

Comparison of two infant chest compression techniques during simulated newborn cardiopulmonary resuscitation performed by a single rescuer: A randomized, crossover multicenter trial

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Abstract

Background: *In newborns, ventilation is a key resuscitation element but optimal chest compression (CC) improves resuscitation quality. The study compared two infant CC techniques during simulated newborn resuscitation performed by nurses.*

Methods: *The randomized crossover manikin, multicenter trial involved 52 nurses. They underwent training with two CC techniques: standard two-finger technique (TFT) and novel two-thumb technique (NTTT; two thumbs at 90° to the chest, fingers in a fist). One week later, the participants performed resuscitation with the two techniques. A Tory[®] S2210 Tetherless and Wireless Full-term Neonatal Simulator was applied, with a 3:1 compression to ventilation ratio. CC quality in accordance with the 2015 American Heart Association guidelines was assessed during the 2-min resuscitation.*

Results: *Median CC depth was 30 mm for TFT and 37 mm for NTTT ($p = 0.002$). Correct hand placement reached 98% in both techniques; full chest relaxation was obtained in 97% vs. 94% for TFT and NTTT, respectively. CC fraction was slightly better for NTTT (74% vs. 70% for TFT; $p = 0.044$), the ventilation volume was comparable for both techniques. On a 100-degree scale (1 — no fatigue; 100 — extreme fatigue), the participant tiredness achieved 72 points (IQR 61–77) for TFT vs. 47 points (IQR 40–63) for NTTT ($p = 0.034$). For real resuscitation, 86.5% would choose NTTT and 13.5% TFT.*

Conclusions: *The NTTT technique proved superior to TFT. Evidence suggests that NTTT offers better CC depth in various medical personnel groups. One-rescuer TFT quality is not consistent with resuscitation guidelines. (Cardiol J 2019; 26, 6: 761–768)*

Key words: newborn, cardiopulmonary resuscitation, chest compression, quality, medical simulation

Introduction

Sudden cardiac arrest in pediatric patients is uncommon [1, 2]. In newborns, correct ventilation is a key element in cardiopulmonary resuscitation and support of transition at birth but correct chest compression (CC) improves resuscitation quality

and thus affects vital organ perfusion, the return of spontaneous circulation, and survival rate [3–6]. The quality of CC is often suboptimal owing to incorrect CC technique, fatigue, and the rescuer position or experience [4, 7]. Some diagnostic feedback devices have been tested in order to improve neonatal and newborn cardiopulmonary resuscita-

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tion [8–10] but their role in clinical settings have not yet been established.

The four main quality measurements of cardiopulmonary resuscitation are CC rate, CC depth, release force, and compression duty cycles [3, 4]. The resuscitation guidelines emphasize the reduction of hands-off time in cardiopulmonary resuscitation, optimal CC frequency, depth, and full chest relaxation [4, 11]. The knowledge of the newborn CC technique is important for all medical personnel, including physicians, nurses, midwives, and paramedics [12].

There are two standard CC techniques in neonatal and newborn resuscitation: the two-finger technique (TFT) and the two-thumb encircling hands technique (TTHT) [3]. For single rescuer resuscitation, TFT is recommended by the American Heart Association (AHA) [3]. However, TFT is often suboptimal in terms of CC depth, correct hand position, full chest relaxation, and coronary perfusion pressure [13–17].

The novel two-thumb technique (NTTT) developed by Smereka et al. [18] consists in using two thumbs directed at the angle of 90° to the chest while closing the fingers of both hands in a fist. The alignment of thumbs with the arms allows body strength to be directed downward to the sternum, in contrast to TFT, which mainly relies on finger and hand strength [18, 19].

The novel technique has been investigated in several studies in different age groups and study participants as well as in different settings, with the consideration of the resuscitation technique, CC and ventilation ratio, and the time of resuscitation efforts [18, 20–22]. The results suggest that NTTT provides several advantages as compared with standard newborn resuscitation techniques, e.g. allowing to overcome problems with the rescuer hand size in TTHT. The initial results of NTTT applied by different medical personnel in different settings and manikins prove that NTTT offers superior hemodynamic parameters than TTHT, as well as better median CC depth and degree of full chest recoil in 2- and 10-min neonatal and infant resuscitation [23, 24].

