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Comparison of chest compression quality between the overlapping hands and interlocking hands techniques:  
a randomized cross-over trial

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## ABSTRACT

**Background:** Performing quality chest compressions (CC) is fundamental to the management of cardiopulmonary arrest. The aim of this study was to compare the efficacy of two hand positions: overlapping versus interlocking for performing chest compressions (CC) during cardiopulmonary arrest.

**Methods:** The HP2C (for Hands Position and Chest Compression) was a prospective, randomised, open-label, cross-over, single-centre study. Participants were recruited from the Emergency Medical Service (EMS) teams (SAMU 49) and the prehospital firefighter teams (SDIS 49). They were randomised to start CC either with overlapping or interlocking hands and then performed the other technique after a washout period. The judgement criteria were the overall CC success score generated by software in accordance with ILCOR recommendations, the quality of compression, release, rate and subjective intensity measured with the Borg scale.

**Results:** A total of 100 participants were included in the pilot. The mean age of the caregivers was  $38 \pm 9.3$  years. The median CPR score was 79.5% IQR [48.5-94.0] in the overlapping hands group and 71% IQR [38.0-92.8] in the interlocking hands group ( $p$ -value=0.37). There was no significant difference for the other criteria, especially no difference in term of intensity of effort. However, there was a trend towards better results with overlapping hands.

**Conclusions:** This study failed to demonstrate a difference in effectiveness between overlapping and interlocking hand chest compressions during cardiopulmonary resuscitation. However, it should be noted that the trial was conducted in a small population and the results suggest that the overlapping hands technique could improve chest compression quality. This should be confirmed by a larger study.

**Keywords:** cardiac arrest; resuscitation; cardiopulmonary resuscitation; chest compressions

## BACKGROUND

Out-of-hospital cardiac arrest (OHCA) is a medical emergency that occurs due to the sudden cessation of cardiac activity, which causes the victim becomes unresponsive with no normal breathing and no signs of circulation. The number of OHCA cases is estimated between 40,000 and 50,000 a year in France [1, 2]. Community survival rates for OHCA is still low at 4.6% to 8%. To improve this outcome, measures are needed to strengthen the “chain of survival” and its components [3]. Indeed, since 1960, when basic cardiopulmonary resuscitation (CPR) was first defined, resuscitation techniques have continued to evolve to improve overall survival.[4] However, while these “basic-life-support (BLS)” techniques are very well codified, they are not implemented by witnesses often enough (32.5%)[3].

Performing chest compressions is fundamental and helps maintain between 25 and 30% of normal brain perfusion [5, 6]. It is a skill that everyone can learn, which makes optimising the technique essential. The 2021 European Resuscitation Council Guidelines for Resuscitation reconfirmed the step-by-step instructions for performing chest compressions instructions:: 1. Kneel by the side of the victim; 2. Place the heel of one hand in the centre of the victim’s chest, in the lower half of the victim’s sternum; 3. Place the heel of the other hand on top of the first hand and interlock the fingers; 4. Keep your arms straight; 5. Position yourself vertically above the victim’s chest and press down on the sternum to a depth of at least 5 cm (but not more than 6 cm); 6. After each compression, release all the pressure on the chest without losing contact between your hands and the sternum; 7. Repeat at a rate of 100-120 bpm [6]. This technique is easy and understandable by all to facilitate learning [7].

Anatomical inter-individual differences and the lack of effect of hand position during manual chest compression on haemodynamics and EtCO<sub>2</sub> make a slight deviation in hand positioning acceptable [8, 9]. Thus, the major prognosis element is the chest compression mechanics and more particularly the chest compression depth and active chest decompression.[10] It is likely that hand positioning with a hand on top of the other and interlocking fingers plays an important role in chest compression depth [6].

Until recently, the French First Aid Practice Guidelines recommended an alternative hand positioning technique (overlapping hands). The withdrawal of this second recommendation simplified practices. However, both techniques are still used in current practice but have never really been compared.

The HP2C (for Hands Position and Chest Compression) study aimed to investigate whether changing the hand position technique during chest compressions in cardiac arrest victims

would influence haemodynamics by evaluating numeric performance scores on a CPR-manikin.

## **METHODS**

### ***Study design***

This study was a prospective, randomised, open-label, cross-over, single-centre trial. This study was conducted between 16 October and 3 December 2021. The protocol is available in the Appendix 1. This study was approved by the ethics committee of Angers University Hospital, France in July 2021 (no. 2021-138). All participants volunteered to participate in this study. They provided written informed consent before starting. The results remained anonymous and were not shared with the participants. The CONSORT guidelines were followed (Appendix 2).

