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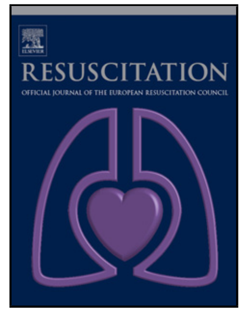

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The POCUS Pulse Check: A Randomized Controlled Crossover Study Comparing Pulse Detection by Palpation versus by Point-of-Care Ultrasound

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Abstract

Background
Manual pulse checks (MP) are an unreliable skill even in the hands of healthcare providers (HCPs). In the context of cardiac arrest, this may translate into inappropriate chest compressions when a pulse is present, or conversely omitting chest compressions when one is absent. To date, no study has assessed the use of B-mode ultrasound (US) for the detection of a carotid pulse. The primary objective of this study was to assess the time required to detect a carotid pulse in live subjects using US compared to the traditional palpation method.

Methods
We conducted a prospective randomized controlled crossover non-inferiority trial. HCPs attended a 15 minute focused US workshop on identification of the carotid pulse. Both pulse check methods were timed for each participant on two different subjects in random order. The primary outcome was time to carotid pulse detection in seconds. Secondary outcomes included confidence levels of pulse detection measured on a 100mm visual analog scale (VAS) and rates of prolonged pulse checks (> 5s or >10s). The study was powered to determine whether US pulse checks were not slower than MP by greater than two seconds. The results are presented as the difference in means with a 90% two-sided confidence interval (CI).

Results
111 participants completed the study. Mean pulse detection times were 4.22s (SD 3.26) by US compared to 4.71s (SD 6.45) by MP with a mean difference in times of -0.49s (90% CI: -1.77 to 0.39). There were no significant differences between US and MP in the rates of prolonged pulse checks of greater than 5 seconds (23% vs 19%, p=0.45) or 10 seconds (9% vs 8%, p=0.81). First attempt at detection of pulse checks was more successful in the US group (99.1% vs 85.6%, p=0.0001). Prior to training, participants reported higher confidence using MP compared to US; 68 (IQR 48-83) vs 15 (IQR 8-42) mm (p < 0.001). Following the study, participants reported higher confidence levels using US than MP; 91 (IQR 82-97) vs 83 (IQR 72-94) mm (p < 0.001).

Conclusions
Carotid pulse detection in live subjects was not slower using US as compared to palpation, and demonstrated higher first attempt success rate and less variability in measurement times. A brief teaching session was sufficient to improve confidence of carotid pulse identification even in those with no previous US training. The preliminary results from this study provide the groundwork for larger studies to evaluate this pulse check method for patients in cardiac arrest.

KeyWords: Pulse check; Point of Care Ultrasound; Carotid; Palpation; CPR.

Introduction

According to the American Heart Association (AHA), the annual incidence of cardiac arrest in the United States alone exceeds 350,000 out-of-hospital arrests and 209,000 in-hospital arrests.[1,2] The importance of early, high-quality chest compressions with minimal interruptions to improve outcomes in cardiopulmonary resuscitation (CPR) cannot be under-emphasized.[2,3] The ability to identify the presence or absence of a pulse is critical to the decision-making in managing cardiac arrest. Over the last three decades, a variety of studies have demonstrated that the detection of a pulse is unreliable, with a significant rate of prolonged pulse checks extending beyond the recommended 10 second window.[3] This has been demonstrated in non-health care professionals (HCP) and HCPs alike.[4-8]

The lack of certainty in identifying a pulse during resuscitation may delay chest compressions, leading to a rapid drop in coronary perfusion pressure and worse patient outcomes.[9-12] Incorrectly identifying the presence of a pulse may also lead to erroneous omission of chest compressions. Likewise, failure to rapidly and reliably detect return of spontaneous circulation may trigger unnecessary compressions and administration of high dose vasopressors, when efforts ought to be targeted towards managing the underlying disease process (e.g., septic, obstructive, or cardiogenic shock).

