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A new method of pulse control in cardiopulmonary resuscitation; Continuous femoral pulse check

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ABSTRACT

Objectives: The reliability of manual pulse checks has been questioned but is still recommended in cardiopulmonary resuscitation (CPR) guidelines. The aim is to compare the 10-s carotid pulse check (CPC) between heart massage cycles with the continuous femoral pulse check (CoFe PuC) in CPR, and to propose a better location to shorten the interruption times for pulse check.
Methods: A prospective study was conducted on 117 Non-traumatic CPR patients between January 2020 and January 2022. A total of 702 dependent pulse measurements were executed, where carotid and femoral pulses were simultaneously assessed. Cardiac ultrasound, end-tidal CO2, saturation, respiration, and blood pressure were employed for pulse validation.
Results: The decision time for determining the presence of a pulse in the last cycle of CPR was 3.03 ± 1.26 s for CoFe PuC, significantly shorter than the 10.31 ± 5.24 s for CPC. CoFe PuC predicted the absence of pulse with 74% sensitivity and 88% specificity, while CPC predicted the absence of pulse with 91% sensitivity and 61% specificity.
Conclusion: CoFe PuC provides much earlier and more effective information about the pulse than CPC. This shortens the interruption times in CPR. CoFe PuC should be recommended as a new and useful method in CPR guidelines.

1. Introduction

In the 2021 European Resuscitation Council (ERC) guidelines, cardiac arrest (CA) is defined as the absence of breathing or the presence of agonic breathing [1]. Although there is a concern that detecting the presence or absence of a pulse during a pulse check is time-consuming, a quick 10-s pulse check is recommended in the American Heart Association (AHA) guidelines [2]. However, in both guidelines, it is recommended to manually check for a pulse in 10-s intervals, every 2 min [1,2].

Accepting pulse control as a vital sign has been criticized in many studies in terms of personal skill, reliability, and objectivity [3-5]. The reliability of the method is still controversial [1,2]. In recent studies, researchers compared Doppler USG with pulse checks [5-8]. Some studies have indicated that end-tidal CO2 (ETCO2) is a good indicator of ROSC [9-13]. However, none of these methods have proven to be ideal.

CPC, which is palpated when heart massages are paused for 10 s, causes a waste of time in accurately feeling and detecting the localization of the pulse, even for the most experienced practitioners. As an alternative to this method, we palpate the femoral pulse while the heart massage continues, feel its location and pulse fullness without taking a break for 10 s, and check whether the pulse continues when the heart massage is interrupted. We predict that we will be able to detect the presence or absence of a pulse more accurately and in a shorter time with continuous femoral pulse check (CoFe PuC).

2. Materials and methods

2.1. Setting and participants

This study was conducted in the Bezmialem Vakif University Medical Faculty Emergency Department, which is a tertiary hospital in the city of İstanbul, where 300 to 400 CPRs are performed annually. We prospectively studied patients who developed nontraumatic cardiopulmonary arrest between January 2020 and January 2022. The STrengthening the Reporting of OBservational studies in Epidemiology (STROBE)

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Statement we use here is a checklist of items that should be included in articles reporting this type of research [14]. We used a previous study as an example to determine the sample size in our study. In this study, the average time it took healthcare professionals to detect the presence of a pulse was found to be 13 ± 9 s [15]. We targeted this duration as 8 s. For this reason, we calculated that our sample size should be at least 87 patients with a power of 0.99 and an alpha error of 0.05 (G power 3.1.9.7). A convenience sample of 117 patients were included in this study.

2.2. Study design

During CPR, it is important to check the carotid pulse while performing chest compressions regularly. However, the use of CoFe PuC during CPR may affect the time required to locate the pulse. With CoFe PuC, the practitioner can locate the femoral pulse relative to the cardiac output generated by chest compressions. This makes it easier to detect the presence or absence of a femoral pulse when compressions are paused. On the other hand, with CPC, the practitioner may need to locate the carotid pulse and then feel for the presence or absence of pulses each time chest compressions are paused. This process may take longer because there is no reference pulse checkpoint and the reference pulse is generated.

