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Comparison of two chest compression techniques during infant resuscitation. A randomized, cross-over study

Porównanie dwóch technik uciskania klatki piersiowej podczas resuscytacji niemowlęcia. Badanie randomizowane krzyżowe

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Keywords

chest compressions, cardiopulmonary resuscitation, baby, medical simulation, quality

Słowa kluczowe

uciski klatki piersiowe, resuscytacja krążeniowo-oddechowa, niemowlę, symulacja medyczna, jakość

S u m m a r y

Introduction. High quality chest compressions are an inherent element of cardiopulmonary resuscitation that directly influences its effectiveness and thus the return of spontaneous circulation. The guidelines of the American Society of Cardiology recommend conducting resuscitation of newborns and infants with one of two techniques: two-finger technique (TFT) or two thumbs technique (TTHT) in which two thumbs are placed on the sternum and the other fingers cover the chest supporting the child's back. However, as numerous studies indicate, each of these techniques has its own advantages and disadvantages.

Aim. The aim of the study was to assess the quality of selected chest compression techniques during simulated cardiopulmonary resuscitation of an infant conducted by final-year medical students.

Material and methods. The consent of the Institutional Review Board of the International Institute of Rescue Research and Education, as well as written consent from all the parents were obtained. The study was designed as a randomized, cross-over study. The study was attended by 41 students in their final year of medicine. Participants of the study performed a two-minute cycle of cardiopulmonary resuscitation on an infant based on a schedule of 15 chest compressions: 2 rescue breaths. Chest compressions were carried out by two techniques: TTHT and the innovative technique of two thumbs (NTTHT). Only the parameters concerning the quality of chest compressions were analyzed in the study.

Results. Chest compressions based on NTTHT compared with TTHT were associated with a higher percentage of chest compressions performed at the appropriate depth (94% (IQR: 87-96) vs. 92% (IQR: 88-95); $p = 0.003$), better chest relaxation (94% (IQR: 92-99) vs. 13% (IQR: 9-18); $p < 0.001$), more correct positioning of the hands on the chest (98% (IQR: 98-100) vs. 95% (IQR: 89-97); $p = 0.045$) and less time without chest compressions (4.5 s (IQR: 3-5) vs. 5.5 s (IQR: 4-6); $p = 0.038$). Depth of chest compressions using TTHT was 42 mm (IQR: 39-44) and 41 mm (IQR: 39-42) for NTTHT.

Conclusions. In the conducted simulation study, students in their final year of medicine using an innovative method of chest compressions were associated with higher-quality compressions of the infant's chest compared to the recommendations by the American Society of Cardiology or the European Resuscitation Council.

S t r e s z c z e n i e

Wstęp. Wysokiej jakości uciski klatki piersiowej stanowią nieodłączny element resuscytacji krążeniowo-oddechowej wpływający bezpośrednio na jej skuteczność, a tym samym powrót spontanicznego krążenia. Wytyczne Amerykańskiego Towarzystwa Kardiologicznego zalecają prowadzenie resuscytacji noworodków i niemowląt jedną z dwóch technik: techniką dwóch palców (TFT) bądź techniką dwóch kciuków (TTHT), w której dwa kciuki oparte są o mostek, zaś pozostałe palce obejmują klatkę piersiową, stanowiąc podporę dla pleców dziecka. Jednakże jak wskazują liczne badania, każda z tych technik ma zarówno plusy, jak i minusy.

Konflikt interesów
Conflict of interest

Brak konfliktu interesów
None

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Cel pracy. Celem pracy była ocena jakości wybranych technik uciskania klatki piersiowej podczas symulowanej resuscytacji krążeniowo-oddechowej niemowlęcia prowadzonej przez studentów ostatniego roku medycyny.

Materiał i metody. Badanie zostało zaprojektowane jako randomizowane krzyżowe. W badaniu udział wzięło 41 studentów ostatniego roku medycyny. Uczestnicy badania wykonywali 2-min cykl resuscytacji krążeniowo-oddechowej niemowlęcia w oparciu o schemat 15 uciśnięć klatki piersiowej: 2 oddechy ratownicze. Uciśnięcia klatki piersiowej były prowadzone dwiema technikami: TTHT oraz nowatorską techniką dwóch kciuków (NTTHT). Analizie poddano jedynie parametry dotyczące jakości uciśnięć klatki piersiowej.