Point-of-care ultrasound (POCUS) is increasingly being used to help guide the management of patients in shock and cardiac arrest. POCUS is used to improve the quality of chest compressions, to help identify reversible causes of cardiac arrest, and for prognosticating short-term survival based on visible cardiac activity.[13-18] POCUS can also be used to directly visualize the carotid artery to determine whether a pulse is present. This ultrasound pulse check may be a more reliable method for determining the presence of a pulse. However, it is important that any new pulse check method be at least as fast as currently accepted methods. The primary objective of this study was to determine whether POCUS pulse checks could be performed as quickly as manual pulse checks in live models.

Methods

Study design

We conducted a randomized crossover non-inferiority trial between July 2017 and January 2018. The institutional review board approved the study.

Setting and Study Population

The study was conducted at an academic tertiary care hospital. HCPs aged 18 years or older enrolled in an advanced life support (ALS) course were eligible to participate. Participants were excluded if they were not 18 years of age or older, or did not provide informed consent.

Models on whom participants assessed the pulses were selected from a list of volunteers provided by the ALS program. Their age, sex, weight, height, body mass index (BMI), heart rate, blood pressure, neck circumference, and neck length were obtained (see Appendix 1 for measurement protocols).

Study Protocol

Participants completed a baseline questionnaire on demographics and prior resuscitation training and US experience. Participants' baseline confidence with pulse identification by US and MP was assessed using a 100mm visual analog scale (VAS). Participants then completed an US training workshop where they were taught to identify the carotid artery using B-mode US on a live model. The US was performed with a 10-5MHz linear transducer from a Sonosite Edge (Fujifilm Sonosite Inc., Bothell, WA) placed in the transverse plane of the neck. US settings were pre-set to optimize the depth and gain. For ease and rapidity, only B-mode was used; no Doppler settings were applied. The sonoanatomy of the carotid artery was delineated to participants, including identifying features such as non-compressibility and pulsatility. Participants were then given three separate practice opportunities to identify the model's carotid artery, with feedback provided by the instructor. Immediately after (<1 min), participants completed a post-training questionnaire to assess their confidence levels.

Following a three-hour washout period, participants underwent a pulse check assessment on two separate live models that were different from the model used in the practice session. Each participant was randomized using an online random number generator to either use MP or US first, and to the model on which each method was tested. After a countdown, participants searched for the pulse using MP or US until it was correctly identified. Detection of the carotid pulse was confirmed by having the investigator simultaneously palpate the model's radial pulse while the participant counted out in time with the model's heartbeat. Time to detect the pulse was subsequently measured by two independent reviewers blinded to group allocation using digital audio recordings of the pulse assessments. Immediately following the assessment (<1 min), participants completed a questionnaire on their confidence levels.

Outcome Measures

The primary outcome measure was time to pulse detection by MP compared to US. Secondary outcomes included number of attempts for each method, proportion of participants who took longer than five and 10 seconds, and confidence levels with each technique. A priori subgroup analyses were performed to determine whether participant demographics or previous experience impacted their performance with each technique.

Statistical Analysis

We chose the non-inferiority margin of two seconds after consultation with several experts in resuscitation, as it was felt that this was a reasonable threshold for a clinically significant pulse check time difference between the groups. A total of 76 participants were required for 80% power to establish a non-inferiority margin of less than two seconds with a 95% one-sided confidence interval (90% two-sided confidence interval).[19] Descriptive analysis is presented as means and standard deviations for continuous variables and frequencies and percentages for categorical variances. Mean times of the pairwise differences between the two methods and 90% confidence intervals were calculated using bootstrap based on 10,000 simulations. To compare proportion of times greater than 5 and 10 seconds between the two methods we used McNemar's test. Paired t-test was employed to test for differences in confidence levels between the methods prior to training and following the study. To explore the associations between times and demographic factors, we used Wilcoxon rank-test or Kruskall-Wallis test for categorical variables and Spearman correlation for continuous variables. We assessed the inter-rater reliability using intraclass correlation.

