nose ventilation at a 30:2 rate on a Resusci Baby QCPR infant manikin (Laerdal, Stavanger, Norway), using a barrier device and the 2-finger and 2-thumb compression techniques. Frequency and depth of chest compressions, proper hand position, complete chest recoil at each compression, hands-off time, tidal volume, and number of ventilations were evaluated through manikin-embedded SkillReporting software. After the interventions, standard Likert questionnaires and analog scales for pain and fatigue were applied. The variables were compared by a paired *t*-test or Wilcoxon test as suitable. Seventy-eight students participated in the study and performed 156 complete interventions. The 2-thumb technique resulted in a greater depth of chest compressions (42 versus 39.7 mm; $P<0.01$), and a higher percentage of chest compressions with adequate depth (89.5% versus 77%; $P<0.01$). There were no differences in ventilatory parameters or hands-off time between techniques. Pain and fatigue scores were higher for the 2-finger technique (5.2 versus 1.8 and 3.8 versus 2.6, respectively; $P<0.01$).

CONCLUSIONS: In a simulation of out-of-hospital, single-rescuer infant cardiopulmonary resuscitation, the 2-thumb technique achieves better quality of chest compressions without interfering with ventilation and causes less rescuer pain and fatigue.

Key Words: cardiopulmonary resuscitation ■ infant ■ out-of-hospital cardiac arrest ■ simulation

Out-of-hospital cardiac arrest in children is a rare event, with a reported incidence ranging from 9.1 to 19.7 cases/1 000 000 per year, and is associated with poor neurological outcome.[1] In infants aged <1 year, the incidence approaches that of adults, but outcomes are even worse, with less chance of survival.[1,2]

Prompt and efficient cardiopulmonary resuscitation (CPR) is the key to sustaining cerebral and coronary perfusion during any cardiac arrest. Effective chest compressions and rescue ventilations are the most important interventions during CPR in the pediatric population, with the potential to change the chances of survival and neurological outcome.[3] Chest compressions are essential to generate perfusion to target organs peculiarly sensitive to ischemia because of the high rates of metabolism of pediatric patients.[4] To increase the odds of survival, the American Heart Association, American Academy of Pediatrics, and European Resuscitation Council guidelines all emphasize the importance of performing high-quality CPR.[5-7] Rescuer fatigue has a major impact on the quality of CPR, decreasing the quality of chest compressions

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CLINICAL PERSPECTIVE

What Is New?

- This study demonstrated that 2-thumb cardiopulmonary resuscitation (CPR) technique in a single-rescuer out-of-hospital setting was more efficient than 2-finger CPR technique, resulting in greater depth of chest compressions and higher percentage of chest compressions with adequate depth, without impact on ventilation quality.
- Additionally, 2-thumb CPR technique was better tolerated by the rescuers.

What Are the Clinical Implications?

- We speculate that, in an out-of-hospital setting with a single rescuer providing CPR for longer periods than those defined in our study (2 minutes), the differences in favor of 2-thumb CPR technique would be greater and could impact survival rates.

Nonstandard Abbreviations and Acronyms

TF	2-finger
TT	2-thumb

during resuscitation.[8-11] Hence, guidelines recommend switching rescuer after every 2 minutes of compression.

Current guidelines recommend two techniques of chest compressions for infants: the 2-thumb (TT) technique for 2-rescuer CPR and the 2-finger (TF) technique for 1-rescuer CPR. The TT technique is preferred because it leads to greater coronary perfusion, achieves greater depth of compressions, and can generate more diastolic and systolic pressure with less impact on rescuer fatigue.[12-17]

Despite this evidence showing that better compressions are achieved with the TT technique, the TF technique is still recommended for 1-rescuer CPR because of the potential difficulty in alternating compressions and ventilations during resuscitation.[12] There is no published literature comparing the 2 compression techniques in an out-of-hospital scenario with 1 rescuer and mouth-to-nose ventilation with barrier device at a 30:2 ratio.