There are studies suggesting that ventilation influences sternal displacement during simulated pediatric cardiopulmonary resuscitation regardless of the compression method used, and the compression forces are significantly lower during synchronous ventilation with TFT [25].

In the current study, we checked the CC quality during constant ventilation with the standard neonatal 3:1 compression-to-ventilation ratio with mouth-to-mouth and nose ventilation. The

aim was to compare the newborn TFT with the authors' NTTT during simulated newborn 2-min one-rescuer cardiopulmonary resuscitation performed by nurses.

Methods

Study design and selection of participants

The study was designed as a prospective, randomized, crossover observational study. The protocol was approved by the Institutional Review Board of the Polish Society of Disaster Medicine (approval No. 23.03.2017.IRB). The participants were recruited from among nurses taking part in emergency medicine training in Warsaw and Wrocław (Poland).

The study is a continuation of the research conducted by the authors on improving the quality of CCs during pediatric resuscitation [18, 20–24] in various study groups and settings.

The inclusion criteria were the following: practice as a nurse and voluntary participation in the study. The exclusion criteria comprised pain in the wrist or upper limb and back pain. Voluntary written informed consent was obtained from all participants. The study involved 52 nurses.

All participants declared that during their studies they had undergone training in cardiopulmonary resuscitation for adults and children.

Scenario simulation

Prior to the study, all subjects took part in a newborn cardiopulmonary resuscitation training, which referred to the causes of cardiac arrest in this age group, as well as resuscitation rules based on the current AHA guidelines [3]. After the theoretical training, the instructor demonstrated the correct CCs with the studied methods. Two techniques of newborn CCs were applied:

- TFT, previously the standard method for infant CC. When using this method, the rescuer compresses the sternum with the tips of two fingers;
- the NTTT method of CCs in an infant, which consists in using two thumbs directed at the angle of 90° to the chest while closing the fingers of both hands in a fist (Fig. 1).

Then, the participants performed 2-min resuscitation cycles with the tested methods using a SimBaby Classic simulator (Laerdal, Stavanger, Norway).

One week after the training completion, the nurses took part in the final study, during which they were tasked with performing a 2-min car-

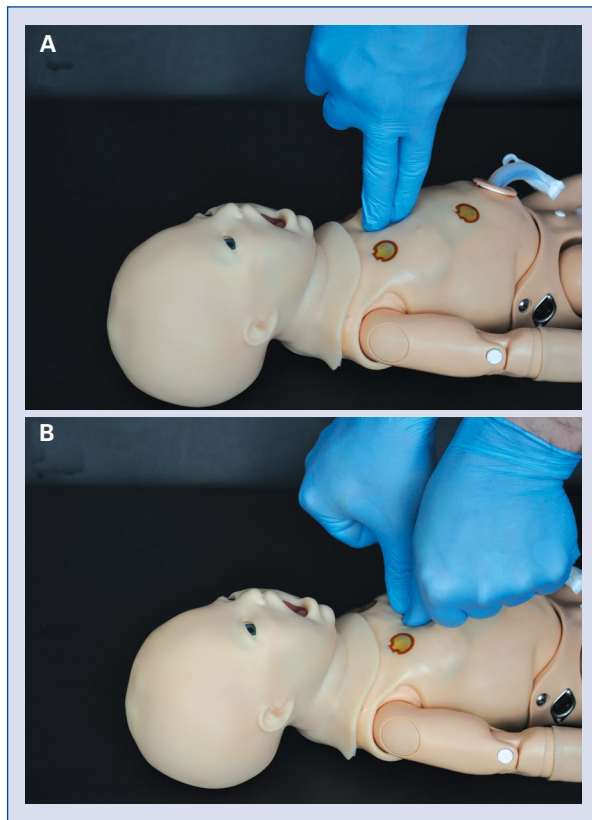


Figure 1. Chest compressions techniques: **A.** Standard two finger technique; **B.** Novel two thumb technique.

