

# Which position should we take during newborn resuscitation? A prospective, randomised, multicentre simulation trial

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## Abstract

**Background:** Early bystander cardiopulmonary resuscitation (CPR) for cardiac arrest is crucial in the chain of survival. Cardiac arrest in infants is rare, but CPR is also performed in severe bradycardia. European Resuscitation Council and American Heart Association guidelines recommend continuing CPR until the heart muscle is sufficiently oxygenated and regains sufficient contractility and function. The most common and recommended CPR techniques that can be applied in newborns are the two-finger technique and two-thumb technique.

**Aim:** We sought to assess the quality of CPR performed in newborns with the two-finger technique depending on the position of the rescuer during resuscitation.

**Methods:** This was a prospective, randomised, crossover, simulated study. It involved 93 nurses who were required to perform a two-minute CPR using the two-finger technique in three scenarios: (A) with the newborn lying on the floor; (B) on a table; and (C) with the newborn on the rescuer's forearm. The Newborn Tory® S2210 manikin was used to simulate a neonatal patient in cardiac arrest. The following parameters were measured: chest compression (CC) depth, CC rate, no-flow time, percentage of full release, ventilation rate, and ventilation volume, as well as the number of effective compressions and effective ventilations.

**Results:** Statistical analysis showed significant differences in CC rates between scenarios A and B ( $p < 0.001$ ) and between scenarios B and C ( $p = 0.002$ ). Significant differences were also observed between the median CC depth. The median percentage of no-flow-fraction was the highest for scenario A (55%), followed by scenario B (48%), and scenario C (46%). There were significant differences between the values of no-flow-fraction between scenarios A and B ( $p < 0.001$ ), and between scenarios A and C ( $p < 0.001$ ). The percentage of chest full releases for scenarios A, B, and C amounted to 94%, 1%, and 92%, respectively. Significant differences in the number of effective CCs between scenarios A and B ( $p < 0.001$ ) as well as B and C ( $p < 0.001$ ) were revealed. The median ventilation rate was highest for scenario B ( $13 \times \text{min}^{-1}$ ), and lowest for scenario A ( $9 \times \text{min}^{-1}$ ). The highest tidal volume was obtained in scenario A (27 mL), and the lowest in scenario C (26 mL). The most effective CPR was performed when resuscitation was carried out on the rescuer's forearm.

**Conclusions:** The quality of CCs in newborns depends on the location of the patient and the rescuer. The optimal form of resuscitation of newborns is resuscitation on the rescuer's forearm.

**Key words:** cardiopulmonary resuscitation, chest compression, quality, newborn, nursing personnel

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## INTRODUCTION

Early bystander cardiopulmonary resuscitation (CPR) for cardiac arrest is crucial in the chain of survival. Fortunately, cardiac arrest in infants is rare; however, in newborns CPR is performed not only in the case of cardiac arrest but also in severe bradycardia. Each year 1.2 million newborns die in asphyxia [1–4]. In newborns the prognosis in sudden cardiac arrest is poor and neurological sequelae are severe [5, 6]. Moreover, in newborns whose heart rate is < 60 bpm despite stimulation and ventilation with positive pressure for 30 s, deep acidosis is likely to develop, which may lead to myocardial dysfunction and reduced contractility. Therefore, the European Resuscitation Council (ERC) and American Heart Association (AHA) guidelines recommend starting CPR and continuing it until the heart muscle is sufficiently oxygenated and regains sufficient contractility and function. CPR in these conditions will also allow oxygen transport to be restored to the brain, eliminating the risk of severe damage of the central nervous system resulting from acute hypoxia [7–9]. Currently, many techniques of CPR in newborns can be applied [10]. The most common, and therefore the ones recommended by the ERC and AHA, are the two-finger technique and two-thumb technique.

The former is easier to perform in the case of a single rescuer CPR and is thus recommended by the ERC and AHA for this setting [8, 9]. Because the heart is located in the lower third of the sternum in infants [11, 12], the person performing resuscitation should compress the chest in the place between the xiphoid and the inter-nipple line. In the two-finger technique, the tips of the second and middle finger or the fourth finger of the same hand are most often used. The fingers are positioned perpendicularly to the chest and the sternum is compressed with the fingertips in the location described above.

