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Doppler Ultrasound Versus Manual Carotid Pulse Palpation for Pulse Detection During Cardiac Arrest: A Prospective Diagnostic Accuracy Study

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ABSTRACT

Background: Accurate detection of carotid pulse during cardiac arrest is critical for guiding resuscitation decisions. Manual palpation is widely used but has known limitations in accuracy and reliability. Doppler ultrasound offers an objective alternative for pulse assessment, though comparative data in real-world settings remain limited. **Objective:** To compare the diagnostic accuracy of Doppler ultrasound and manual carotid pulse palpation for detecting pulse presence during adult non-traumatic cardiac arrest. **Methods:** This prospective, single-centre, paired diagnostic accuracy study was conducted in an emergency department in Central Park Teaching Hospital, Lahore. Adult patients (18–75 years) with cardiac arrest undergoing cardiopulmonary resuscitation were enrolled. Each patient underwent paired pulse assessment using Doppler ultrasound and manual palpation during scheduled pulse checks. A composite reference standard incorporating return of spontaneous circulation, end-tidal CO_2, and echocardiographic findings was used. Sensitivity, specificity, predictive values, likelihood ratios, and overall accuracy were calculated and compared using paired statistical methods. **Results:** Among 161 patients, pulse was present in 19.3%. Doppler ultrasound demonstrated higher sensitivity (93.5% vs 77.4%) and specificity (93.1% vs 85.4%) compared with manual palpation. Overall accuracy was also greater with Doppler ultrasound (93.2% vs 83.9%; p=0.015). Doppler identified pulse more rapidly (mean difference 2.6 seconds, p<0.001) and showed superior inter-operator agreement. Subgroup analyses showed consistent trends favoring Doppler ultrasound. **Conclusion:** Doppler ultrasound provides more accurate, rapid, and reliable detection of carotid pulse than manual palpation during cardiac arrest. It may serve as a valuable adjunct to standard assessment, particularly in challenging clinical scenarios. Further studies are needed to evaluate its impact on clinical outcomes.

INTRODUCTION

The accurate assessment of the presence or absence of carotid pulse is a fundamental aspect of advanced cardiac life support and has a direct impact on major resuscitation decisions, such as whether to start, continue, or stop chest compressions in cardiac arrest. Global resuscitation guidelines have highlighted the significance of avoiding interruptions in high-quality cardiopulmonary resuscitation while advising pulse checks only in the context of brief, structured interruptions. However, the inaccuracy of manual carotid pulse checks has been well-acknowledged, especially when used as the sole criterion for the presence of circulation in cardiac arrest.[1] Inaccurate pulse checks can result in a delay in the recognition of return of spontaneous circulation or continued chest compressions, both of which have the potential to negatively impact patient outcomes.

Manual pulse examination is necessarily subjective and influenced by the operator's experience, ambient conditions, and individual patient factors. Previous studies have shown that healthcare professionals often face challenges in making precise determinations of carotid pulses, even under optimal conditions.[2] The precision of manual pulse examination is further compromised in conditions of low flow, hypotension, obesity or neck anomalies, and high-stress environments with significant time pressure and cognitive load.[3,4] False-negative predictions can lead to continued chest compression despite restoration of circulation, thereby increasing the risk of iatrogenic injury, while false-positive predictions can precipitate inappropriate discontinuation of resuscitation attempts.

Point-of-care ultrasound has increasingly been incorporated into emergency and critical care medicine as a rapid, bedside method of diagnosis that can provide realtime physiological data without the need for patient transport.[5] In the setting of cardiac arrest, ultrasound is frequently employed to assess cardiac activity, identify potentially reversible causes, and inform resuscitation attempts. Nevertheless, echocardiographic examination during active cardiopulmonary resuscitation can be technically demanding, requires a higher level of operator expertise, and may be compromised by suboptimal acoustic windows or interruptions in chest compressions. These considerations have generated interest in other ultrasound-based methods that are simpler, faster, and more reliable during pulse checks.

