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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

The quality of a newly developed infant chest compression method applied by paramedics: a randomised crossover manikin trial

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Abstract

Background: The aetiology of sudden cardiac arrest in infants is different from that in adults, with respiratory failure, sudden infant death syndrome, and drowning being the primary causes in the former. According to the European Resuscitation Council (ERC) and American Heart Association (AHA) recommendations, the quality of chest compressions (CC) is a key element affecting the effectiveness of cardiopulmonary resuscitation (CPR). The current ERC and AHA guidelines recommend the 'two-finger technique' (TFT) or 'two-thumb encircling hands technique' (TTHT) for external CCs during infant CPR.

Aim: The aim of the randomised crossover manikin trial was to assess the CC quality during simulated resuscitation in infants performed by paramedics.

Methods: A prospective, randomised, crossover, single-centre study was conducted between June and August 2016. The study material consisted of 120 fully trained and licensed paramedics (39 females, 32.5%) with a minimum of five years of professional experience (mean 7.5 ± 4.8 years) in emergency medicine (mean age, 30.5 ± 5.5 years). The participants performed CCs using three techniques: TFT (the rescuer compresses the sternum with the tips of two fingers); TTHT; and the 'new two-thumb technique' (nTTT). The novel method of CCs in an infant consists of using two thumbs directed at the angle of 90 degrees to the chest while closing the fingers of both hands in a fist.

Results: The median CC rate when using the TFT, the TTHT, and nTTT methods varied and amounted to 134 min^{-1} vs. 126 min^{-1} vs. 114 min^{-1}, respectively. There was a statistically significant difference in the median CC frequency between TFT and TTHT ($p < 0.001$), TFT and nTTT ($p < 0.001$), and between TTHT and nTTT ($p < 0.001$). The highest percentage of compressions with the frequency recommended by the ERC guidelines (100–120 min^{-1}) was achieved by the study participants only with the nTTT. The median CC depth during the TFT was 28 mm (interquartile range [IQR] 27–30 mm) and was significantly lower than in the static TTHT (40.5 [IQR 39–41] mm; $p < 0.001$) and nTTT (40 [IQR 39–41] mm; $p < 0.001$). The percentage of adequate depth CCs was correctly obtained with TTHT and nTTT. The largest proportion of total decompression of the chest was observed with the nTTT technique (96 [IQR 96–98] %), followed by TFT (95.5 [IQR 85.5–99] %) and TTHT (5 [IQR 3–7] %). In all scenarios, the correct placement of the CC point was achieved in more than 90% of cases.

Conclusions: Our novel infant CC method provides the highest percentage of CCs with the frequency recommended by the ERC guidelines as compared with standard techniques. It also allows optimal CC depth.

Key words: cardiopulmonary resuscitation, chest compression, quality, infant, paramedic

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INTRODUCTION

The aetiology of sudden cardiac arrest in infants is different from that in adults, with respiratory failure, sudden infant death syndrome, and drowning being the primary causes in the former [1–3]. The World Health Organisation reported infant mortality of 5 per 1000 live births for Australia and 7 per 1000 live births for the United States, and the under-5-year-old mortality is 6 per 1000 live births for Australia and 8 per 1000 live births in the United States. In a smaller study from Helsinki, the incidence of any cause out-of-hospital cardiac arrest in below 16-year-olds equalled 9.8 per 100,000 person-years [4]. Although sudden cardiac arrest occurs rarely in children, the rate of survival without a major neurologic deficit is only 10% [5].

According to the European Resuscitation Council (ERC) and American Heart Association (AHA) recommendations, the quality of chest compressions (CC) is a key element affecting the effectiveness of cardiopulmonary resuscitation (CPR) [6, 7]. The current ERC and AHA guidelines recommend the 'two-finger technique' (TFT) or 'two-thumb encircling hands technique' (TTHT) for external CCs during infant CPR [6, 7]. In turn, the 2015 CoSTR guidelines point out that CCs in an infant should be delivered with the TTHT as the preferred option, compared with the TFT [8]. It is worth nothing that the TTHT allows a more consistent CC depth and higher coronary perfusion pressures in animal studies [9], as well as higher CC pressures in human manikin studies [10]. However, the CC quality with the use of either the TFT or TTHT proved to be insufficient [10].