Results

Characteristics of Study Population

Between July 2017 and January 2018, 115 participants were enrolled. Four participants were subsequently excluded, leaving 111 participants for final analysis (Figure 1). Exclusions were due to incorrect US equipment setup (2 participants) and models prompting the participants (2 participants). Baseline characteristics of the participants are shown in Table 1. The participants' median age was 29 (IQR 25-40 years) and 39% were female. 110 (99%) participants had taken at least one previous basic life support (BLS) course, 81 (73%) of whom had taken it within the last year. 67 (60%) had taken at least one advanced cardiac life support (ACLS) course, 28 (25%) within the last year. 46 (41%) had previous US experience.

Main Results

Pulse check times are listed in Table 2. The mean time to carotid pulse identification with US was 4.22 (SD 3.26) seconds compared to 4.71 (SD 6.45) seconds by MP, with a mean difference in times of -0.49 seconds (90% CI: -1.77 to 0.39). Using US, 110 (99.1%) of participants were able to successfully identify a pulse on the first attempt compared to 95 (85.6%) by MP ($p = 0.0001$).

The proportion of participants in each method who took more than five and 10 seconds to identify the pulse was not significantly different between the methods. There were four extreme outlier measurements of greater than 20 seconds for pulse detection, all using the MP technique. Overall, there was a higher variability in pulse detection times using MP, with a wider range of times and larger standard deviation ($p<0.001$) (Figure 2).

We assessed whether demographic factors and previous experience had an impact on pulse detection times. There was no association with recency of BLS or ACLS training with pulse assessment times using MP technique. Pulse check times were 5.02 (SD 7.56) seconds for those with recent ACLS certification compared to 4.25 (SD 4.29) seconds for those without recent ACLS certification ($p=0.55$). Previous US experience did not affect MP times. Factors associated with the duration of pulse checks using US included previous US experience and type of work. Those who had previously used an US had a mean time of 3.13s compared to 5.00s for those without any prior US experience ($p = 0.003$). Staff physicians and residents tended to have quicker US pulse check times (3.29s) followed by paramedics, medical students (4.04s) and nurses (5.12s) ($p = 0.02$).

At baseline, participants had higher confidence with MP than US on a VAS (68 mm (IQR 48-83) vs 15 mm (IQR 8-42), $p<0.001$). However, after completion of the study, participants reported higher confidence levels with US compared to MP (91 mm (IQR 82-97) vs 83 mm (IQR 72-94), $p<0.001$) (Figure 3).

The inter-rater reliability for both palpation and ultrasound times as measured by intraclass correlation was excellent (ICC=0.99).

Discussion

In this study, HCPs were not slower to identify the carotid pulse of live models using US compared to MP. We found that the use of US for pulse detection had a higher first attempt success rate and produced more consistent results with fewer outliers. In addition, we found that after a brief training session, HCPs were able to identify a pulse in live models using US with a higher self-reported confidence than with palpation.

The rapid detection of a pulse is critical for the management of cardiac arrest. The American Heart Association (AHA) has emphasized the importance of minimizing interruptions to chest compressions and have advocated for a pulse check time of less than 10 seconds.[1] Prolonged interruptions in compressions cause a drop in coronary perfusion pressure, which is associated with poor outcomes.[9-12] Despite this, due to the difficulty in determining the presence of a pulse, pulse checks routinely extend beyond this 10 second window.[6,20-21] In an observational study of 105 allied healthcare providers, only 38.1% correctly identified a pulse within 10 seconds.[6] Only 9 participants (8.6%) were able to correctly identify the absence of a pulse within 10 seconds.