### ***Participants***

The participants for this study were recruited from the Emergency Medical Service (EMS) teams (SAMU 49) and the prehospital firefighter teams (SDIS 49). All contributors are routinely involved in the management and treatment of critically ill patients. Staff on medical beta-blocker treatment and those unable to optimally perform CC were not included in the study.

### ***Interventions***

Prior to the study, all the participants were given a demonstration of the 2 techniques (overlapping hands and interlocking hands) and an explanation of the procedure and Borg scale. A standardized Resusci Anne QCPR adult manikin (Laerdal Medical, Stavanger, Norway) was used. A forehead pulse oximetry sensor (Masimo, Neuchâtel, Switzerland) for per-procedure heart rate (HR) collection was placed on the forehead of the participants and an initial resting HR measurement was collected before any compressions were started. Eligible participants were randomly assigned to start with overlapping hands or interlocking hands in a 1:1 ratio (appendix 1). This allocation determined which hand position technique the participant would start with, as well as the sequence of compression phases. For each caregiver, the procedure consisted of starting CC (the first technique assigned by randomisation) for 2 minutes without interruption while trying to respect the international recommendations (rate target of 100 to 120 bpm, chest compression depth 5 to 6 cm). No real-time feedback was given to the candidate, so they did not attempt to correct their technique. The following data were collected during or at the end of the 2 minutes:

- o Collection of the overall chest compression score, release efficiency score in %, mean depth in cm and mean frequency at the end of the CC session on the Resusci Anne Skill Reporter.
- o Simultaneous and continuous reading of the caregiver's heart rate (HR) using a forehead oximetry monitor. The data of interest collected during this 2-minute phase was the maximum HR during the effort.
- o Self-assessment of exercise intensity using the modified Borg scale within the first minute post-stress. The modified Borg scale was explained and detailed before the start of each subject's participation. It is scored from 0 to 10 (5 corresponding to a severe level of exertion and 10 maximal level of exertion).

After a ten-minute break, a new phase of chest compressions using the second technique was started. The conditions of this second phase were identical to the first phase. The same data were collected during or at the end of the 2 minutes of compressions. Participation in the study ended after the completion of the 2 sessions.

### **Outcomes**

The primary objective was to compare the effectiveness of the two techniques (overlapping or interlocking hands) on an adult training dummy. The primary endpoint was the overall chest compression success score (QCPR score expressed as a percentage) in accordance with the International Liaison Committee on Resuscitation (ILCOR) guidelines. This score is generated by the adult training dummy software. Variables measured were compression fraction, percentages of compressions with correct depth > 5 cm, rate 100-120, full recoil percentage, and hand position. The score represents the percentage success rate with 100% being quality variables perfectly in line with the latest recommendations in terms of frequency, depth, hand position, full recoil and compressions fractions. The secondary endpoints were chest relaxation quality score (expressed in %), chest indentation quality score (expressed in %), average depth of chest compression (in centimetres), chest compression score at an adequate rate (between 100 and 120 per minute and expressed in %), maximum HR using a frontal pulse oximetry sensor, measurement of the subjective intensity of effort felt by the caregiver using the modified Borg scale.

### **Statistical analysis**

For descriptive analyses, quantitative variables were reported as mean  $\pm$  standard deviation (SD) with a Gaussian distribution, and with median and inter quartile ranges (IQR).

Qualitative variables were reported using numbers and proportions. Comparisons were performed using Student's t-test or the Mann-Whitney test for quantitative variables and the Fisher's exact test for qualitative variables. Because caregivers did both cross-over measures, we accounted for the design and the caregiver cluster effect in the model. All analyses were carried out in the intention-to-treat population. We predefined subgroup analyses for the primary outcome according to the sex, age, body mass index and work experience. These subgroup analyses were only descriptive without any formal hypothesis testing performed. All data were analysed using R (R Core Team, 2017, package glmmTMB, R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria).

## RESULTS

A total of 101 participants were included. One participant was excluded as he was taking beta-blockers (exclusion criteria). Among the 100 participants, all of them performed both techniques with a wash-out period in between: 50 started with overlapping hands and 50 with interlocking hands (Figure 1). The average professional experience was  $13 \pm 8.4$  years. The participants reported having performed an average of  $4 \pm 1.2$  cardiopulmonary resuscitations in their career. To estimate chest compression fatigue, we recorded their resting heart rate. The average was  $75 \pm 11.6$  beats per minute.