Emergency department residents, specialists, and data entry personnel were included in this study. Prior to the study, the team received 6 h of femoral and carotid pulse control training on the Simulaids® STAT Manikin (Simulaids Ltd., Leicestershire, England). During this training, everyone was taught to constantly check the femoral pulse when compressions started and only moved away from the patient if shock occurred. This pulse control procedure was called continuous femoral pulse check, and its abbreviation was CoFe PuC. He was asked to report out loud as soon as possible, at 10-s intervals, whether the pulse he felt during the massage continued. For carotid artery pulse, the person was asked to palpate the pulse only at 10-s intervals, as in the ALS guideline, and to report as soon as possible whether he or she felt the pulse. During this time, a data entry member counted the seconds out loud and recorded notifications. Additionally, a third controller emergency specialist checked the compatibility of the positivity statement with the monitor.

2.3. Variables

In accordance with Advanced Cardiac Life Support (ACLS) guidelines, chest compressions were initiated at 100 to 120 compressions per minute for all patients in whom CPR was initiated outside or within the hospital, and 8–10/min ventilation was performed since all patients in the study group were intubated. After intubation, capnography was performed in many patients to measure ETCO2. In the last cycle of the study, the presence or absence of a pulse was confirmed by point-of-care ultrasound (POCUS), ETCO2 blood pressure, saturation, and respiratory effort methods. The EMMA (Masimo Corporation, Irvine, USA) capnography device was used to measure ETCO2 with reference intervals of 0–99 mmHg using the mainstream method. POCUS was performed using a Toshiba XARIO 200 cardiac ultrasound probe with a frequency of 10 MHz (Toshiba, Osaka, JAPAN). A total of 702 dependent pulse measurements, 351 femoral and 351 carotid, were recorded in 117 patients.

The primary outcome of the study is to detect the presence or absence of a pulse in the last CPR cycle, comparing the times in continuous femoral pulse checks with the times in intermittent carotid pulse checks. The secondary outcome is whether the measurements of pulse detection times in two random heart massage cycles in the same patients correlate well with those measured in the last cycle.

Inclusion criteria were non-traumatic CPR patients over 18 years of age. Exclusion criteria in this study were patients whose CPR lasted >20 min, patients who achieved ROSC with shock in the first 3 cycles, and patients whose research team was unable to complete CPR.

2.4. Statistical analysis

The behaviors of the quantitative variables were expressed using centralization and measures of variance: mean ± SD. The difference between dependent variables was assessed using the Paired Samples *T*-Tes*t* (Student's *t*-test). The correlation between measurements was demonstrated using the Pearson correlation matrix. The threshold values and performances of decision times in pulse check were analyzed using ROC analysis. The upper limit for statistical significance was set at $p = 0.05$. Statistical analyses were performed using the jamovi project (2023). jamovi (Version 2.3) Sydney, Australia [Computer Software].

3. Results

This study included 117 of 358 patients who underwent CPR in the emergency department between 01.01.2020 and 01.01.2022. Those excluded from the study included eighty-eight OHCA patients who underwent CPR for >20 min, 27 patients who experienced shock in the last three cycles of CPR, 32 patients who achieved ROSC in the first three cycles of CPR, 49 patients for whom we could not perform all stages, and 45 patients for whom we could not form a team (Fig. 1).

A total of 57.3% of the patients were male ($n = 67$), and 42.7% were female ($n = 50$). The mean age of the patients was 68.91 ± 14.33 years. A total of 87.2% ($n = 102$) of the patients were OHCA patients, 12.8% ($n = 15$) were IECA patients, 53% ($n = 62$) were intubated, and 47% ($n = 55$) were not intubated at the beginning of CPR. A pulse was detected once in 50.4% ($n = 59$) of the patients included in the study, while it was never achieved in 49.6% ($n = 58$) of the patients. Of course, we observed that most patients with pulse developed cardiac arrest (CA) again. In total, ROSC was achieved in 28 (23.9%) patients. A total of 94% ($n = 110$) of the patients had no breathing, while 6% ($n = 7$) had agonic breathing at the beginning of CPR. The initial monitor rhythm was 31.6% ($n = 37$) asystole, 64.1% ($n = 75$) PEA, and 4.3% ($n = 5$) shockable (Table 1). The decision time for determining the presence of a pulse in the last cycle of CPR was 3.03 ± 1.26 s for CoFe PuC, significantly shorter than the 10.31 ± 5.24 s for CPC. The decision time was 2.37 (0.79) seconds for pulse detected, whereas it was 3.71 (1.30) seconds for pulse not detected (Table 2). We found similar results in two other CPR cycles we recorded to test its reliability. In CoFe PuC, there was a high correlation between pulse decisions and the actual presence or absence of a pulse (Pearson's r 0.81, 083, 088. $p = 0.001$) (Table 3). While CPC predicted pulse absence with 91% sensitivity and 61% specificity, CoFe PuC predicted pulse absence with 82.76% sensitivity and 74.58% specificity, resulting in a higher AUC (Area Under the Curve) value of 0.800. CoFe PuC has a 3-s cutoff time and provides effective and concise results compared to the CPC's 10-s—cutoff time. This indicated a stronger performance in a shorter time (Table 4).