diopulmonary resuscitation cycle with the tested techniques. The standard newborn 3:1 compression-to-ventilation ratio with a mouth-to-mouth and nose ventilation rescue breath was applied, with the aim of achieving 90 CCs and 30 rescue breaths per minute [4]. In order to simulate a newborn requiring cardiopulmonary resuscitation, a Tory[®] S2210 Tetherless and Wireless Full-term Neonatal Simulator (Gaumard Scientific, Miami, FL, USA) was used. The simulator was placed on a hard table, each time set to the height of 2/3 of the participant's thigh for the purpose of standardization.

The order of both the participants and the research methods was random. For this purpose, the Research Randomizer program (randomizer.org) was used and the study participants were divided into two groups. The first group performed resuscitation with the TFT and the other applied the NTTT. After a 2-min resuscitation cycle, the participants had a 1-h rest and then performed resuscitation using the other technique. A detailed randomization procedure is shown in Figure 2.

Measurements

During the whole study, the parameters of CCs were recorded by the software controlling the simulator (Fig. 3), and the whole test was

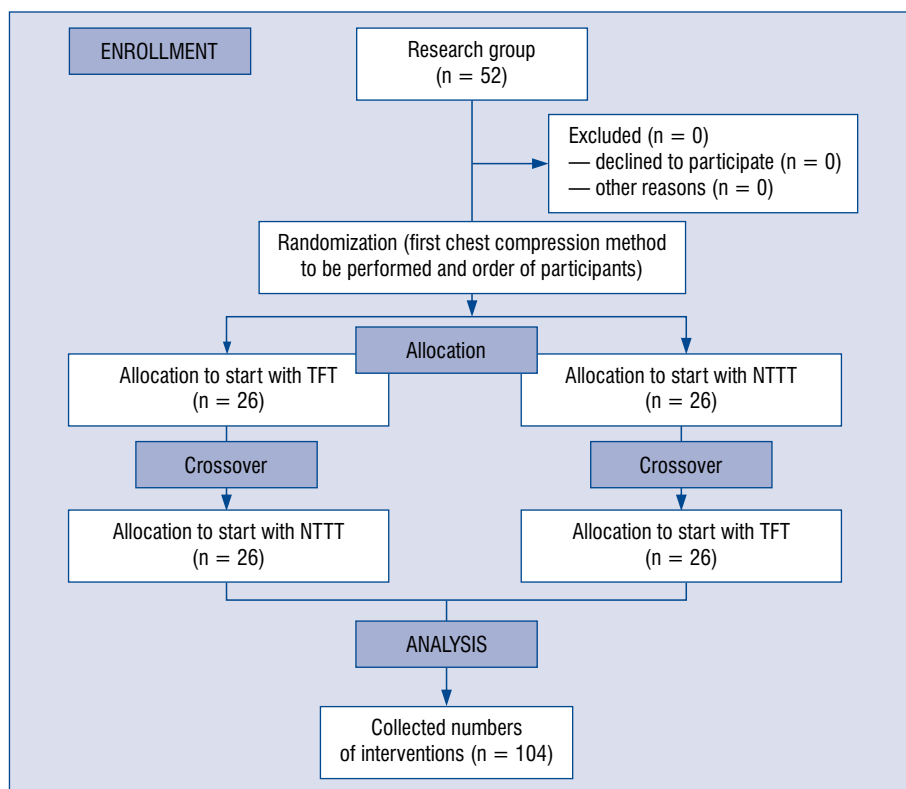


Figure 2. Randomization flow chart; NTTT — novel two-thumb technique; TFT — two-finger technique.