In the case of CPR performed by two rescuers, the recommended method is the two-thumb technique, which consists in bending the torso with both hands and placing the thumbs on the sternum so that the other fingers are under the child's back and support the spine. In this technique, the thumbs can be placed side by side or, in a small newborn, on top of each other. Chest compression (CC) is performed in the same place as in the two-finger technique.

There are also several modifications of the presented techniques, including the two-thumb technique developed by Smereka et al. [13–16].

In the case of single-rescuer CPR, the AHA guidelines recommend that the rescuer performs CPR for two minutes and proceeds to seek help only after this period. This is, however, connected with discontinuation of resuscitation efforts for the time of calling for help and returning to the patient.

The aim of this study was to evaluate the quality of CPR performed in newborns with the two-finger technique

depending on the position of the rescuer during resuscitation.

## METHODS

The study was of a prospective, randomised, crossover, simulated design. It was a multicentre study, carried out with the same methodology in the cities of Katowice, Poznań, and Warsaw, Poland. The study protocol was approved by the Institutional Review Board of the Polish Society of Disaster Medicine (approval No.: 23.04.2017.IRB).

The study involved 93 nurses participating in basic life support (BLS) training sessions, in accordance with the AHA 2015 guidelines. The training was conducted by AHA-accredited instructors. Prior to the study, all participants took part in BLS adult and neonatal resuscitation training.

After the completion of the training, the nurses were required to perform a two-minute CPR using the two-finger technique in three different scenarios:

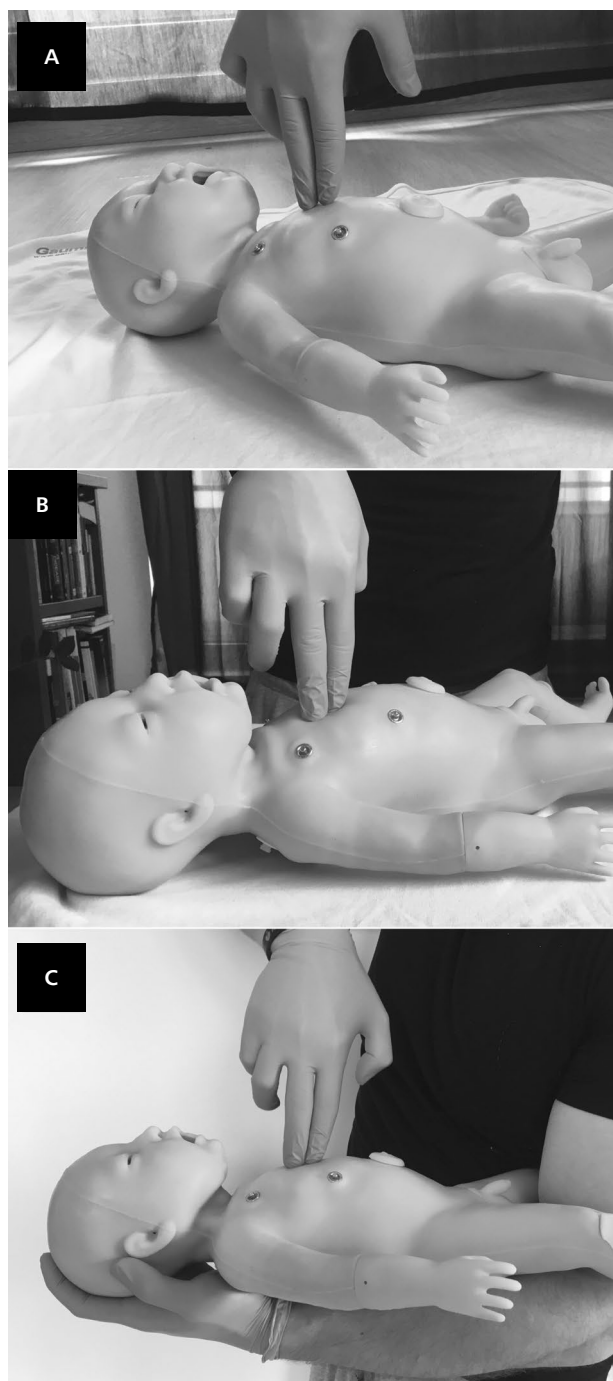
- scenario A: CPR performed with the newborn lying on the floor;
- scenario B: CPR performed on a table; the table top was adjusted to the height of two-thirds of the rescuer's thigh;
- scenario C: CPR performed with the newborn on the rescuer's forearm (Fig. 1).