The aim of the randomised crossover manikin trial was to assess the CC quality during simulated resuscitation in infants performed by paramedics.

METHODS

Trial design

The prospective, randomised, crossover, single-centre study was conducted between June and August 2016 and was approved by the Institutional Review Board of the Polish Society of Disaster Medicine (IRB N14.07.2016).

Participants

The paramedics included in the study were recruited on a voluntary basis. The inclusion criteria were: to be fully trained and licensed as a paramedic and to have a minimum of five years of professional experience in emergency medicine. The trial finally involved 120 paramedics.

Interventions

Prior to the study, all the participants received a 30-min training session on advanced life support in infant cardiac arrest, according to the current ERC guidelines [6].

A standardised ALS Baby trainer manikin (Laerdal Medical, Stavanger, Norway) simulating a three-month-old infant was used. The manikin was placed on a high adjustable hospital stretcher. The bed was levelled to the iliac crest of each rescuer for standardisation. The manikin was intubated, and the paramedics were asked to perform uninterrupted CCs for a period of 2 min.

Figure 1. The 'new two-thumb technique'

The participants performed CCs using three techniques:

1. The TFT, which was previously a standard method for infant CC. With this method, the rescuer compresses the sternum with the tips of two fingers.
2. The TTHT. In this technique, two thumbs are placed over the lower third of the sternum, with the fingers encircling the torso and supporting the back. The method was associated with better coronary artery perfusion and less fatigue than the TFT [11].
3. The 'new two-thumb technique' (nTTT). The novel method of CCs in an infant consists in using two thumbs directed at the angle of 90 degrees to the chest while closing the fingers of both hands in a fist (Fig. 1).

The order of both the participants and the applied CC techniques was randomised. For this purpose, Research Randomiser software was used. The participants were divided into three groups. The first group started their CCs using the TFT, the second group with the TTHT, and the third group applied the nTTT (Fig. 2). After completing one cycle of CCs, each participant took a 20-min break and was then asked to perform CCs with another technique.

Outcomes

Performance data were collected with the use of the Resusci Anne Skill Reporter (Laerdal Medical, Stavanger, Norway). During the study, the following parameters were evaluated: the frequency of CCs (min^{-1}), the percentage of CCs with an adequate rate (%), the CC depth (mm), the percentage of CCs with an adequate depth (%), the percentage of fully released CCs (%), as well as the percentage of correct hand position cases (%). The study participants had no insight into the manikin monitoring system, and they performed the CPR as guided by their own experience. After each CPR attempt, the respondents