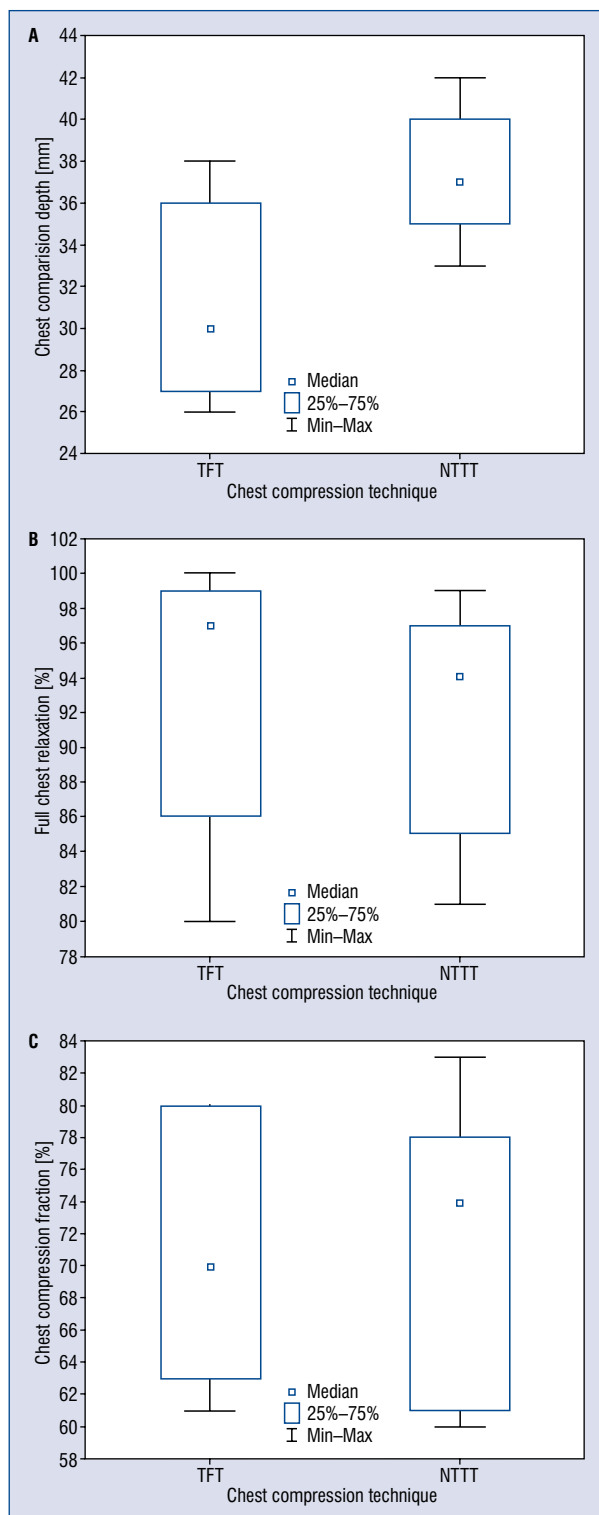


Figure 3. Chest compression quality: **A.** Chest compression depth; **B.** Full chest relaxation; **C.** Chest compression fraction; NTTT — novel two-thumb technique; TFT — two-finger technique.

documented with a GoPro HERO5 Black 4K Ultra HD camera (GoPro, Inc., San Mateo, CA, USA) in

order to reconstruct its course over time. The following parameters of CCs quality were analyzed: frequency, depth, degree of full chest relaxation, correctness of hand position on the chest, and CC fraction, which was measured as the total time when the chest was compressed during the 2-min resuscitation. The volume of ventilation during rescue breaths was also measured. In addition, at the end of the study, the participants were asked to determine the level of fatigue on a 100-degree scale (1 — no fatigue; 100 — extreme fatigue) for both procedures. Also, their preferences regarding the technique to be used during real cardiopulmonary resuscitation were evaluated.

Statistical analysis

Continuous and original data are presented as median and interquartile range (IQR), and the categorical data are presented as raw numbers and frequencies. Non-parametric tests were used because the data distribution was not normal, as implied by the Shapiro-Wilk and Kolmogorov-Smirnov tests. The data were analyzed with the Statistica 13.3 statistical package (TIBCO Software Inc., Tulsa, OK, USA). Values of $p < 0.05$ were considered significant.