The rates of prolonged pulse checks are likely related to the difficulty in determining the presence of a pulse in unresponsive patients. [4-8,22-24] In a prospective randomized trial, 206 HCPs and laypeople were asked to determine the presence of a pulse for patients undergoing cardiopulmonary bypass. [5] In this study, only 65% of participants were able to accurately detect the presence or absence of a pulse with a specificity of 55%. This study demonstrated that in 10% of cases, CPR would not have been initiated due to the participants' false detection of a pulse. In a mannequin study, 64 HCPs were given 30 seconds to detect the presence or absence of a pulse and only 50% were correct.[24] In a study of 153 HCPs palpating the pulse of paediatric patients undergoing cardiopulmonary bypass found that in 24% of cases, CPR would have been incorrectly withheld due to the false detection of a pulse.[25]

The difficulty and unreliability of the manual pulse check has led the AHA to remove pulse checks from lay rescuer training guidelines.[26] However, the pulse check remains a mainstay of management of cardiac arrest for health care practitioners. With the increasing use of POCUS in resuscitations, new and potentially more reliable methods for determining the presence of a pulse have emerged. By applying a high-frequency linear array transducer directly to the carotid artery, the presence or absence of pulsations can be directly visualized. A patient with a pulse will have a central artery that appears to pulsate on the screen, whereas a patient without any significant perfusion will have an artery without pulsations that collapses with minimal transducer pressure. This technique is appealing as the visual representation of a pulsating vessel on a screen is intuitive and easy to learn. In our study, participants felt more confident identifying pulses using US than by MP after minimal training.

Prior studies have attempted to identify a pulse in patients in cardiac arrest or shock using US.[27,28] These studies used more complex and time-consuming methods. In one study, blood flow was detected through the internal common carotid artery (ICA).[27] This method is more complex and may not be suitable for novice sonographers as the ICA must be differentiated from the external carotid artery by analyzing flow velocity tracings. Additionally, Doppler was applied to the ICA which adds time and complexity to the scan. Another recent trial assessed pulse checks by Doppler flow through the femoral artery, which again may be more difficult and time consuming than simple B-Mode.[28]

While new methods of more accurately identifying a pulse are needed, it is important to ensure that any new technology does not introduce delays in chest compressions. In this study, we found that pulse checks using US were not slower by more than two seconds compared with palpation in live models. US pulse checks took an average of 4.2 seconds and had significantly less variability in timing compared with MP. Despite an ideal environment with a simulated patient with a known pulse, several participants took greater than 20 seconds to detect a carotid pulse when using the palpation method. In addition, there was a significantly higher rate of correct first-attempt pulse detection with US compared with palpation. For the purpose of this study, the US unit was turned on and the transducer ready prior to performing the pulse check. When using this technique, it is important to perform these setup tasks prior to the pulse check to minimize pauses in compressions.

Other studies have attempted to use POCUS views of the heart to replace manual pulse checks during resuscitations. Despite its utility in determining the presence or absence of cardiac activity, cardiac POCUS can be challenging, time consuming and may not help in diagnosing an underlying etiology as previously believed.[29-31] Cardiac views during resuscitation may be obscured by gastric insufflation, body habitus, and subcutaneous emphysema rendering cardiac POCUS uninterpretable. Furthermore, recent studies have demonstrated that cardiac POCUS has the potential to prolong pulse checks and delay chest compressions.[29-31] One prospective observational cohort found that the use of POCUS during cardiac arrest prolonged pulse checks by 8.4s (95% CI, 6.7-10.0, $p<0.0001$).[29] Another study noted an average of 17s (IQR 13-22.5) were required to perform a pulse check while POCUS was being performed, compared to 11s (IQR 7-16) without POCUS.[30] In contrast with these studies, the advantage of performing carotid US is that the neck is easily accessible, is out of the way of chest compressions, and the carotid is a superficial structure that is easily visualized even by ultrasound novices.