### *Primary and secondary outcomes*

The median CPR score was 79.5% IQR [48.5 – 94.0] in the overlapping hands group and 71% IQR [38.0-92.8] in the interlocking hands group (p-value = 0.37), taking into account the cluster effect in the model (Figure 2). A total of 19 participants (19%) had a QCPR under 25% in both groups (overlap and interlocking hands). Six participants had a QCPR of zero because their rhythm was too fast and too deep without decompression. A total of 56 in the overlapping hands group and 48 in the interlocking hands group had a QCPR score higher than 75%. The median chest relaxation quality score was 78% IQR [10-99] in the overlapping hands group and 73.5% IQR in the interlocking hands group [20-99] (p-value=0.97). All secondary outcomes were summarized in Table 2. Subgroup analyses for the primary outcome were reported in Table 3 for the sex, age, body mass index and work experience.

## DISCUSSION

The HP2C randomised trial failed to demonstrate a difference between the overlapping hands and interlocking hands techniques on the QCPR efficiency score. Efficacy appears to be better when the hands are overlapped than when they are interlocked on the overall QCPR score, quality of relaxation, chest indentation, and median depth of chest compression.

The main reason for this discrepancy seems to be a lack of power. This study was designed as a pilot study without estimating the sample size due to a lack of data on this subject. The number of patients was arbitrarily set at 100. In contrast to the data for the overall population, the youngest and least experienced participants appear to perform better with their hands interlocked without statistical significance. We did not find any difference between the two techniques according to body mass index, even though some of the data describe variable capacities according to this criterion [11]. Other studies have looked at the overall positioning of the caregiver, but no differences were found. While the CPR kinematics differed significantly according to the position of the caregiver in the study by Chih-Hsien et al., these differences did not affect the strength, depth, and frequency of compressions performed by experienced caregivers [12, 13].

One fifth of the participants had a QCPR score of less than 25%, which does not allow for sufficient quality of chest compressions [14]. Poor-quality CPR should be considered a preventable harm [15]. In healthcare environments, variability in clinician performance has affected the ability to reduce healthcare-associated complications and a standardised approach has been advocated to improve outcomes and reduce preventable harms[16]. Anderson et al. assessed the optimal training frequency for retention of high-quality CPR skills [17]. Participants were randomised to 1-month, 3-month, 6-month, and 12-month CPR training intervals over the course of a 12-month study period. This study highlights that a short CPR training session each month on a manikin with real-time visual feedback was more effective than training every 3, 6, or 12 months. The American Heart Association (AHA) suggested booster training involving brief weekly or monthly sessions focused on repetition of content presented in an initial group learning course [18–21]. It therefore seems important to standardise training workshops on a regular and ongoing basis for caregivers to avoid high poor performance rates.

For caregivers, there was no difference in the maximum compression frequency and Borg fatigue scale rating between the two groups. These results were relatively high (tachycardia with a median at 129bpm and 5 on the Borg fatigue scale corresponding to a severe level of exertion) but consistent with the literature [22, 23]. It is important to remember that the success of CPR relies on frequent handovers between caregivers to limit this.



The additional argument not evaluated in this study that favours the use of overlapping hands is the simplicity of telephone guidance. Telephone guidance improves the quality of CPR, as does the use of applications to correct hand positions [24–26]. The use of short and clear sentences is recommended. Simply overlapping both hands is easier to explain than interlocking.

## **LIMITATIONS**

This study has some limitations. We performed this study with continuous compressions for 2 minutes without breaks. The entire cardiopulmonary resuscitation sequence was not evaluated: ventilation, defibrillation, etc. These different elements can vary the quality and effectiveness of compressions according to the two techniques. Participants' fatigue was assessed over a short period of time. Another possible limitation in the generalisability of our findings is the single-centre nature of our study with a reduced number of participants and a multiplicity of pre-hospital and intra-hospital professions. Some paramedic teams have remarkable efficacy with a QCPR score above 95%. It would be interesting to analyse their performance with these 2 techniques. Sometimes the total score is unexpectedly low or even zero, even though compression rate, depth, and release appear to be correct. This may be related to the binary feedback of CPR. A rate of compressions at 122 compressions per minute, for example, lowers the score because it is just a little outside the optimal 100-120 limit in the guidelines. If a life was at stake, we would still want this participant to be able to perform CPR.

## **CONCLUSIONS**

The HP2C randomised controlled trial failed to demonstrate a difference in effectiveness between overlapping and interlocking hands when performing chest compressions during cardiopulmonary resuscitation. However, it should be noted that the trial was conducted in a small population and the results suggest that the overlapping hands technique could improve chest compression quality.

Conflicts of interest: The authors have no conflicts of interest to declare.