The order of both the participants and CPR methods was random. For this purpose, the Research Randomizer was used ([www.randomizer.org](http://www.randomizer.org)). The nurses were divided into three groups, performing resuscitation first with scenario A, then scenario B, and scenario C, respectively. After performing a two-minute CPR based on the AHA guidelines, the participants took a 30-minute rest and then performed resuscitation using another scenario. The randomisation procedure of the study is presented in detail in Figure 2.

The Newborn Tory® S2210 manikin (Gaumard® Scientific, Miami, FL, USA) was used to simulate a neonatal patient in cardiac arrest; it depicts true-to-life physical and physiological attributes essential for effective simulation training in neonatal care. The following parameters were measured: CC depth, CC rate, no-flow time, percentage of full release, ventilation rate, and ventilation volume, as well as the number of effective compressions and effective ventilations. All parameters were measured with the use of UNI® software (Gaumard® Scientific, Miami, FL, USA), supplied with a simulator.

## Statistical analysis

The data obtained in the study were exported to Microsoft Excel 2010. Statistica version 12 software (StatSoft, Tulsa, OK, USA) was used for statistical analysis. The results were considered significant at  $p < 0.05$ . 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.



**Figure 1.** Chest compression scenarios used during the study; **A.** Scenario A: Resuscitation performed with the newborn lying on the floor; **B.** Scenario B: Resuscitation performed on a table; the table top was adjusted to the height of two-thirds of the rescuer's thigh; **C.** Scenario C: Resuscitation performed with the newborn on the rescuer's forearm

## RESULTS

A total of 93 nurses participated in the study. All participants were women. Their median age was 31 years (IQR 26–41 years) and median work experience was 15 years (IQR 2–19 years).

A detailed summary of the results is presented in Figure 3 and Table 1.

The median CC rates in the investigated scenarios were varied and amounted to 120 compressions per minute (cpm) (IQR 113–120 cpm) for scenario A, 111 cpm (IQR 102–115 cpm) for scenario B, and 115 cpm (IQR 111–124 cpm) for scenario C. Statistical analysis showed significant differences in CC rates between scenarios A and B ( $p < 0.001$ ) and between scenarios B and C ( $p = 0.002$ , Fig. 3A).

The median depth of CCs equalled 2.2 cm (IQR 2.1–2.2 cm) in scenario A (resuscitation at the floor level), 1.4 cm (IQR 1.1–1.4 cm) in scenario B (resuscitation on a table), and 2.5 cm (IQR 1.4–2.8 cm) in scenario C (resuscitation on the forearm). Significant differences were also observed in this case (Fig. 3B, Table 1).

The median percentage of no-flow fraction was the highest for scenario A and amounted to 55% (IQR 54%–58%), followed by scenario B — 48% (IQR 46%–48%), and scenario C — 46% (IQR 43%–48%). There were significant differences between the values of no-flow fraction between scenarios A and B ( $p < 0.001$ ), as well as between scenarios A and C ( $p < 0.001$ , Fig. 3C).

The percentage of full releases of the chest in the analysed scenarios was varied and amounted to 94% (IQR 94%–96%) for scenario A, 1% (IQR 0.9%–1%) for scenario B, and 92% (IQR 91%–100%) for scenario C.

The median of effective CCs during particular scenarios was varied and amounted to 80% (IQR 80%–80%) for scenario A, 65% (IQR 60%–66%) for scenario B, and 86% (IQR 66%–88%) for scenario C. Significant differences in the number of effective CCs between scenarios A and B ( $p < 0.001$ ) as well as B and C ( $p < 0.001$ , Fig. 3D) were revealed.