4. Discussion

The time lost to pulse check significantly affected CPR quality. In this study, we performed 702 dependent measurements in patients undergoing non-traumatic CPR. We found that pulse check with CoFe PuC was significantly more effective in determining the presence or absence of a pulse in a much earlier and more accurate manner than a traditional carotid pulse check. It is important to check the carotid pulse while performing regular chest compressions during CPR. However, the use of CoFe PuC during CPR affects the time required to locate the pulse. With CoFe PuC, it becomes easier for the practitioner to locate the femoral pulse relative to the cardiac output generated by chest compressions. On the other hand, in CPC it will take time for the practitioner to sense the presence or absence of pulses each time chest compressions are paused. This process may take longer because there is no reference pulse checkpoint and the reference pulse is generated.

Although new methods and technological tools have been employed for pulse check, manual pulse checks remain indispensable in some

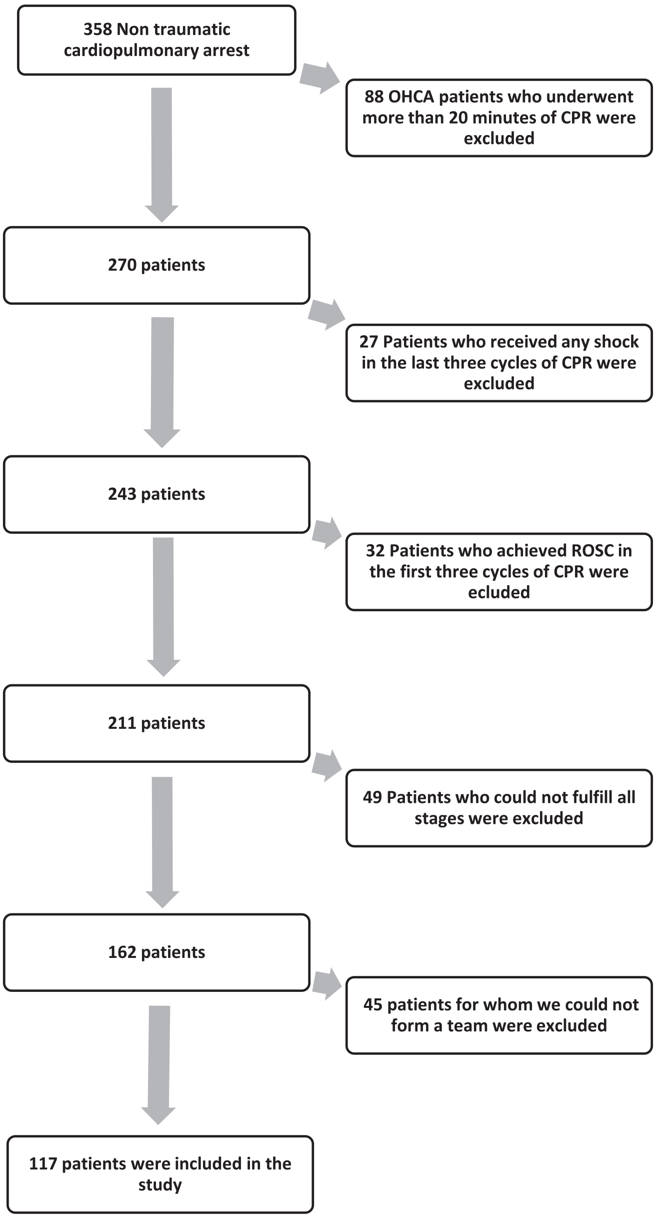

Fig. 1. Flow chart of the study. CPR: Cardiopulmonary Resuscitation, ROSC: Return Of Spontaneus Circulation.
* Abbreviations: ROSC return of spontaneous circulation, CPC carotid pulse check, CoFe PuC: continuous femoral pulse check.