Results

The study involved 52 nurses (45 females; 86.3%) with median age of 25.5 (IQR 24.5–26) years. Their median work experience was 9.4 (IQR 6–14) years.

Chest compression quality

The median CC depth was 30 mm for TFT and 37 mm for NTTT ($p = 0.002$). Correct hand placement reached 98% in both techniques, and full chest relaxation was obtained in 97% vs. 94% for TFT and NTTT, respectively. CC fraction was slightly better for NTTT (74% vs. 70% for TFT; $p = 0.044$) and the ventilation volume turned out to be comparable for both techniques. CC quality results are shown in Table 1.

Participants' self-assessment

The degree of the participant tiredness that resulted from performing CCs with the two tested techniques was varied, assessed as 72 points (IQR 61–77) for TFT and 47 points (IQR 40–63) for NTTT ($p = 0.034$). During real resuscitation, 86.5% of the study participants would choose NTTT and 13.5% — the currently recommended technique of compression, TFT.

Table 1. Cardiopulmonary resuscitation quality variables.

Parameter	TFT	NTTT	P
Chest compression depth [mm]	30 [27–36]	37 [35–40]	0.002
Full chest relaxation [%]	97 [86–99]	94 [85–97]	0.845
Correct hand placement [%]	98 [92–99]	98 [93–100]	0.677
Chest compression fraction [%]	70 [63–80]	74 [61–78]	0.044
Ventilation volume [mL]	71 [63–81]	69 [60–83]	0.012

TFT — two-finger technique; NTTT — novel two-thumb technique

Discussion

American Heart Association recommends five components of high-quality pediatric cardiopulmonary resuscitation: ensuring CCs of adequate rate and depth, allowing full chest recoil between compressions, minimizing interruptions in CCs, and avoiding excessive ventilation [3, 26]. The suboptimal quality of CCs with TFT was emphasized by several studies indicating that the only main advantage of TFT as compared with TTHT was optimal full chest relaxation [27]. Incomplete chest release can decrease the return of venous blood to the heart and consequently reduce the perfusion pressure [28].

Several modifications for neonatal and infant resuscitation have been proposed, including the “vertical two-thumb technique” [29] and “knocking-fingers” CC technique [30]. A method of “high-impulse cardiopulmonary resuscitation” was also suggested as the alternative for neonatal CC [31]; moreover, changing fingers during TFT was investigated [32, 33]. Currently, only two standard neonatal CC techniques (TTHT and TFT) are recommended by AHA and the European Resuscitation Council (ERC).

The NTTT has been tested in various medical personnel groups. However, in this study we checked the quality of one-rescuer, 2-min newborn resuscitation performed by nurses without the use of a metronome, with the 3:1 compression-to-ventilation ratio with a mouth-to-mouth and nose ventilation rescue breath; the aim was to achieve 90 CCs and 30 rescue breaths per minute [4].

American Heart Association and ERC recommend at least 40 mm or 1/3 of the anterior-posterior diameter as the CC depth [1]. In the present study, median CC depth for standard TFT achieved 30 mm compared with 37 mm for NTTT. Several other studies suggest that CC depth with TFT turns out far below the current resuscitation guidelines [14, 34]. In a study by Smereka et al. [18], in

a 3-month-old infant manikin model resuscitation, novice physicians obtained the median CC depth of 26 mm with TFT and 39 mm with NTTT.

Another study of 2-min cardiopulmonary resuscitation using a Newborn Tory® S2210 manikin (Gaumard® Scientific, Miami, FL, USA) to compare TFT chest compressions in different resuscitation positions of the rescuer revealed that in no tested manikin position were TFT nurses able to reach the recommended CC depth (14–25 mm, the best result for the rescuers; forearm position) [35]. When resuscitation was performed on a table with the top adjusted to the height of 2/3 of the rescuer’s thigh, the median CC depth for TFT achieved 14 mm only [22]. The second standard CC technique, TTHT, offers better CC depth compared with TFT [21].