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Appendix 1. Protocol

Appendix 2. CONSORT Checklist

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Table 1. Baseline patient characteristics.

<i>Characteristics</i>	Overall n = 100
Age – mean $\pm$ SD – yr	38 $\pm$ 9.3
Female sex – no. (%)	56 (56)
Weight – mean $\pm$ SD – kg	68 $\pm$ 15.0
Height – mean $\pm$ SD – cm	170 $\pm$ 8.2
Body Mass Index – mean $\pm$ SD – kg/m <sup>2</sup>	23 $\pm$ 4.1
Occupation – no. (%)	
Nurse	48 (48)
Nurse anaesthetist	4 (4)
Nursing assistant	21 (21)
Ambulance driver	11 (11)
Fireman	16 (16)
Work experience – mean $\pm$ SD – yr	13 $\pm$ 8.4
Number of CPR* performed before – mean $\pm$ SD	4 $\pm$ 1.2
Resting heart rate – mean $\pm$ SD – beats per minute	75 $\pm$ 11.6

\*CPR: cardiopulmonary resuscitation, yr: year, SD: standard deviation, kg: kilogram, cm: centimetre, kg/m<sup>2</sup>: kilogram/square metre

Table 2. Primary and Secondary Outcomes

Outcomes	Intention-to-Treat Population			
	Overlapping hands group (N=100) % [IQR]	Interlocking hands group (N=100) % [IQR]	Difference <i>percentage points</i>	P-value*
<b>Primary outcome:</b> QCPR score†	79.5 [49–94]	71.0 [38–93]	+8.5%	0.37
<b>Secondary outcomes</b>				
Chest relaxation quality score	78.0 [10–99]	73.5 [20–99]	+4.5%	0.97
Chest indentation quality score	72.5 [6–100]	57.0 [7–99]	+15.5%	0.41
Median depth of thorax depression (median in millimetres) [IQR]‡	50.0 [45–56]	49.0 [44–55]	+1	0.54
Chest compression rate at an adequate frequency, n, %	36 (36)	42 (42)	-6%	0.53
Maximum heart rate, median [IQR]	129.0 [116–145]	129.5 [118–146]	-0.5	0.76
Subjective intensity of effort, median [IQR]	5 [4–6]	5 [4–6]	0	0.71

Abbreviation: IQR interquartile range; QCPR: quality of cardiopulmonary resuscitation.  
 \*Mann-Whitney test  
 † The overall chest compression success score (QCPR) was calculated in accordance with the International Liaison Committee on Resuscitation (ILCOR) guidelines and expressed as a percentage. We used the standardized Resusci Anne QCPR adult manikin (Laerdal Medical, Stavanger, Norway).  
 ‡ n=92 in the overlapping hands group and n=93 in the interlocking hands group due to a problem with the manikin registration.

Table 3. Subgroup Analysis for the Primary Outcome

<b>Outcomes</b>	Overlapping hands group (N=100)	Interlocking hands group (N=100)	Difference (CI)
	% [IQR]		<i>percentage points</i>
<b>Primary outcome: QCPR score*</b>	79.5 [49–94]	71.0 [38–93]	+8.5%
<b>Sex</b>			
Female	67.0 [20–87]	64.0 [27–86]	+3%
Male	89.5 [68–89]	83.0 [63–96]	+6.5%
<b>Age</b>			
< 25 years old	48.5 [17–81]	59.5 [18–69]	-11%
between 25 to 45 years old	83.5 [53–94]	76.0 [37–94]	+7.5%
> 45 years old	68.0 [43–91]	76.5 [47–87]	-8.5%
<b>Body Mass Index</b>			
< 25 kg/m <sup>2</sup>	82.0 [50–92]	78.0 [54–94]	+4%
≥ 25 kg/m <sup>2</sup>	87 [61–92]	85 [57–98]	+2%
<b>Work experience</b>			
< 13 years (median time)	75.5 [44–88]	79.5 [57–98]	-4%
≥ 13 years (median time)	87.7 [60–98]	77.0 [45–96]	+10.7%

\* The overall chest compression success score (QCPR) was calculated in accordance with the International Liaison Committee on Resuscitation (ILCOR) guidelines and expressed as a percentage. We used the standardized Resusci Anne QCPR adult manikin (Laerdal Medical, Stavanger, Norway).



## Figure 1. Flow chart

Figure 2. Violin plot for primary endpoint violin: CPR score (percentage) according to hand positioning.

In the box plots, the boundary of the box closest to zero indicates the 25th percentile, a black line within the box marks the median, and the boundary of the box farthest from zero indicates the 75th percentile.