Table 1
Baseline characteristics of the enrolled patients.

Descriptive parameters		N (%)
Age (years)		68.91 ± 14.33
Sex	Male	67 (%57.3)
	Female	50 (%42.7)
Cardiac Arrest location	Cardiac arrest in the emergency department	102 (%87.2)
	Out Of Hospital Cardiac Arrest	15 (%12.8)
The initial rhythm of CPR	Asystole	37 (%31.6)
	Pulseless electrical activity	75 (%64.1)
	Shockable rhythm (VT-VF)	5 (%4.3)
Return of spontaneous circulation	Yes	28 (%23.9)
	No	89 (%76.1)
Pulse detected in the last cycle	Yes	59 (%50.4)
	No	58 (%49.6)

hospitals and out-of-hospital CPR situations. Additive manual pulse check retains its importance, especially in scenarios in which other methods or technological alternatives may not be readily available or practical.

However, the studies on which this recommendation is based are generally operating rooms and model-applied studies. In addition, it has been criticized for the difficulty and time-consuming pulse control. In a randomized trial of trained and untrained health care professionals providing care to 16 patients undergoing coronary artery bypass grafting, the specificity was only 55%, although the central pulseless sensitivity of the participants approached 90%. Within 10 s, only 16.5% of participants (34 of 206) were able to make any judgment about their patient's pulse status. Rapid and accurate assessments (15%, or 31 of 206) occurred almost exclusively in pulsatile patients. However, only 2% of participants (1 in 59) correctly recognized a patient who actually had no pulse within 10 s [16]. In line with existing literature, our study found that decision time was longer in the pulse not detected group. However, decisions could still have been made earlier compared to traditional methods. In another experimental mock study, lifeguards checked the pulse in 6.6 s and health care professionals in 7 s, and this time was found to be 20.5 s in untrained people [17]. A study in which paramedics checked the brachial pulse of 17 children (1 day-11 years) in the extracorporeal circulation due to CA or heart failure, 28 (85%) of 33 diagnosed as having CA at 13 ± 9 s and experienced physicians confirmed the absence of a pulse. The accuracy rates were 85% for experienced physicians, 82% for inexperienced physicians, 80% for experienced nurses, and 52% for inexperienced nurses [15]. These studies, which formed the basis of manual pulse check recommendations, did not include actual CA patients. Pulse checks during CPR in our CA patients showed that CoFe PuC predicted the absence of ROSC with 74% sensitivity and 88% specificity, while carotid PC predicted the absence of ROSC with 91% sensitivity and 61% specificity. Additionally, CoFe PuC has a good cutoff time (3 s.) and provides effective and very short results compared to the CPC cutoff time (10 s.). Although CPC sensitivity and cutoff times were similar to those in these studies, CoFe PuC showed higher specificity, and the cutoff time was quite short. The AHA and the ERC recommend in the ACLS guidelines that pulse and rhythm checks are performed between chest compressions [1,2]. Breathing, eye opening, or other movements may occur during CPR. A pulse check is important to confirm ROSC in CPR, because although the presence of a pulse indicates ROSC, it can sometimes indicate that adequate circulation has been achieved [18]. However, in those with low cardiac output conditions and low blood pressure, a pulse may not be detected [19]. There are also those who suggest that a carotid pulse during CPR does not necessarily indicate adequate myocardial or cerebral perfusion [20].

Reducing the time between chest compressions in CPR is among the recommendations. Manual pulse checking, which is closely related to this situation, is still a widely used method. However, it is not clear which central pulse (femoral or carotis) will be used in this method [1,2]. New studies are being conducted in which researchers aim to reduce the time for the manual pulse check and to determine the most accurate place. In this regard, carotid and femoral arteries were compared to determine the most appropriate pulse check localization in a study of CA patients undergoing CPR in the emergency department. A carotid pulse check performed between cycles has been shown to be superior to a femoral pulse check [21]. However, by using our method, we predict that it will be somewhat easy to determine the location of the pulse during chest compressions. By determining the location, we found that we can detect the presence or absence of pulses in the heart massage cycle interval over a shorter time and more effectively. The second important point is that since the pulse continues to be palpable during CPR, when paused to check the pulse, the practitioner says “the pulse continues” or “the pulse has disappeared”. The value of trying to feel arterial pulses during CPR to evaluate the effectiveness of chest compressions is uncertain. In one study, researchers predict that the absence of valves in the

Table 2
Duration comparison of CPC and CoFe PuC in CPR heart massage cycles.