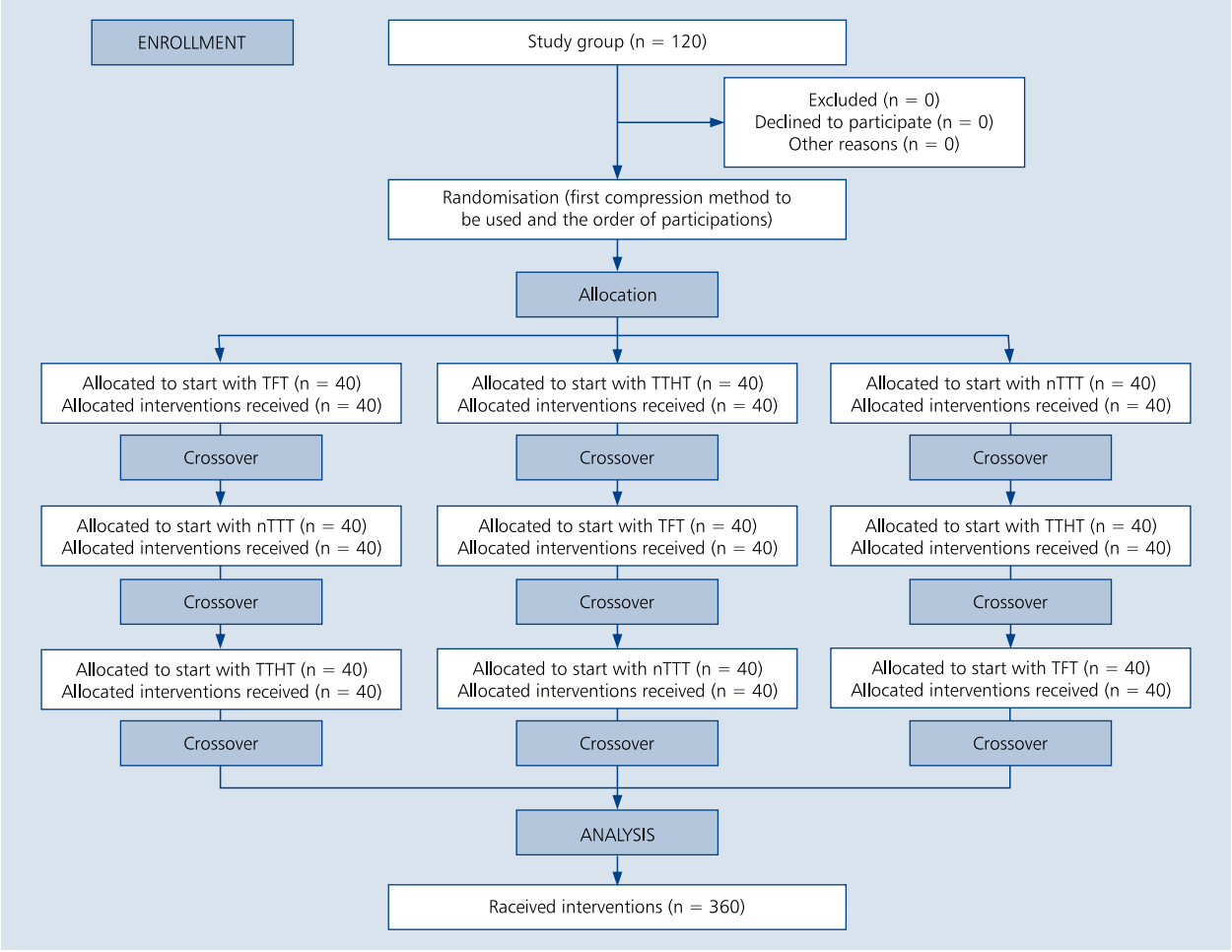

Figure 2. Flow chart of design and recruitment of participants according to CONSORT statement; TFT — 'two-finger technique'; TTHT — 'two-thumb encircling hands technique'; nTTT — 'new two-thumb technique'

were asked to identify their preferences with regard to the CC techniques. The rating was based on a 1–10 scale (1 — a useless technique, 10 — a definitely useful technique).

Statistical analysis

All the statistical analyses were performed with Statistica software v.12 (StatSoft Inc., Tulsa, USA). The results are shown as numbers (percentages), means and standard deviations (SD), or medians and interquartile ranges (IQR). The occurrence of normal distribution was confirmed by the Kolmogorov-Smirnov test. When the data were not characterised by normal distribution, non-parametric tests were used. All the statistical tests were two-sided. A p-value of less than 0.05 was considered significant.

RESULTS

The trial involved 120 paramedics (39 females, 32.5%). Their mean age was 30.5 ± 5.5 years, and their mean work experience equalled 7.5 ± 4.8 years. All the participants worked in Emergency Medical Service teams.

The median CC rate when using the TFT, the TTHT, and nTTT methods varied and amounted to 134 min^{-1} vs. 126 min^{-1} vs. 114 min^{-1}, respectively (Fig. 3). There was a statistically significant difference in the median CC frequency between TFT and TTHT ($p < 0.001$), TFT and nTTT ($p < 0.001$), and between TTHT and the nTTT ($p < 0.001$). The highest percentage of compressions with the frequency recommended by the ERC guidelines (100–120 min^{-1}) was achieved by the study participants only with the nTTT. The median CC depth during the TFT was 28 mm (IQR 27–30 mm) and was significantly lower than in the static TTHT (40.5 [IQR 39–41] mm; $p < 0.001$) and nTTT (40 [IQR 39–41] mm; $p < 0.001$) (Fig. 4). The percentage of adequate depth CCs was correctly obtained with TTHT and nTTT (Table 1). The largest proportion of total decompression of the chest was observed with the nTTT technique (96 [IQR 96–98] %), followed by TFT (95.5 [IQR 85.5–99] %) and TTHT (5 [IQR 3–7] %). In all scenarios, the correct placement of the CC point was achieved in more than 90% of cases (Table 1).