Our results suggest that a brief (15 minute) US training session can improve HCPs' confidence in US pulse identification. A medical student teaching seminar on femoral artery identification using POCUS also corroborates this finding.[32] In this study, limited bedside teaching increased students' confidence levels in artery identification in live subjects pre and post US teaching. Given the ease of this skill, and ultrasound's growing ubiquity, POCUS for pulse identification has the potential to be applied by a variety of care providers in the acute care setting.[31, 33-36]

Limitations

This study has several limitations. First, we assessed participants' ability to detect pulses in live subjects only who were not bradycardic. In bradycardic patients, it is possible that a pulse check time of at least five seconds would be necessary, however this would apply equally to both assessment methods. It is unclear whether the findings from our study would be similar in patients in actual cardiac arrest. However, it is possible that the benefit of POCUS may be even greater for patients in an arrest scenario, where pulse checks have been shown to be even more unreliable. For practical reasons, we could not blind our study participants to the pulse check method. However, the measurements were made by two independent reviewers blinded to the pulse detection method used, and we attempted to reduce any operator bias by randomizing the order of the technique used and not revealing the objective of the study. Additionally, the use of a radial pulse on models is not as reliable a gold standard as more invasive methods such as arterial line pulse detection. For practical and ethical reasons, arterial line insertions in healthy subjects was not performed in this study but would be a more reliable method if used in patients in shock or cardiac arrest. Our study does not take into account time required to turn on an US unit, select, and prepare the transducer. However, in a resuscitation scenario, these tasks can be performed while chest compressions are ongoing prior to the pulse check. The study population was heterogeneous, including nurses, physicians, and paramedics. However, this improves the generalizability of our study results to a broad HCP population.

Conclusion

In this study, pulse checks performed with US were not slower than by palpation in live models. Pulse checks using US required fewer attempts and had less variability in times. Furthermore, a brief training session was effective for teaching these skills to participants of various professional backgrounds and levels. The results from this study provide the groundwork for future studies evaluating whether US can provide a more efficient and reliable means for detecting pulses in cardiac arrest patients.

Disclaimers: Views expressed in this article are our own and not an official position of the affiliated institutions.

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Conflicts of interest: None

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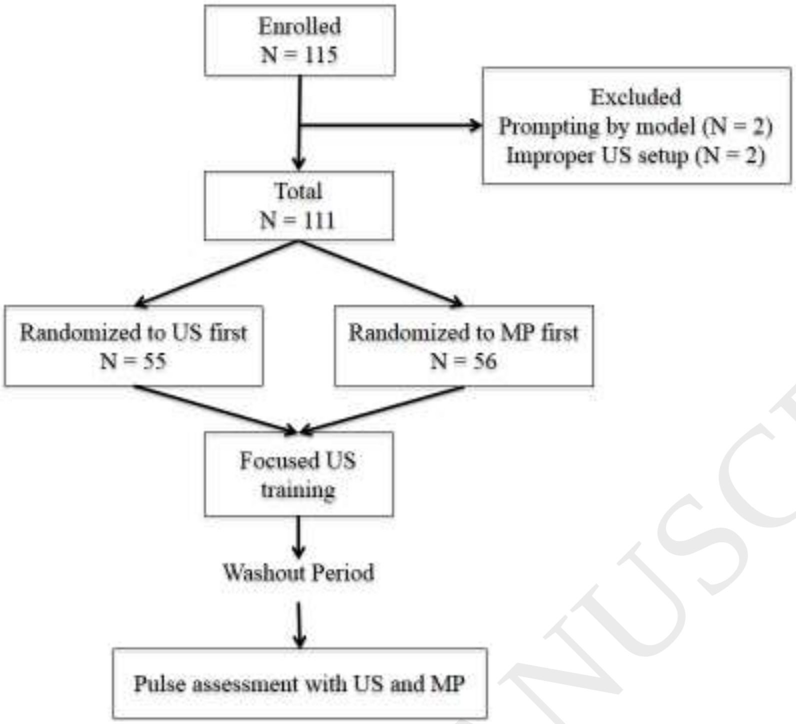
Figure 1