Heart massage cycles in CPR		CPC *sec.* (SD)	CoFe PuC sec. (SD)	P*	Mean difference	95% Confidence Interval	
						Lower	Upper
Cycle 1 ($n = 117$)		10.3 (1.48)	2.42 (1.20)	<0.001	7.56	7.28	7.83
Cycle 2 ($n = 117$)		10.84 (1.46)	2.86 (1.17)	<0.001	7.97	7.65	8.3
Last cycle ($n = 117$)		10.31 (5.24)	3.03 (1.26)	<0.001	7.27	6.32	8.23
Last cycle	Pulse detected (59)	8.61 (6.81)	2.37 (0.79)		6.24	4.41	8.07
	Pulse not detected (58)	12.03 (1.66)	3.71 (1.30)		8.33	7.87	8.79

Not. H_a μMeasure 1 - Measure 2 $\neq 0$.
Abbreviations: CPC carotid pulse check, CoFe PuC continuous femoral pulse check, CPR cardiopulmonary resuscitation.
* Paired Samples T-Test (student t-test),

Table 3
Correlation between the last cycle with the other two measured cycles*.

		ROSC	CPC 1	CPC 2	Last cycle CPC	CoFe PuC 1	CoFe PuC 2
CPC 1	Pearson's r	0.69					
	p-value	<0.001					
CPC 2	Pearson's r	0.71	0.5				
	p-value	<0.001	<0.001				
Last cycle CPC	Pearson's r	0.73	0.56	0.57			
	p-value	<0.001	<0.001	<0.001			
CoFe PuC 1	Pearson's r	0.81	0.57	0.59	0.61		
	p-value	<0.001	<0.001	<0.001	<0.001		
CoFe PuC 2	Pearson's r	0.83	0.52	0.57	0.59	0.71	
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	
Last cycle CoFe PuC	Pearson's r	0.88	0.61	0.69	0.61	0.73	0.74
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Abbreviations: CPC carotid pulse check, CoFe PuC continuous femoral pulse check, ROSC return of spontaneous circulation.
* Pearson correlation matrix.

inferior vena cava and backward blood flow into the venous system can produce femoral vein pulsations. The investigators conducting this study argue that the pulse felt in the femoral region may be related to venous blood flow rather than arterial blood flow [22]. This information, which is included in the 2015 ERC CPR guideline, is based on the presentation of two children whose femoral pulse was easily palpated during open chest CPR after aortic occlusion [23]. We are not aware of any other research to support this claim. Our study may also be used to determine whether aortic occlusion in these cases causes this result.

It is also important to compare carotid pulse checks with femoral pulse checks in terms of the ease of application in CPR. This is because many interventions are performed in 10-s intervals to avoid interrupting chest compressions during CPR. Most importantly, CPC is not possible during intubation. Due to unsuccessful attempts, this process can be repeated even in subsequent heart massage cycles. Furthermore, supraglottic device placement or repositioning may be a challenging factor. We think that many variables added to the scenario, such as regurgitation of intubated patients, insertion of a pacemaker, and subclavian vein intervention, which will be preferred for effective fluid, blood or blood product replacement, will adversely affect CPC.

Many recent methods that are expected to be alternatives to manual pulse checks have been used to estimate ROSC. Currently, in the AHA, ERC and ILCOR guidelines, ETCO2 has been identified as an indicator to confirm endotracheal tube placement and is recommended as both a method of monitoring CPR quality and as an early indicator of ROSC. ETCO2 has been shown to correlate well with cardiac output and central perfusion pressure [24]. Unfortunately, ETCO2 is dependent on multiple variables. For example, the dependency on these variables includes minute ventilation during CPR [25], discordant values after vasopressor [26] and bicarbonate administration [27].