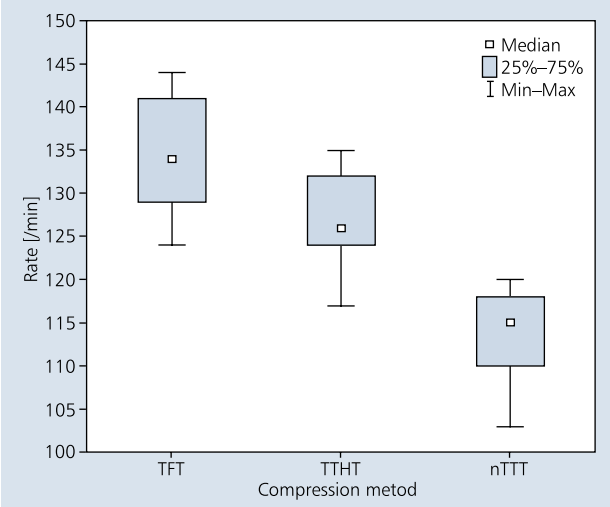

Figure 3. The median chest compression rate using different compression methods; TFT — 'two-finger technique'; TTHT — 'two-thumb encircling hands technique'; nTTT — 'new two-thumb technique'

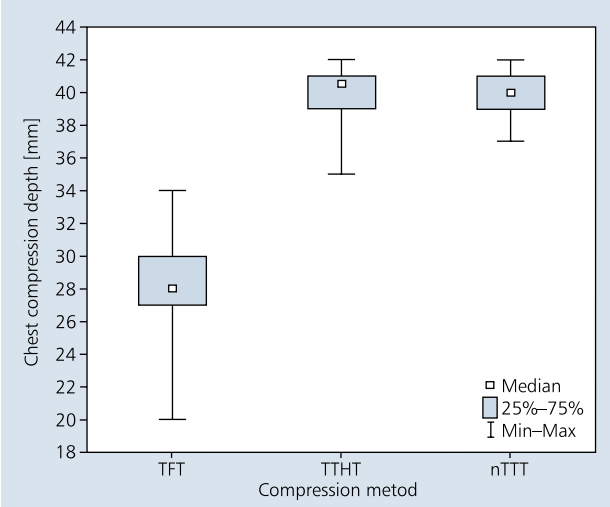

Figure 4. The median chest compression depth using different compression methods; TFT — 'two-finger technique'; TTHT — 'two-thumb encircling hands technique'; nTTT — 'new two-thumb technique'

Table 1. Comparison of the three chest compression techniques

Parameter	Chest compression method			p
	TFT	TTHT	nTTT	
Compression rate [min^{-1}]	134 [129–141]	126 [124–132]	114 [110–118]	< 0.001 for TFT vs. TTHT < 0.001 for TFT vs. nTTT < 0.001 for TTHT vs. nTTT
Compressions with adequate rate [%]	4 [1–7.5]	12 [2.5–29.5]	89 [67–95]	0.002 for TFT vs. TTHT < 0.001 for TFT vs. nTTT < 0.001 for TTHT vs. nTTT
Compression depth [mm]	28 [27–30]	40.5 [39–41]	40 [39–41]	< 0.001 for TFT vs. TTHT < 0.001 for TFT vs. nTTT NS for others
Compressions with adequate depth [%]	0 [0–2.5]	93.5 [91–96]	99 [98.5–100]	< 0.01 for TFT vs. TTHT < 0.01 for TFT vs. nTTT < 0.01 for TTHT vs. nTTT
Compressions fully released [%]	95.5 [85.5–99]	5 [3–7]	96 [96–98]	< 0.001 for TFT vs. TTHT < 0.001 for TTHT vs. nTTT NS for others
Correct hand position [%]	98.5 [93.5–100]	98 [97–99]	100 [97–100]	< 0.001 for TFT vs. nTTT < 0.001 for TTHT vs. nTTT NS for others

TFT — 'two-finger technique'; TTHT — 'two-thumb encircling hands technique'; nTTT — 'new two-thumb technique'; NS — not significant

The study participants declared that, in their opinion, the nTTT was the least effective technique, and scored it 3.5 (3–5) points. The next technique was the TFT, with a score of 5.5 (4–7) points, and then the TTHT, which received 6 (3.5–7) points.