The objective of this study was to compare the TF and TT compression techniques, performed on manikins in a simulated out-of-hospital cardiac arrest setting, in relation to the effectiveness of compressions, ventilation, and rescuer pain and fatigue.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request. A randomized crossover design was used. The study was approved by the institutional review board (IRB) of the Federal University of Rio Grande do Sul with opinion number 2.957.428.

Subjects

All students from 2 medical schools in Brazil (Universidade Federal da Fronteira Sul and Universidade de Passo Fundo) were invited to participate in the study through posters. Students with any medical condition that contraindicated performing CPR with their knees on the floor were excluded. The first 80 students who completed the enrollment form and provided written informed consent were considered eligible to participate in the study.

Study Protocol

A 20-minute practical training session about CPR on infant manikins was provided to groups of 4 students. After the session, each student was invited to perform 2 minutes of CPR on a manikin on the floor at the rate of 30 compressions and 2 mouth-to-nose ventilations with a barrier device, to simulate single-rescuer out-of-hospital CPR. The first chest compression technique to be performed was randomized through an opaque envelope containing “2-finger” or “2-thumb.” After 2 minutes of compressions, the student rested for at least 20 minutes and crossed over to perform the second chest compression technique. Each student’s heart rate was measured before and after each chest compression cycle. After 2 cycles of CPR, the student was invited to complete a standard Likert fatigue questionnaire and 2 visual analog scales for pain and fatigue. No interventions were performed during CPR. Participants had no access to the collected data and did not know the purpose of the study.

Data Collection

Demographic data (age, sex, weight, height, body mass index) were collected from all participants. They were also questioned about preexisting diseases, smoking, previous experience in performing CPR, previous training in CPR, and semester of graduation. Participants who engaged in >150 min/wk of physical activity were considered nonsedentary.[18]

All research was performed on a Resusci Baby QCPR manikin equipped with SkillReporting software (Laerdal, Stavanger, Norway), which simulates a 3-month-old infant and allows measurement of chest compression rate, chest compression depth, complete chest recoil, number of cycles, tidal volume, and hands-off time.

An analog scale was used to evaluate pain and fatigue, and a Likert scale was administered for self-assessment of the quality of CPR performed. The

highest value on the scale (5) corresponded to "agree completely."

Sample Calculation

The sample size, calculated to identify a difference between the techniques of 0.6 seconds hands-off time, was estimated at 73 rescuers (assuming a statistical power of 90% and an error of 0.05).

Statistical Analysis

Categorical variables were described as frequencies and percentages and compared using the chi-square test. Continuous variables were described by mean and standard deviation and compared by paired *t*-test (if normally distributed) or as medians with interquartile range (25%–75%) and compared using the Wilcoxon test. $P<0.05$ were considered significant.

RESULTS

Seventy-nine medical students were considered fit to participate in the study. Data from 1 volunteer were lost and excluded from analysis, for a total of 78 subjects who performed the 2 complete maneuvers (Table 1). The average age was 24±3.7 years, and 73% were female. There were participants from all undergraduate semesters; however, 58.2% attended the seventh semester onwards. The only comorbidities reported by the rescuers were anemia (n=2) and asthma (n=8). There was no difference in characteristics between groups randomized to each technique.

During the TT technique, both the mean chest compression depth (42 mm versus 39.7 mm; $P<0.01$) and the percentage of chest compressions with adequate depth (89.5% versus 77%; $P<0.01$) were greater than during the TF technique. On the other hand, the percentage of compressions performed with complete chest recoil was higher with the TF technique (93% versus 86.7%; $P=0.007$). TF and TT techniques presented similar mean rate of chest compressions (109.7 versus 107.1, respectively; $P=0.06$) and without difference in the percentage of appropriate rate of chest compressions ($P=0.5$). Additionally, there was no difference in average hands-off time (6.6 seconds for TT versus 6.3 for TF; $P=0.16$) and no difference in the percentage of time chest compressions were performed in the CPR cycle, also known as compression fraction (72% versus 73%, $P=0.19$), as shown in Table 2.