Wyniki. Prowadzenie uciśnięć klatki piersiowej w oparciu o NTTHT w porównaniu z TTHT wiązało się z wyższym odsetkiem uciśnięć klatki piersiowej wykonanych na odpowiednią głębokość (94% (IQR: 87-96) vs. 92% (IQR: 88-95); $p = 0,003$), lepszą relaksacją klatki piersiowej (94% (IQR: 92-99) vs. 13% (IQR: 9-18); $p < 0,001$), bardziej poprawnym ułożeniem rąk na klatce piersiowej (98% (IQR: 98-100) vs. 95% (IQR: 89-97); $p = 0,045$) oraz niższym czasem bez uciśnięć klatki piersiowej (4,5 s (IQR: 3-5) vs. 5,5 s (IQR: 4-6); $p = 0,038$). Głębokość uciśnięć klatki piersiowej z wykorzystaniem TTHT wynosiła 42 mm (IQR: 39-44), zaś w przypadku NTTHT – 41 mm (IQR: 39-42).

Wnioski. W przeprowadzonym badaniu symulacyjnym stosowanie nowatorskiej metody uciskania klatki piersiowej wiązało się z wyższej jakości uciśnięciami klatki piersiowej niemowlęcia w porównaniu z rekomendowaną przez wytyczne Amerykańskiego Towarzystwa Kardiologicznego czy też Europejskiej Rady Resuscytacji.

INTRODUCTION

Sudden cardiac arrest in pediatric patients, including infants and newborns, occurs relatively less frequently than in adults (1, 2). Also, the main cause of cardiac arrest in children is different than in adults (3). In the case of adults, the main cause of cardiac arrest is cardiovascular dysfunction, while in the case of pediatric patients, airway obstruction and progressive hypoxia result in cardiac arrest (4).

Guidelines for cardiopulmonary resuscitation recommended by the European Resuscitation Council (ERC) as well as the American Heart Association (AHA) recommend two techniques for chest compressions for infants and newborns (5-8). In the case where resuscitation is carried out by one rescuer, the recommended chest compression method is the two-finger technique (TFT), during which chest compressions are performed using two fingers of one hand at right angles to the chest. In the case when resuscitation is carried out by two rescuers, the recommended technique is based on two thumbs (TTHT), during which the thumbs are located on the patient's bridge, and the other fingers, including the chest scaffold, constitute a kind of support for the patient's back. Both techniques have their pros and cons. In the TFT technique, studies indicate much better chest relaxation than in the case of TTHT, however TFT is characterized by chest compressions at a more shallow depth.

Considering the above assumption, it is important to look for new techniques of chest compressions, which will be associated with a higher compression technique. One such technique is a technique developed by the team of Smereka et al. (9, 10) during which chest compressions are performed using two thumbs set perpendicular to the chest, so that they constitute a kind of extension of the forearms.

AIM

The aim of the study was to evaluate the chest compression technique prescribed by the guidelines using the two-thumb method and the author's two-thumb method during simulated cardiopulmonary resuscitation of an infant conducted by final year medical students.

MATERIAL AND METHODS

The consent of the Institutional Review Board of the International Institute of Rescue Research and Education, as well as written consent from all the parents were obtained. The study is a continuation of the authors' research cycle on the evaluation of the author's method of chest compressions in newborns and infants (9-14). Students in their final year of medicine who qualified for the study successfully completed the training module in the field of emergency medicine. The inclusion criterion in the study was the 6th year of medical studies student status and the voluntary willingness to participate in the study. Exclusion criterion from the study was failure to meet the inclusion criteria, back pain or pain in the upper limb that prevents chest compressions. Prior to the study, all participants expressed their willingness to participate in the study.

Prior to the study, all participants took part in training in the field of cardiopulmonary resuscitation including demonstrations in the field of standard chest compressions in infants – TTHT, as well as demonstrations in the field of chest compressions developed by Smereka et al. (9, 10), during which the thumbs are directed perpendicular to the chest, constituting a specific prolongation of the forearms (fig. 1a, b). Then they had the opportunity to practice the tested techniques using an infant simulator. To this end, SimBaby™ was used (Laerdal, Stavanger, Norway).