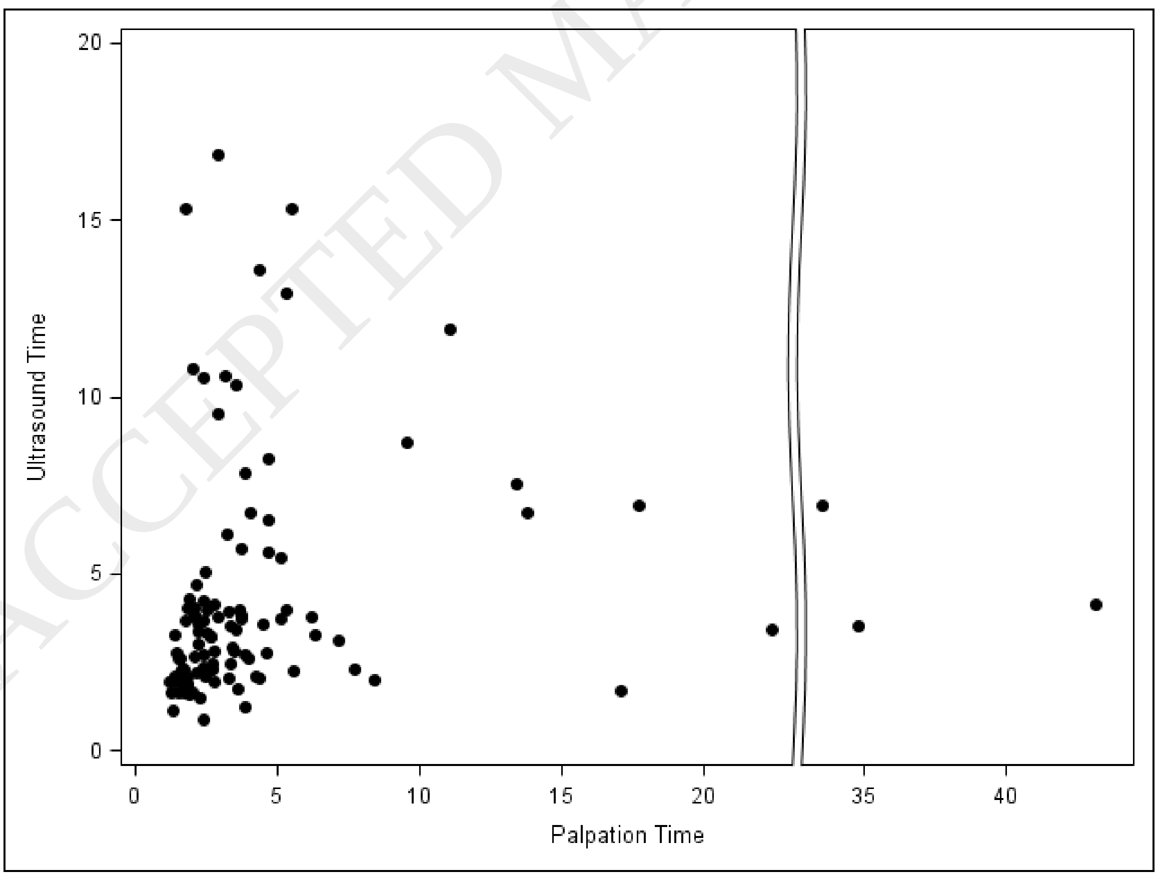


Figure 2. Scatter plot diagram of pulse detection times (in seconds) by US and palpation