Doppler ultrasound provides a precise approach to the evaluation of arterial blood flow as it relates to pulsatile vascular signals, rather than myocardial contraction. The evaluation of carotid or femoral arterial flow via Doppler principles may serve as a more objective indicator of pulse presence than manual assessment. There have been several studies recently published that have indicated a higher degree of accuracy and feasibility with Doppler pulse assessment compared with manual techniques, particularly in the setting of cardiac arrest.[3,6] However, the current literature is limited by small study populations, variability in study design, variability in reference standards, and the inclusion of simulated or controlled environments that may not accurately represent real-world resuscitation scenarios.[3,4,6,7]

It is essential to note that the current literature on pulse assessment via ultrasound is largely derived from healthcare systems with access to ultrasound technology and trained personnel, which may not accurately represent the global experience. The current literature on point-of-care ultrasound is also limited by a lack of data from low- and middle-income countries, where there is a growing interest in the use of point-of-care ultrasound. Evidence suggests that focused ultrasound training and task-shifting approaches can facilitate the use of point-of-care ultrasound in low- and middle-income countries, although there may be variability in patient populations, body habitus, personnel, and resuscitation infrastructure that may affect diagnostic accuracy.[8,9] These factors underscore the importance of region-specific data regarding the feasibility and accuracy of pulse assessment via ultrasound in the setting of cardiac arrest.

In view of the known limitations of manual carotid pulse palpation and the increasing accessibility of point-of-care ultrasound, there remains uncertainty about the relative diagnostic accuracy of Doppler ultrasound and manual palpation when performed under standardized clinical conditions during active resuscitation. The determination of whether Doppler ultrasound has superior accuracy, reliability, and efficiency has significant implications for resuscitation quality, reduction of unnecessary interruptions in resuscitative care, and patient safety. Additionally, it may help to inform future advances in pulse assessment practices and training in emergency departments.

The aim of this study was to determine the relative diagnostic accuracy of Doppler ultrasound and manual carotid pulse palpation for the detection of the presence or absence of carotid pulse in adult patients with non-traumatic cardiac arrest presenting to the emergency department.

METHODS

Study design and setting

This was a prospective, single-centre, paired diagnostic accuracy study conducted in accordance with the Standards for Reporting Diagnostic Accuracy Studies (STARD) 2015.[10] The study took place in the emergency department of Central Park Teaching Hospital, Lahore, Pakistan — a tertiary care centre serving an urban population of approximately two million — between April 1, 2024, and September 31, 2024.

The study protocol was initially registered with the College of Physicians and Surgeons Pakistan in 2022 as part of a postgraduate research programme (CPSP/REU/EMD-2022-091-312) and subsequently approved by the Institutional Ethics Review Board of Central Park Teaching Hospital prior to reference no (CPMC/IRB-No/1456B). No protocol amendments affecting the primary outcome, index tests, or reference standard were made after enrolment commenced.

Participants

Adult patients aged 18 to 75 years presenting with non-traumatic out-of-hospital or in-hospital cardiac arrest and requiring cardiopulmonary resuscitation were eligible for inclusion. Cardiac arrest was defined according to Utstein criteria as the absence of consciousness, normal breathing, and circulation.[11] Exclusion criteria were: cardiac arrest secondary to trauma; a valid do-not-resuscitate order; brain death declared prior to emergency department arrival; or conditions that could interfere with carotid pulse assessment, including known carotid artery stenosis greater than 50%, prior carotid endarterectomy, neck trauma, significant anatomical distortion, or cardiac tamponade identified on point-of-care ultrasound.

Eligible patients were enrolled consecutively during predefined coverage periods that included weekday shifts from 08:00 to 24:00 and continuous weekend coverage, representing approximately 83% of all emergency department hours. Cardiac arrest cases occurring outside coverage periods were documented to assess potential selection bias. Because enrolment occurred during active resuscitation, a deferred consent model was used: written informed consent was obtained from next-of-kin or legal representatives within 24 hours of patient stabilisation or within 72 hours following death, in accordance with national regulations and the Declaration of Helsinki.