The final study was performed the next day after the demonstrations. During the test, the baby simulator was placed on the floor in a well-lit room. Participants of the study were tasked with performing a two-minute cycle of CPR based on the standard of 15 chest compressions and 2 rescue breaths based on three tested techniques of chest compressions. Both the

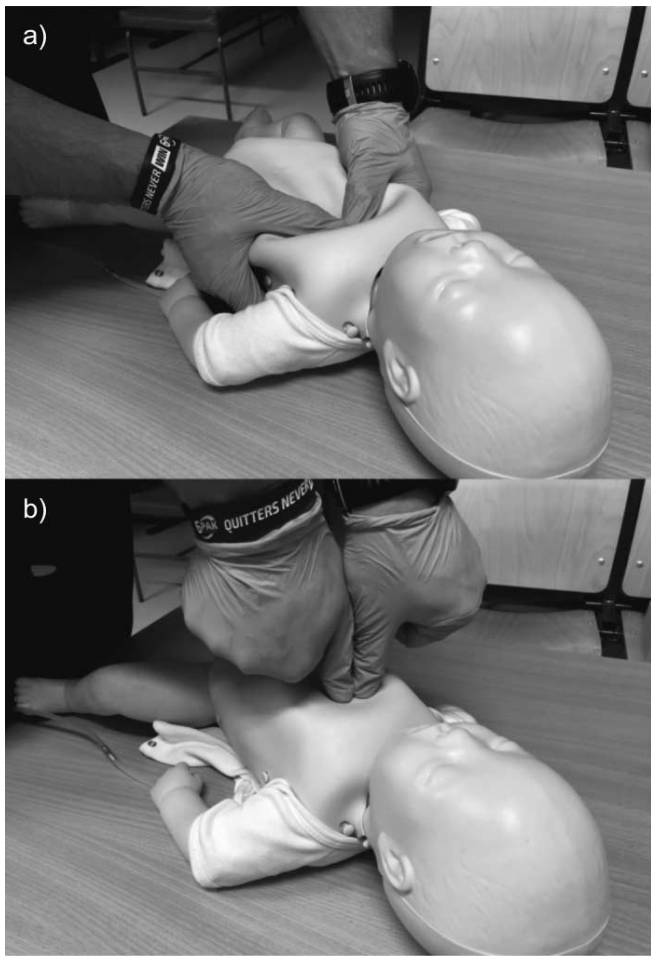

Fig. 1a, b. Chest compression techniques used in the study: a) standard two thumb technique (TTHT); b) novel two thumb technique (NTTHT)

order of study participants and methods of chest compressions were randomized. For this purpose, the Research Randomizer program was used, with which participants were divided into three groups. The first group began resuscitation based on the TTHT technique and the second group used the NTTHT method. After, the participants had a 10-minute break and then chest compressions were performed using a different technique. A detailed randomization procedure is shown on figure 2.

All parameters measured in the study were analyzed thanks to the software attached to the simulator. The main parameter measured in the study was the depth of chest compressions, which in the case of newborns should be around 40 mm (7). The derivative of the depth of chest compressions was the percentage of chest compressions at the appropriate depth. Additional parameters related to the quality of chest compressions were number of compressions fully released, compression rate, number of compressions with correct hand positioning and no flow time. No flow time was defined as the time during which the chest was not squeezed or rescue breaths were not performed.

All statistical analysis were performed using the STATISTICA 13.3EN statistical package (StatSoft, Tulusa, OK, USA). The results were presented as numbers and percentages or medians and interquartile ranges (IQR). Normal distribution was confirmed by the Kolmogorov-Smirnov test. When the data did not follow normal distribution, non-parametric tests were used. The results were considered significant at $p < 0.05$.