Near-infrared spectroscopy (NIRS) is a noninvasive method used to estimate regional cerebral oxygen saturation (rcSO2), and can detect the absence of blood circulation, thus indicating the quality of CPR by providing feedback on cerebral oxygenation achieved during CPR [28,29]. It has been shown that a higher rcSO2 is associated with a greater likelihood of achieving ROSC and an increased chance of survival, while a lower rcSO2 is associated with increased mortality [30-32]. However, a clear rcSO2 threshold at which an estimate of ROSC, survival, and neurological well-being can be determined has not yet been confirmed [30]. Studies with these devices are mostly focused on prognostic indicators [33]. Another method is ultrasound-assisted CPR. Although some ultrasound-assisted studies on pulse checks report positive contributions to CPR by reducing interruptions, [6,7] there are also those who claim the opposite [34-36]. Another study suggests that it may be possible to detect ROSC by cardiac monitoring in the presence of continuous compressions without regular pulse checks [37]. However, this study has limitations, as it is a study of CA due to ventricular fibrillation. Considering the production of devices or software that will perform the analysis and test reliability, we do not expect rapid developments in this regard soon.

These studies of technological device studies have changed the perception of some researchers, which may lead to the complete abandonment of pulse checks [38]. However, we think that it will not be easy for clinicians to abandon their long-established habits or conduct sufficient studies to eliminate manual pulse checks.

Table 4
ROC analysis for CPC and CoFe PuC in the last heart massage cycles of CPR.

Cutpoint (sec.)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC
10	98.28	61.02	71.25	97.30	0.710
3	82.76	74.58	76.19	81.48	0.800

Abbreviations: CPC carotid pulse check, CoFe PuC continuous femoral pulse check, CPR cardiopulmonary resuscitation.

4.1. Limitations

It was difficult to precisely collect the data since patient safety was prioritized in all cases. Since this study included patients with a sudden onset, the physical condition of the patients and their current diseases could not be differentiated, thus their effects could not be observed.

The presence or absence of a pulse was especially clear in the last cycle in terms of ROSC or asystole. However, one of the limitations of our study was the need for other methods to definitively prove the presence or absence of pulse in intermediate cycles, especially pulseless electrical activity. For example, in POCUS there may be cardiac activity but cardiac output may be too low or a pulse may not be palpable because other factors (such as hypovolemia, acidosis, etc.) are present.

Observation of ROSC with significant bradycardia may take longer to confirm the presence or absence of a pulse, especially when checking for intermittent carotid pulses that are not previously located. During the study, it was not investigated how many bradycardia attacks caused ROSC and how these affected the two groups.

An important limitation of CoFe PuC is the thickness of the subcutaneous tissue in the groin area through which the femoral pulse is controlled. Since information about the body size or depth of the femoral pulse in the groin area of the patients was not recorded, we do not know whether there is a limitation in detecting the femoral pulse in overweight patients.

5. Conclusion

CoFe PuC has a good cutoff time (3 s.) and provides effective and very short results compared to CPC cutoff times (10 s.). While CPC sensitivity and cutoff times were similar to those in prior studies, CoFe PuC was better with higher specificity, and the cutoff time was quite short. With this method in CPR, pulse checking will be easier, more effective and can be performed over a short time. Moreover, randomized controlled studies can be performed for this method.

Ethics approval and consent to participate

The study was approved by the research ethics committee of Bezmialem Vakif University under protocol no. 54022451–050.05.04.

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Data linking

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We warrant that the article is the Authors' original work. We warrant that the article has not received prior publication and is not under consideration for publication elsewhere. On behalf of all Co-Authors, the corresponding Author shall bear full responsibility for the submission.

Human rights statements and informed consent

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1964 and its later amendments. Informed consent was obtained from all patients for being included in the study.

CRediT authorship contribution statement

E. Sonmez: Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **A. Ozkan**: Conceptualization, Methodology, Reviewing and Editing, Software, Supervision. **B. Taslidere**: Data curation, Writing, Original draft preparation, Visualization, Investigation.

Data availability

All data analyzed during this study are available: Sönmez, Ertan (2024), "Continuous femoral pulse check is more useful in cardiopulmonary resuscitation than intermittent carotid pulse check", Mendeley Data, V1, https://doi.org/10.17632/8g8n4gjsy2.1.

Declaration of competing interest

There are no conflicts of interest, and the authors received no financial support for the research. The authors have approved the final version of the article, including the authorship list, and do not have any relevant declarations.

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