Effective ventilation was also varied and amounted to 54% (IQR 48%–57%), 70% (IQR 55%–81%), and 70% (IQR 62%–72%) in scenarios A, B, and C, respectively. The median ventilation rate was highest for scenario B ( $13 \times \text{min}^{-1}$ ; IQR  $13\text{--}14 \text{ min}^{-1}$ ) and lowest in scenario A ( $9 \times \text{min}^{-1}$ ; IQR  $9\text{--}9 \text{ min}^{-1}$ ; Table 1). As for the ventilation volume parameter, the highest tidal volume was obtained in scenario A (27 mL; IQR 27–27 mL), and the lowest in scenario C (26 mL; IQR 24–26 mL; Table 1).

## DISCUSSION

To the authors' knowledge, the study is the first one in the world to compare the quality of resuscitation in newborns related to the position of the rescuer. The study aimed to evaluate the different techniques of CPR performed in newborns in the case of single-rescuer CCs using the two-finger technique.

One of the important factors affecting the quality of CCs is the frequency of the compressions. According to the AHA guidelines, it should range between 100 and 120 cpm. One should not omit rescue breaths, and both activities — CCs and rescue breathing — should not be carried out in neonates at the same time because one activity reduces the effective-

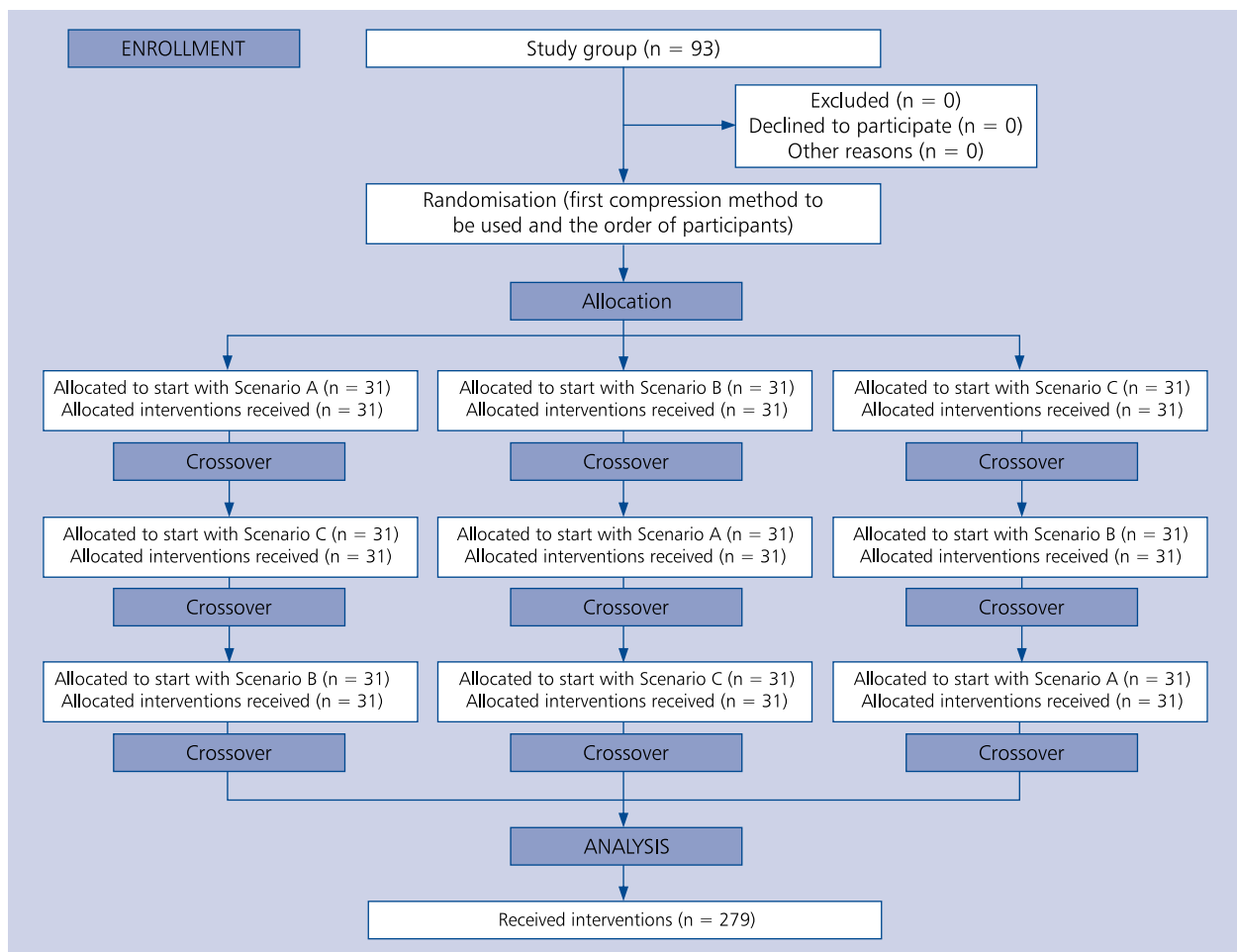
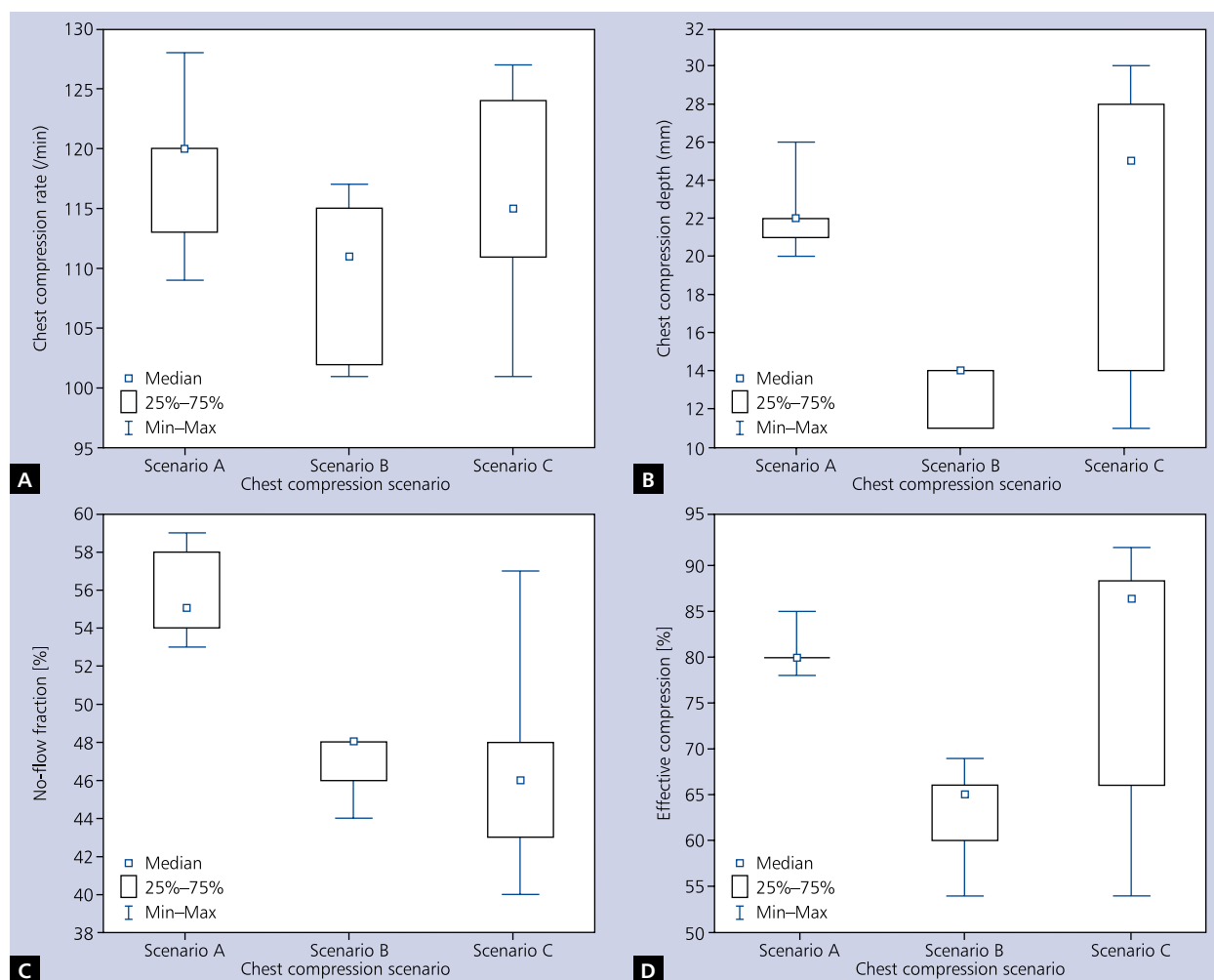