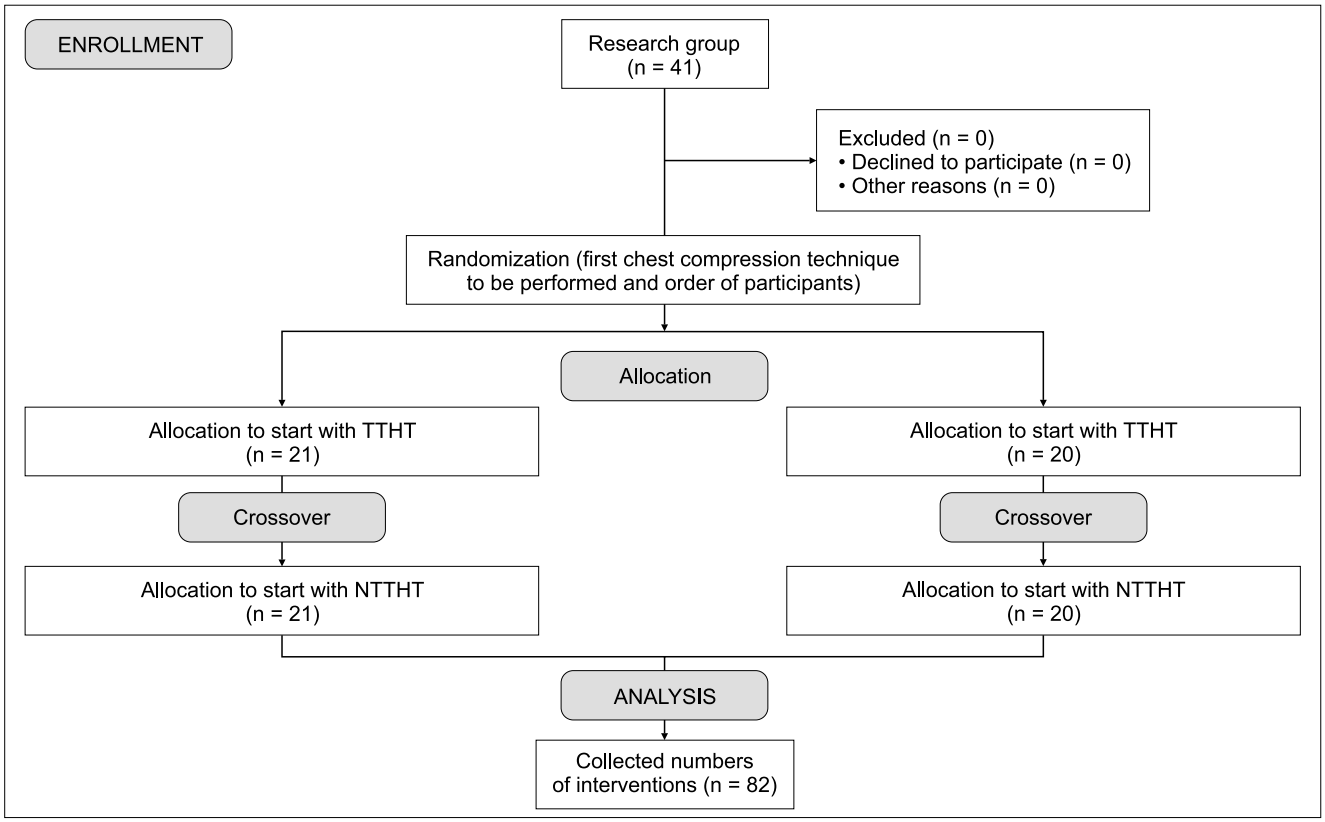

Fig. 2. Consolidated standards of reporting trials flow chart diagram

RESULTS

The study was attended by 41 students in their final year of medicine.

The depth of chest compressions using TTHT was 42 mm (IQR: 39-44), while in the case of NTTHT it was 41 mm (IQR: 39-42) (fig. 3a, tab. 1). The number of compressions with correct depth using distinct compression techniques varied and amounted to 92% (IQR: 88-95) for TTHT, and 94% (IQR: 87-96). The above difference was statistically significant ($p = 0.003$) (fig. 3b).

The number of chest compressions fully released for TTHT technique was 13% (IQR: 9-18), and 94% (IQR: 92-99, $p < 0.001$) (fig. 3c).

Tab. 1. Results of chest compressions

Parameter	Standard two thumbs technique	Novel two thumbs technique	p value
Compression depth (mm)	42 (IQR: 39-44)	41 (IQR: 39-42)	0.127
Number of compressions with correct depth (%)	92 (IQR: 88-95)	94 (IQR: 87-96)	0.003
Number of compressions fully released (%)	13 (IQR: 9-18)	94 (IQR: 92-99)	< 0.001
Compressions rate (/min)	128 (IQR: 118-130)	122 (IQR: 112-124)	0.054
Number of compressions with correct hand positioning (%)	95 (IQR: 89-97)	98 (IQR: 98-100)	0.045
No flow time (s)	5.5 (IQR: 4-6)	4.5 (IQR: 3-5)	0.038

The frequency of chest compressions based on thorax compression testing methods is shown on figure 3d. The compression rate using TTHT was 128 CPM (IQR: 118-130) and 122 CMP (IQR: 112-124) for NTTHT ($p = 0.054$).