Figure 3

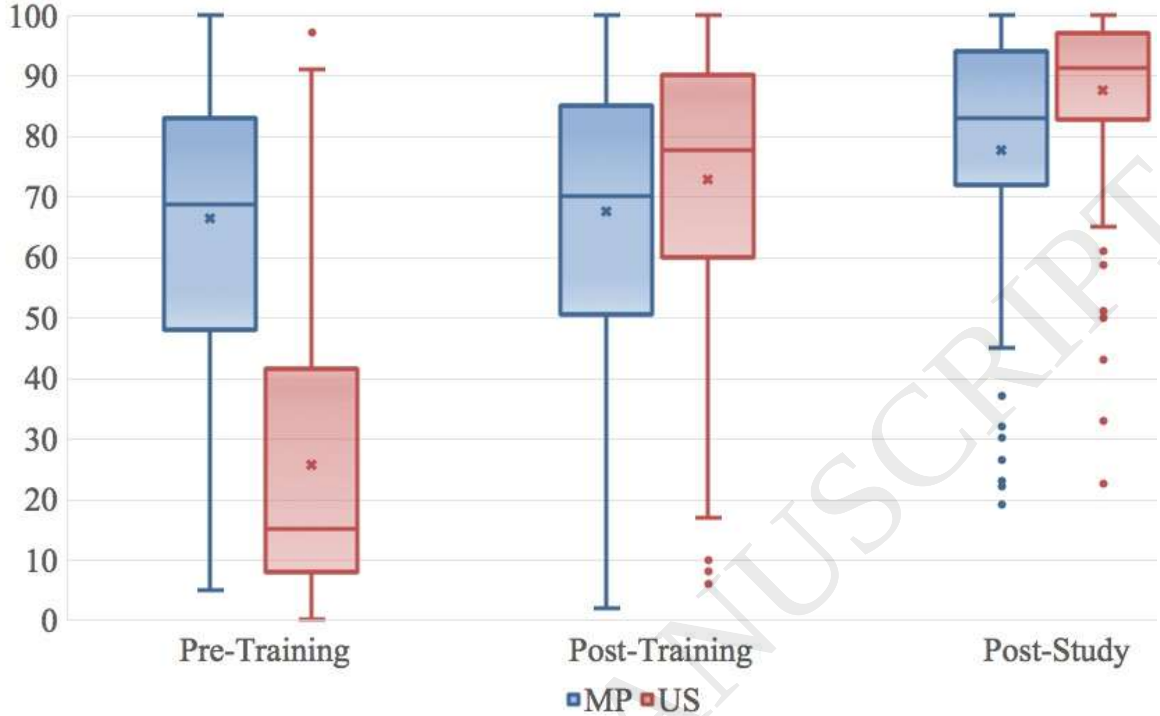


Figure 3. Participant confidence levels with manual pulse check (MP) and US pulse check (US) as assessed on a VAS throughout enrolment. Post-Training and Post-Study questionnaires were administered immediately after (<1 min) the respective sessions.

Table 1. Participant Demographics

Demographics	N (%)
Female	43 (39)
Age – years (median and IQR)	29 (25-40)
Hand dominance - Right	101 (91)
Profession	
Staff physician	16 (14)
Resident	29 (26)
Medical Student	3 (3)
Nurse	50 (45)
Paramedic	1 (1)
Other	12 (11)
Years in current profession	
Mean (SD) Median (IQR)	4.1 (7.1) 1.5 (0-5)
Previous BLS course within 1 year	81 (73)
Previous ACLS course within 1 year	28 (25)
Previous US experience	46 (41)

Table 2. Post-Study Pulse Check Times

Outcome	US	MP	Statistical Measure
Pulse time, mean (SD), seconds	4.22 (3.26)	4.71 (6.45)	90% CI: -1.77 – 0.39
Pulse identification >5 seconds, n (%)	26 (23)	21 (19)	P = 0.466
Pulse identification >10 seconds, n (%)	10 (9)	9 (8)	P = 0.819
Successful on 1st attempt, n (%)	110 (99.1)	95 (85.6)	P = 0.0001