All participants judged that 20 minutes of rest between chest compression cycles were sufficient. There was no difference in baseline heart rate between the groups. Likert scale scores revealed better self-perceived quality of CPR with the TT technique (29.0 versus 25.5; $P<0.01$). Visual analog scales for pain and fatigue both showed higher scores with the TF technique than with the TT technique ($P<0.01$) as shown in Table 3.

Table 1. General Characteristics of Participants (n=78)

Age, y, mean (SD)	24 (3.7)
Female sex, n (%)	57 (73%)
Body mass index, kg/m^{-2}, mean (SD)	22.9 (3.3)
Semester of medical school (IQR)	7 (4–11)
Previous training, n (%)	33 (41.8)
Previous attendance, n (%)	31 (39.2)
Prior comorbidity, n (%)	10 (12.7)
Physical activity, n (%)	27 (34)

IQR indicates interquartile range.

DISCUSSION

To the best of our knowledge, we are unaware of previous studies comparing the TF versus TT chest compression techniques and ventilation effects in simulated 1-rescuer out-of-hospital CPR following current CPR recommendations with 78 participants. The 2015 guidelines recommended using the TF technique for 1-rescuer CPR in infants, but the 2020 guidelines did not make any endorsements

Table 2. Comparison of Cardiopulmonary Resuscitation Parameters Between the TT and TF Techniques (n=78)

	TT	TF	*P* Value
Chest compression parameters			
Mean chest compression depth (mm), mean (SD)	42.0 (2.7)	39.7 (5.9)	<0.01*
Mean chest compression rate (min), mean (SD)	107.1 (17.6)	109.7 (16)	0.06*
Percentage of chest compressions with adequate rate, median (IQR)	65 (12–91)	58 (11–89)	0.6†
Percentage of chest compressions with adequate depth, mean (SD)	89.5 (25.9)	77.0 (32.7)	<0.01*
Percentage full-recoil chest compression, mean (SD)	86.7 (24.1)	93.0 (14.7)	0.007*
Percentage chest compressions with correct hand position, mean (SD)	92.7 (17.9)	89.5 (20.7)	0.2*
Hands-off time (s), mean (SD)	6.6 (1.6)	6.3 (1.6)	0.2*
Compression fraction (%), mean (SD)	72.6 (4.7)	73.3 (5.4)	0.2*
Ventilation parameters			
Mean tidal volume, median (IQR)	56 (41–80)	56 (39–86)	0.7†
Breaths/min, mean (SD)	4.2 (1.0)	4.5 (2.1)	0.35*
Total number of breaths/session, mean (SD)	8.7 (2.1)	9.2 (4.1)	0.3*

IQR indicates interquartile range; TF, 2-fingers; and TT, 2-thumbs.
*Paired *t*-test.
†Wilcoxon test.

in this regard, probably as a consequence of the paucity of studies in the literature to support this recommendation.[5,19]

The association between adequate depth of chest compressions and greater odds of survival is well established in adults.[20,21] In our study, chest compression depth was greater with the TT technique, with a difference of 2.3 mm compared with the TF technique. The percentage of compressions performed at the appropriate depth was much higher with the TT technique (89%) than with the TF technique (77%). Jo and colleagues reported similar results (mean depth of chest compressions, TT=42.6±1.4 mm, TF=39.3±3.1 mm) in a sample of 48 participants.[22] Studies since 1993 suggest that chest compression performed with the TT technique achieves greater depth of chest compressions with higher systolic and diastolic pressure and greater coronary perfusion[12,13,23,24] because of the greater strength provided by the thumbs than by the fingers.[25] A recent systematic review analyzed data from 6 simulation studies comparing the TT and TF techniques. Despite the great heterogeneity of the meta-analysis, the depth of chest compressions was greater with TT than with TF (mean difference, 5.50; 95% CI, 0.32–0.69; *P*=0.04).[26]

The TF technique allowed complete recoil after most chest compressions. The complete return of the chest wall after each compression allows adequate diastolic filling and higher coronary perfusion pressure.[27] This result was also found in other studies.[23,28] It has been speculated that the TF technique allows greater recoil because it is associated with greater rescuer pain when performing compressions and greater pain relief when removing pressure.[29]