Full chest relaxation is another important parameter affecting CC depth, blood flow and pressure. In both analyzed CC techniques, full chest relaxation was obtained in a very high percentage of CCs (97% for TFT and 94% for NTTT; the difference was not statistically significant). In other studies it was emphasized that one of the main advantages of TFT was a high percentage of full chest relaxation, which turned out significantly better with the use of TTHT [20].

Correct hand placement during CCs was observed nearly in 100% for both analyzed techniques. The same results were obtained in a study by Smereka et al. [18] in a 3-month-old infant manikin model resuscitation performed by novice physicians. In the same study, correct hand position for TFT and NTTT reached 100%. The correct hand position was 98.5% vs. 100% for TFT and NTTT, respectively, in a study investigating 120 paramedics for 2-min 3-month-old manikin resuscitation [22].

The CC fraction was better for NTTT comparing with TFT (70% vs. 74%, respectively; the difference was statistically significant). The so-called hands-off time is defined as the time without CC and it should be minimized [10]. Another study by

Smereka et al. [23] revealed that paramedics using NTTT achieved significantly better systolic, diastolic, and mean blood pressure during 10-min resuscitation with TFT.

The fatigue during newborn resuscitation with different CC to ventilation ratio methods is a well-known problem [36–38], resulting in a decreasing quality of CCs over time. It can even appear during a relatively short-lasting neonatal resuscitation (below 10 min) and is associated with lack of aerobic activity and body mass index ≥ 25 [39, 40]. In the standard CC techniques (TFT, TTHT), finger and thumb pain is common [23]. This study revealed that the NTTT technique was less tiring for nurses performing CCs as compared with TFT. For real resuscitation, 86.5% of the study participants would choose NTTT and 13.5% — currently recommended TFT technique. Similar results were obtained in other studies on NTTT, suggesting less hand fatigue and exhaustion among the paramedics and physicians performing resuscitation [23].

Previous studies have proven advantages of NTTT in infant, neonatal, and newborn resuscitation in various simulation settings, including 2-min vs. 10-min CCs, different manikin models, and diverse study methodology [20–24]. In contrast to previous research in newborn simulation settings [21, 35], in this study the standard CC was used: the 3:1 ventilation ratio for newborn resuscitation [4], allowing to achieve approximately 90 CCs per minute. In pediatric patients, the standard recommended CC rate equals 100–120 per minute [3]. CC alone or with epinephrine in a delivery room is associated with poor prognosis [41]. However, there are some studies suggesting that different CC to ventilation ratios (2:1, 3:1, 4:1) result in similar return of spontaneous circulation and similar mortality during resuscitation in a porcine model of neonatal asphyxia [42].

Limitations and strengths

The presented paper has several limitations. Firstly, the use of a newborn manikin cannot fully replicate the properties of human anatomy and physiology, and the study was not a clinical trial. As randomized crossover resuscitation trials are unethical, a decision was made to use a Newborn Tory® S2210 manikin simulator, the most advanced neonatal simulator available. Simulation studies allow achievement of statistical power via a crossover design of the trial. Another limitation is that the study was conducted only among nursing personnel, and only two CC techniques were

analyzed. The strength of the study consists in its crossover design.

Conclusions

The novel CC technique for newborn one-rescuer resuscitation performed by nurses turned out better than the standard TFT technique. There is consistently growing evidence that NTTT offers superior CC depth as compared with TFT for newborn resuscitation in various medical personnel groups. The quality of one-rescuer TFT is constantly suboptimal and not consistent with international resuscitation guidelines. Further animal studies are necessary to validate results in terms of clinical usefulness.

Ethical approval: Approval was granted by the Institutional Review Board of the Polish Society of Disaster Medicine (approval no.: 23.03.2017.IRB).

Informed consent: Informed consent was obtained from all individual participants included in the study.

Conflict of interest: None declared

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