Number of compressions with correct hand positioning using TTHT and NTTHT varied and amounted to 95% (IQR: 89-97) and 98% (IQR: 98-100), respectively (fig. 3e).

No flow time in the case of TTHT was 5.5 s (IQR: 4-6) and was statistically significantly longer than in the case of NTTHT resulting in 4.5 s (IQR: 3-5, $p = 0.038$) (fig. 3f).

DISCUSSION

The study demonstrated the superiority of the NTTHT technique over the standard two-thumb technique recommended by the American Heart Association resuscitation guidelines (7, 8), as well as the European Resuscitation Council (5, 6).

The quality of chest compression for both adults and children depends on many factors, including depth of compressions, the frequency of compressions, degree of relaxation of the chest, no flow time, as well as correct hand placement on the chest during chest compressions (15). In the Pellegrino et al. (16), the participants performed chest compressions using two TFT and TTHT techniques over a period of eight minutes. In the present study, thanks to the TTHT technique, a greater depth of compressions of the infant's chest was obtained than in the case of the TFT technique. In addition, 64% of the participants preferred the technique of two thumbs rather than the two fingers technique. Also, research carried out by Christman et al. (17) on the neonatological model indicate the superiority of the TTHT technique over the TFT technique. However, as Christman points out, the depth of chest compressions in the case of uninterrupted chest compressions was 22.1 ± 4.6 mm for TFT and 27.2 ± 5.7 mm for TTHT ($p = 0.0008$). For the 3:1 resuscitation technique, the depth of compressions was 23.7 ± 5.8 and 29 ± 5.4 mm (TFT vs. TTHT, respectively). The results obtained by Christman indicate an insufficient depth of chest compressions. Similar results in case of the TFT technique were also obtained by other authors (9-14). In turn, in the study, the author's method of chest compression where the thumbs are perpendicular to the chest obtained a similar depth of chest compressions as in the standard TTHT technique, however, the percentage of compressions performed at the appropriate depth recommended by the AHA guidelines for NTTHT was 94% and was statistically significantly higher than in the case of TTHT resulting in 92%. Smereka et al. published in the journal Frontiers in Pediatrics (12) analyzing the quality of chest compressions using three techniques; TFT, TTHT, and NTTHT showed that effective chest compression with the NTTHT was higher than for TTHT or TFT. This dependence is also confirmed by other studies (18-20).

Another important parameter from the point of view of the quality of chest compressions is the level of chest relaxation. Lee et al. (21) indicated that the number of high-quality CPR compressions was the highest at a compression rate of 120 min and increased incomplete recoil occurred with increasing compression rate. In turn Yannopoulos et al. (22) indicated that incomplete chest wall recoil during the decompression phase of CPR increases endotracheal pressure, impedes venous return and decreases mean arterial pressure, and coronary and cerebral perfusion pressures.

In our own studies, using the standard two-thumb technique (TTHT), the lowest degree of full chest decompression was achieved due to limitations in the abduction of the thumbs. When using the innovative method of chest compressions using the NTTHT technique, correct compression and relieving of chest compressions by withdrawal of the arms results in full chest relaxation, thus optimizing the quality of the compressions (9-14). This fact is confirmed both by the results obtained in this study as well as the results of previous tests, including the use of hemodynamic measurements (13).

The next parameter is the frequency of chest compressions. Guidelines for CPR recommend that chest compressions be performed at a frequency of 100