Ventilation is essential during pediatric CPR because the main causes of out-of-hospital cardiac arrest in this age range are asphyxia related.[30-32] The TF technique is suggested for 1-rescuer CPR because it would allow switching between compressions and ventilation more easily.[12]

We identified 5 studies analyzing the relationship between ventilation and compression, although they were conducted in an in-hospital cardiac arrest setting, and 3 of them used another chest compression technique. One study found a difference in median tidal volume between the TT and TF techniques (40 mL versus 50 mL; *P*<0.001).[33] None of these studies used the TF and TT techniques in a 1-rescuer out-of-hospital setting with a compression-to-ventilation ratio of 30:2 and mouth-to-mouth-and-nose ventilation.[22,25,28,34,35]

In our study, there was no difference in the mean tidal volume performed with mouth-to-nose ventilation nor in number of breaths given at each CPR cycle between the 2 chest compression techniques. Also, there was no difference in hands-off time or in compression fraction. This was probably facilitated by the use of a 3-month-old infant manikin, which allowed easy switching of arm position in relation to the simulated victim.

Rescuer fatigue reduces the quality of chest compressions in adults and children.[9,11,36] In our study, we evaluated fatigue by measuring rescuer heart rate before and after each compression cycle, finger pain (scored on a visual analog scale), and rescuer preference. There was no difference between pre- and post-CPR heart rate between the 2 techniques. Subjectively, participants reported more finger pain and greater fatigue with the TF technique. Participants' self-assessment of the quality of CPR performed, also assessed on a Likert scale, yielded superior scores for the TT technique.

In the out-of-hospital setting, the odds of victim survival are proportional to the early onset of CPR by a first responder until the arrival of advanced emergency services.[37] In some settings, it may take 9 to 17 minutes for rescue to arrive. During this time, the first responder is expected to perform chest compressions with the TF technique until a second rescuer arrives to switch positions. Since the TF technique produces greater rescuer pain and fatigue, it is inferred that this may not be the best approach for 1-rescuer out-of-hospital CPR. In addition, to maximize the simplicity of CPR training, it is reasonable to simplify the chest compression technique taught for use in infants.

Limitations of this study include assessment of the quality of chest compressions on a manikin in a simulated environment. It is known that the chest wall distensibility and compressibility of infant manikins do not exactly simulate those observed in infants. Even though subjects were blinded to outcomes, the Hawthorne effect may have occurred, as they were observed by the researchers and were aware of this observation. Finally, the simulated CPR time was shorter than is expected to occur in reality (2 minutes

Table 3. Comparison of Self-Perceived CPR Quality, Rescuer Heart Rate, Fatigue, and Pain During CPR Performance With the TT and TF Techniques (n=78)

	TT	TF	*P* Value
Self-perceived CPR quality	29.04	25.49	<0.001*
Pain, mean (SD)	1.85 (1.9)	5.27 (2.2)	<0.001*
Fatigue, mean (SD)	2.67 (1.6)	3.86 (1.8)	<0.001*
Baseline HR, beats/min, mean (SD)	82.6 (13.6)	81.4 (14.1)	0.4*
HR after CPR, beats/min, mean (SD)	102.8 (18.8)	100.2 (18.4)	0.08*
ΔHR, mean (SD)	20 (12)	18 (15)	0.3†

CPR indicates cardiopulmonary resuscitation; HR, heart rate; TF, 2-fingers; and TT, 2-thumbs.
*Paired *t*-test.
†Wilcoxon test.

versus up to 8 minutes until arrival of emergency services in an out-of-hospital setting). Even considering these limitations, it can be inferred that, in a real environment, these results would be reproducible and even more pronounced because of a longer out-of-hospital CPR duration.

CONCLUSIONS

Compared with the TF technique, the TT technique for infant chest compressions achieves better compression quality without interfering with ventilation and causes less rescuer pain and fatigue during simulated resuscitation of out-of-hospital cardiac arrest. Future studies, both in real-life scenarios and in simulations, are needed to confirm these findings and ascertain the superiority of chest compression techniques in infants.

ARTICLE INFORMATION

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Disclosures

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