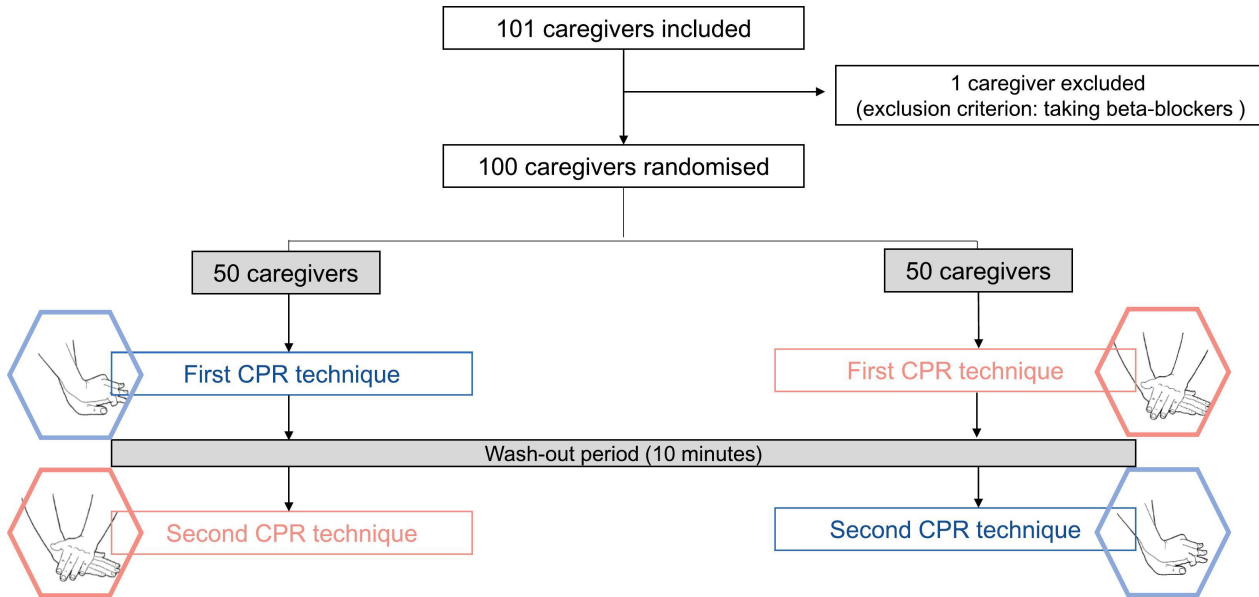


Figure 1

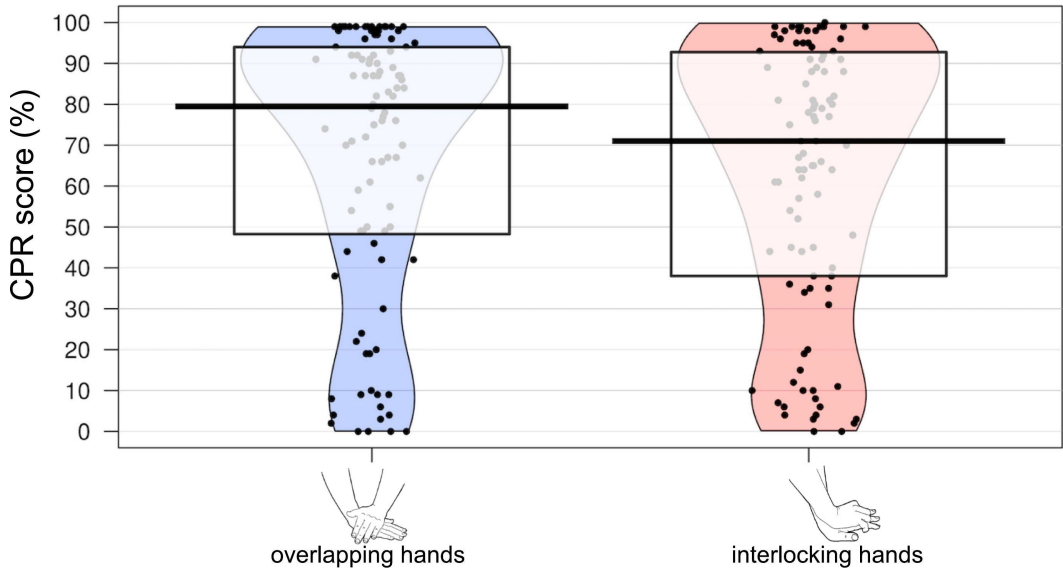


Figure 2