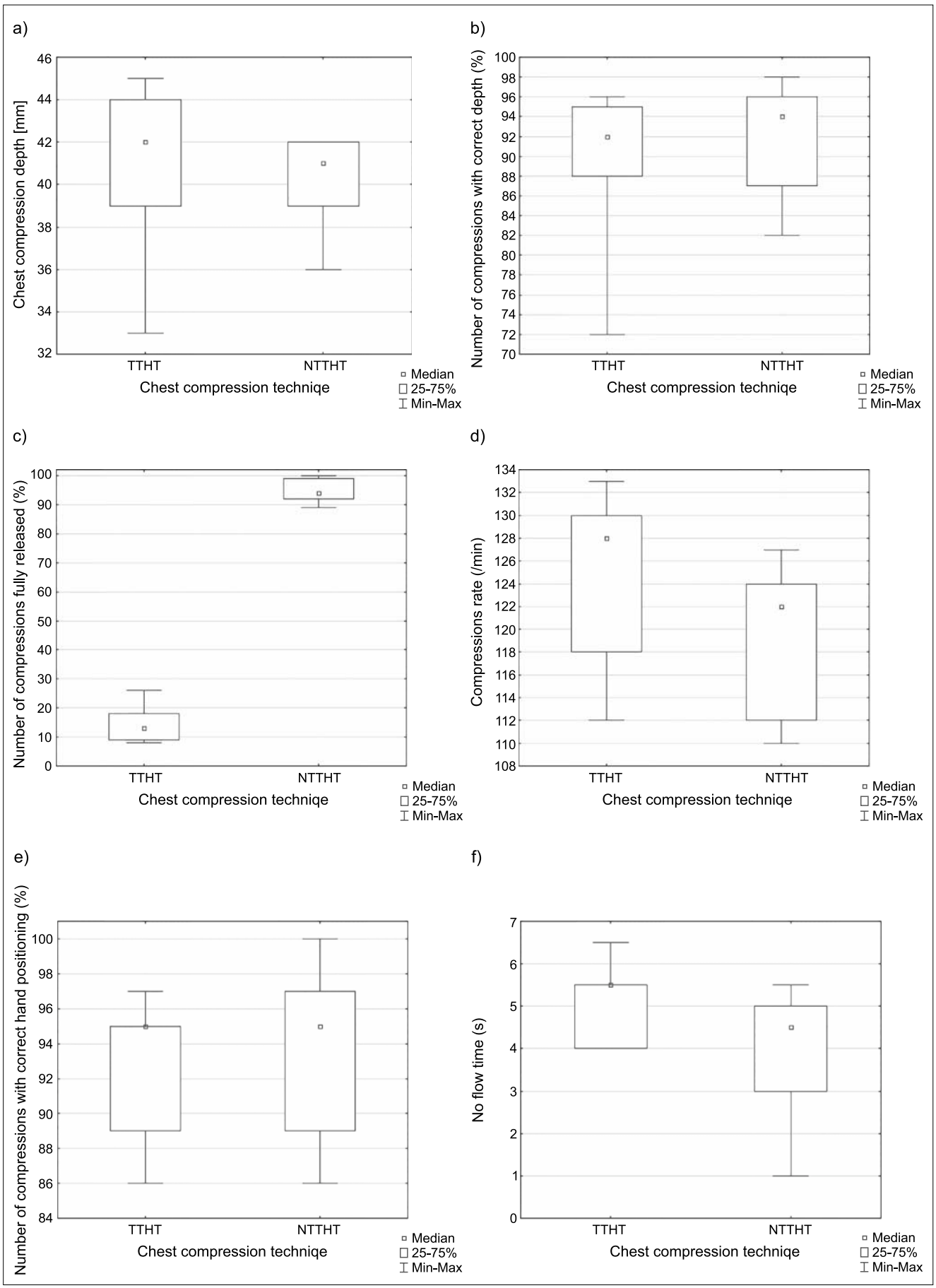

Fig. 3a-f. Quality parameters of chest compressions: a) compression depth; b) number of compressions with correct depth; c) number of compressions fully released; d) compression rate; e) number of compressions with correct hand position; f) no flow time

to 120 compressions per minute. Zou et al. indicate that an appropriate choice may be 120 compressions/min (23). The recent study showed that final year medical students have a tendency to compress the chest too quickly, both in the standard and the innovative two-thumb technique.

The study has limitations. One of the limitations is to perform a test based on a patient simulator, however, only this way to conduct a research experiment allows to perform fully standardized, randomized, cross-study trials in the conditions of cardiopulmonary resuscitation (24-26). The second limitation is resuscitation based on two-minute CPR cycles, however this is the cycle recommended by the ERC and AHA guidelines. In addition, further studies are being conducted to show the effect of prolonged resuscitation and individual chest compressions on the quality of resuscitation parameters.

CONCLUSIONS

In the conducted simulation study carried out by final year medical students, the use of an innovative method of chest compressions was associated with higher-quality compressions of the infant's chest compared to the recommendations of the American Heart Association or the European Resuscitation Council.

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