DISCUSSION

The trial was the first study comparing the quality of CCs performed with the authors' method with two standard CC techniques. The main and critical task during CPR is to provide adequate blood flow to the heart and brain. CC increases the

pressure in the thorax, allowing adequate blood flow to the lungs, brain, and other critically important areas.

The is no consensus in the literature concerning the best CC technique in infants. Some studies focus on comparing the TFT and TTHT [10], and the results consistently show the superiority of the latter. Although several studies have recommended the TTHT, even in lone-rescuer CPR [12, 13], in one trial the hands-off-time of the TTHT proved to be significantly longer than that of the TFT [12]. Some manikin studies, as well as animal studies, of haemodynamic monitoring in infants showed that the TTHT produced higher systolic and diastolic arterial pressures and more consistent correct depth as compared with the TFT [9, 14–16].

The present study does not refer to haemodynamic measurements, but one can assume that the nTTT can also cause higher pressure due to greater CC depth as compared with the TFT. As already indicated, an important element affecting CC quality is the depth of the compressions. In the present study, the CC depth was highest for the nTTT (it equalled 28 mm for the THT and 39 mm for the TTHT). Studies comparing the TFT and TTHT indicate greater CC depth in the case of the TTHT [13, 17].

The current ERC guidelines recommend that CCs should be performed with a frequency of between 100 and 120 min^{-1} [6]. In the present study, the CC frequency varied and depended on the specific CC technique. The median CC rate was 134 min^{-1} for the TFT, 126 min^{-1} for the TTHT, and 114 min^{-1} for the nTTT. The percentage of CCs with the frequency located within the standards recommended by the ERC was highest in the case of the nTTT and amounted to 89%. Studies published by Christman et al. [17] and Fakhraddin et al. [18] confirm that the TFT allows for faster CPR performance than the TTHT. The CC rate is one of the basic parameters specified by both the ERC and AHA guidelines. In their studies assessing the optimum CC rate, Lampe et al. [19] discovered that CC rates greater than 100 min^{-1} interfered with the second period of flow and reduced the net forward flow per compression. Lampe et al. [19] emphasised that rates below100 min^{-1} allow for the second forward oscillation to occur.

The quality of CCs is also affected by the correctness of the hand position. Before 1986, the recommended position for external CC in infants was the point over the middle third of the sternum [20, 21]. Subsequently, three trials published in 1986 helped to define the adequate position of the heart in the infant chest. They found that it lay under the lower third of the sternum, thus raising questions regarding the recommended hand position for external infant CCs [22–24]. The CC point was confirmed by other studies, including those based on computer tomography imaging [25].

Limitations of the study

The present study has several limitations. Firstly, the results were obtained for a manikin and may not be representative for real-life situations. Secondly, the authors conducted the study among paramedics; however, the choice of the study group was intentional because in the Emergency Medical Service setting paramedics have to perform CPR both in adults and in children. Thirdly, the experiment was conducted with the use of a manikin, and the participants performed continuous CC without ventilation because the manikin was intubated and ventilated in a continuous 2-min period, according to the current guidelines. This scenario was applied because medical staff, including paramedics, are taught to perform endotracheal intubation, which is the gold standard for airway management during CPR. Moreover, the importance of providing uninterrupted CCs is emphasised because every interruption causes a dramatic decrease in coronary perfusion pressure [26]. Among the strengths of the research, one should mention the comparison of three different CC techniques, including the authors' new method, as well as the randomised crossover nature of the study.

CONCLUSIONS

Our novel infant CC method, in which two thumbs are directed at the angle of 90 degrees to the chest while the fingers of both hands are closed in a fist, provides the highest percentage of CCs with the frequency recommended by the ERC guidelines as compared with standard techniques. It also allows better CC depths and optimal CC depth. Human clinical trials are needed to confirm the presented results.