Figure 2. Randomisation flow chart

ness of the other. Therefore, CPR should be performed in cycles consisting of three CCs and one rescue breath. During the present study, most participants performed CCs at the frequency recommended by the AHA and ERC [8, 9]. According to numerous studies, CCs with a frequency higher than 120 cpm have no effect on survival improvement and furthermore cause the rescuer to tire more quickly, which may result in lowering the quality of CCs [17]. As indicated in numerous studies involving both children and adults, maintaining adequate CC frequency can be problematic because medical staff tend to perform CCs with too high a rate [18–20]. Moreover, the optimal frequency of CCs in both children and adults is not specified [21–23]. Li et al. [24] showed that even though it was possible for neonatal staff to perform continuous CCs at rates of 90 and  $120 \times \text{min}^{-1}$ , a significant decay in CC pressure occurred after 96 s and 72 s, respectively. Moreover, when CPR was performed with the standard 3:1 compression:ventilation (C:V) ratio, a significant decay occurred only after 156 s. According to Li et al. [24], good quality CCs might be maintained for more than twice as

long in 3:1 C:V CPR compared with uninterrupted CCs at the rate of  $120 \times \text{min}^{-1}$  (CCaV-120). In addition, the three-minute CC depth decline was 50% if CCs were performed at the rate of  $120 \times \text{min}^{-1}$  vs. 30% if they were performed at the rate of  $90 \times \text{min}^{-1}$ . Schmöler et al. [25] indicated that newborn piglets resuscitated by continuous CCs had a similar return of spontaneous circulation, survival, and haemodynamic recovery compared with piglets resuscitated with 3:1 C:V ratio. In contrast, Zhan et al. [26] found that bystander-administered, CC-only CPR supported by telephone instruction increased the proportion of people who survived to hospital discharge as compared to conventional interrupted CC CPR plus rescue breathing.

The depth of the CC in a newborn should be one-third of the anteroposterior thoracic size. After each compression, full chest recoil should be obtained. In our study, the nurses were able to compress the chest at the maximum depth of 2.5 cm when holding the patient on their own forearm during CPR. In the case of CPR performed on the floor or on a resuscitation table, the depth of the CCs was even lower. This result



**Figure 3.** Detailed summary of the results; **A.** Chest compression rate; **B.** Chest compression depth; **C.** No-flow fraction; **D.** Effective compression

is interesting and requires further thorough research indicating the possible causes of this phenomenon. Obtaining the correct depth of CCs during CPR for adults, children, and newborns is crucial. It is this parameter, combined with the full chest recoil and CC frequency, that results in a significant difference in chest pressure, responsible for sufficient organ perfusion [27]. The current guidelines recommend compressing the chest of a newborn at one-third of the chest anterior-posterior diameter, which is about 4 cm in the case of newborns [8, 9].

Another parameter analysed in the study and indicated in the CPR guidelines is the degree of correct chest recoil. According to the AHA and ERC guidelines, full recoil should occur after each CC [8, 9]. This is crucial to produce — as previously mentioned — the appropriate perfusion pressure. In the case of resuscitation at the floor level and on the forearm of the rescuer, almost 100% of the chest recoil was achieved [28]. Similar results were obtained by Smereka et al. [16] in newborn resuscitation. The situation was quite

different with resuscitation on a table: full chest recoil was noted only in 1% of the subjects. This may be related to the abdominal pressure of the newborn during CCs resulting in incomplete chest recoil.

Taking into consideration all the above-described parameters related to CCs, including the frequency and depth of compressions and correct chest recoil provided to the simulator, the percentage of effective compressions was calculated. The most effective CPR was performed when resuscitation was carried out on the rescuer's forearm. This is important because apart from the fact that the resuscitation is effective, it can also be continued while the rescuer goes to seek help. In the remaining two cases, the rescuer is forced to stop resuscitation and go for help, which can take several minutes.