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Conflict of interest: *none declared*

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Jakość pośredniego masażu serca wykonywanego przez ratowników medycznych u niemowląt z zastosowaniem nowej metody uciskania klatki piersiowej: randomizowane badanie krzyżowe z wykorzystaniem fantomów

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Streszczenie

Wstęp: Etiologia nagłego zatrzymania krążenia różni się w przypadku noworodków i niemowląt oraz osób dorosłych, a niewydolność oddechowa, zespół nagłej śmierci niemowląt oraz utonięcie stanowią główne przyczyny zgonu w tej pierwszej grupie pacjentów. Zgodnie z zaleceniami wynikającymi z Wytycznych Europejskiej Rady Resuscytacji (ERC) i Amerykańskiego Towarzystwa Kardiologicznego (AHA) jakość pośredniego masażu serca (CC) jest zasadniczym elementem wpływającym na skuteczność resuscytacji krążeniowo-oddechowej (CPR). W obecnie obowiązujących wytycznych ERC i AHA w przypadku prowadzenia resuscytacji u noworodków i niemowląt zaleca się stosowanie pośredniego masażu serca techniką dwóch palców (TFT) lub techniką dwóch kciuków i dłoni z objęciem klatki piersiowej (TTHT).

Cel: Celem niniejszego randomizowanego badania krzyżowego przeprowadzanego na fantomach była ocena jakości pośredniego masażu serca w trakcie symulowanej resuscytacji u niemowląt, prowadzonej przez ratowników medycznych.

Metody: Badanie prospektywne, randomizowane, krzyżowe, jednoośrodkowe było przeprowadzone w okresie od czerwca do sierpnia 2016 roku. Materiał badawczy stanowiło 120 czynnych zawodowo ratowników medycznych (39 kobiet, 32,5%) posiadających co najmniej 5-letnie (7,5 ± 4,8 roku) doświadczenie zawodowe w ratownictwie medycznym (średnia wieku 30,5 ± 5,5 roku). Każdy z uczestników prowadził CC, stosując każdą z trzech technik: TFT (ratownik uciska mostek opuszkami dwóch palców), TTHT oraz nową techniką uciskania dwoma kciukami (nTTT). Nowa metoda CC u noworodków i niemowląt polega na uciskaniu dwoma kciukami skierowanymi pod kątem 90 stopni do klatki piersiowej przy jednoczesnym zaciśnięciu palców obu dłoni w pięści.

Wyniki: Średnia częstość uciskania klatki piersiowej przy stosowaniu technik TFT, TTHT oraz nTTT różniła się i wynosiła odpowiednio 134 min^{-1}, 126 min^{-1} i 114 min^{-1}. Stwierdzono istotną statystycznie różnicę w średniej częstości CC między technikami TFT i TTHT ($p < 0,001$), TFT i nTTT ($p < 0,001$) oraz TTHT i nTTT ($p < 0,001$). Najwyższy odsetek uciśnięć klatki piersiowej zgodnych z wytycznymi ERC (100–120 min^{-1}) uczestnicy badania osiągnęli, stosując technikę nTTT. Średnia głębokość CC przy technice TFT wyniosła 28 (odstęp międzykwartylowy [IQR] 27–30 mm) i była istotnie statystycznie niższa niż w grupie TTHT (40,5 [IQR 39–41] mm; $p < 0,001$) oraz nTTT (40 [IQR 39–41] mm; $p < 0,001$). Odpowiedni odsetek prawidłowych uciśnięć klatki piersiowej osiągnięto, stosując techniki TTHT i nTTT. Najwyższy odsetek całkowitej dekompresji klatki piersiowej obserwowano przy stosowaniu techniki nTTT (96 [IQR 96–98] %), na dalszych miejscach były technika TFT (95.5 [IQR 85,5–99] %) i TTHT (5 [IQR 3–7] %). We wszystkich scenariuszach prawidłową lokalizację miejsca uciskania klatki piersiowej osiągnięto w ponad 90% przypadków.

Wnioski: Zaproponowana nowa metoda uciskania klatki piersiowej u noworodków i niemowląt zapewnia wyższy odsetek uciśnięć klatki piersiowej w zakresie częstości zalecanej w wytycznych ERC w porównaniu z technikami standardowymi. Technika ta zapewnia uzyskanie optymalnej głębokości uciskania klatki piersiowej.

Słowa kluczowe: resuscytacja krążeniowo-oddechowa, uciskanie klatki piersiowej, jakość, niemowlę, ratownik medyczny

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