Cardiopulmonary resuscitation due to specific resuscitation cycles (three CCs and one rescue breath) is connected with long periods in which the chest is not compressed, which determines the “no-flow-fraction” parameter. However, owing

**Table 1.** Chest compression and ventilation parameters

	Scenario A	Scenario B	Scenario C	P
CC rate [ $n \times \text{min}^{-1}$ ]	120 [IQR 113–120]	111 [IQR 102–115]	115 [IQR 111–124]	Scenario A vs. Scenario B < 0.001 Scenario A vs. Scenario C = 0.002 Others: NS
CC depth [mm]	2.2 [IQR 2.1–2.2]	1.4 [IQR 1.1–1.4]	2.5 [IQR 1.4–2.8]	Scenario A vs. Scenario B < 0.001 Scenario B vs. Scenario C < 0.001 Others: NS
No-flow fraction [%]	055 [IQR 54–58]	48 [IQR 46–48]	46 [IQR 43–48]	Scenario A vs. Scenario B < 0.001 Scenario A vs. Scenario C < 0.001 Others: NS
Full release [%]	94 [IQR 94–96]	100 [IQR 99–100]	92 [IQR 91–100]	Scenario A vs. Scenario B < 0.01 Scenario B vs. Scenario C < 0.001 Others: NS
Effective compressions [%]	80 [IQR 80–80]	65 [IQR 60–66]	86 [IQR 66–88]	Scenario A vs. Scenario B < 0.001 Scenario B vs. Scenario C < 0.001 Others: NS
Ventilation rate [ $n \times \text{min}^{-1}$ ]	9 [IQR 9–9]	13 [IQR 13–14]	12 [IQR 11–13]	Scenario A vs. Scenario B < 0.001 Scenario A vs. Scenario C < 0.001 Scenario B vs. Scenario C = 0.01
Ventilation volume [mL]	27 [IQR 27–27]	26 [IQR 25–27]	26 [IQR 24–26]	Scenario A vs. Scenario B < 0.001 Scenario A vs. Scenario C < 0.001 Others: NS
Effective ventilations [%]	54 [IQR 48–57]	70 [IQR 66–81]	70 [IQR 62–72]	Scenario A vs. Scenario B < 0.001 Scenario A vs. Scenario C < 0.001 Others: NS

CC — chest compression; IQR — interquartile range; NS — not significant

to the high levels of oxygen demand in a newborn, there is a need for rescue breathing at a higher rate than in adults [29, 30]. In the case of resuscitation performed on the forearm or on a resuscitation table, the no-flow fraction was 48% and 46%, respectively. In resuscitation performed on the floor, the no-flow fraction equalled 55%. With regard to scenario A (resuscitation at the floor level), the length of time in which the chest is not compressed is probably influenced by the unnatural position of the rescuer during CCs in the newborn and by the need to move to perform rescue breathing, which in the case of the two remaining scenarios is significantly facilitated.

The presented paper has several limitations. The first is that the study was designed as a simulation trial using a newborn manikin and it was not a clinical trial. However, this action was deliberate because randomised cross-over resuscitation trials are unethical, and the parameters obtained with the software included with the simulator would not be achievable in real resuscitation settings. A Newborn Tory® S2210 manikin simulator, the most advanced neonatal simulator in the world, was employed. Second limitation of the study is that the trial was conducted only

among nursing personnel; however, it is nurses who relatively often come across the need for CPR in their professional work. Another limitation of the study is the fact that CPR was performed only with the two-finger technique. The choice of this method was, however, deliberate because resuscitation of a newborn in a single-rescuer manner is a method that is currently preferred by both the ERC and the AHA guidelines.

In conclusion, the quality of CCs in a newborn depends on the location of the patient and the rescuer. The location of the patient can also affect ventilation parameters during CPR. The optimal form of resuscitation of the newborn is resuscitation on the rescuer's forearm. Further research is needed for better evaluation of these dependencies.

**Conflict of interest:** none declared

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