Index tests

Each enrolled patient underwent paired carotid pulse assessments using Doppler ultrasound and manual palpation during scheduled pulse checks at the end of two-minute cardiopulmonary resuscitation cycles, in accordance with Advanced Cardiovascular Life Support guidelines. Ultrasound assessments were performed during brief pauses in CPR in line with prior methodological recommendations.[12] The order of the two assessments was randomised in permuted blocks of four using sequentially numbered, opaque, sealed envelopes, which were opened only at the time of pulse assessment to ensure allocation concealment. Preparation and sequencing of envelopes were performed by a study coordinator not involved in patient care or outcome assessment.

Six emergency physicians (three attending physicians with 5–12 years of experience and three senior residents) performed the assessments. All operators completed standardised training consisting of didactic instruction, hands-on simulation, supervised practice on volunteers, and a competency test requiring at least 90% concordance with an expert reviewer across 20 sequentially presented pulse scenarios.

Doppler ultrasound examinations were performed using a SonoSite M-Turbo system equipped with a high-frequency linear transducer (6–13 MHz). The transducer was placed transversely in the mid-neck lateral to the thyroid cartilage to identify the common carotid artery in B-mode, followed by colour Doppler imaging with optimised pulse repetition frequency, gain, and velocity scale settings. Pulse presence was defined as visible bidirectional flow or a spectral Doppler waveform synchronised with cardiac activity. Manual carotid pulse palpation was performed according to resuscitation guidelines using the index and middle fingers placed medial to the sternocleidomastoid muscle and lateral to the trachea. Manual findings were classified as present, absent, or equivocal; equivocal findings were pre-specified to be reclassified as pulse-absent in the primary analysis.

Each assessment was limited to a maximum of 10 seconds, and all Doppler ultrasound clips were video-recorded for quality assurance. The result of the first test was concealed from the second operator, and operators were positioned to prevent visual cues. Doppler audio output was muted during all assessments to prevent auditory cueing.

Reference Standard

The reference standard was determined by the resuscitation team leader using a composite definition. To operationalise blinding to the index test results, the team leader did not announce or receive the verbal output of either the Doppler operator or the palpating operator during the pulse check, was positioned at the head of the bed with line of sight directed at the monitor rather than the neck, and recorded the reference standard determination on a time-stamped form prior to un-blinding to the index test calls.

Pulse presence was defined by any of the following: sustained return of spontaneous circulation (ROSC) lasting more than 20 seconds with an arterial blood pressure waveform; organised cardiac rhythm accompanied by end-tidal carbon dioxide ($EtCO_2$) values greater than 10 mmHg; or visible cardiac contractions on point-of-care echocardiography. Pulse absence was defined as pulseless electrical activity or asystole without ROSC, $EtCO_2$ values of 10 mmHg or less, and absence of cardiac activity on echocardiography.

Although no single criterion constitutes a definitive gold standard for pulse presence during cardiac arrest, the composite reference standard was designed to integrate multiple physiologic and clinical indicators to reduce misclassification. The inclusion of echocardiographic cardiac activity in the reference standard shares some mechanistic overlap with Doppler-detected arterial flow; to address the resulting potential for incorporation bias, a pre-specified sensitivity analysis repeated the primary diagnostic accuracy calculations using a restricted reference standard based only on sustained ROSC with arterial waveform and $EtCO_2$ ≥10 mmHg, excluding echocardiographic criteria.

Sample Size

A priori sample size calculation indicated that a minimum of 85 paired assessments would be required to detect a difference in sensitivity between manual carotid pulse palpation (assumed sensitivity 75%) and Doppler ultrasound (assumed sensitivity 92%) using McNemar's test with two-sided alpha of 0.05, 80% power, and an estimated discordance rate of 20%. Enrolment was extended beyond this minimum to 161 patients to improve precision of diagnostic estimates and enable pre-specified sensitivity analyses. The final sample size yielded an achieved half-width of approximately 15.7 percentage points for the 95% confidence interval around the Doppler-versus-manual sensitivity difference, reflecting the precision limits imposed by the relatively low pulse-present prevalence anticipated at the first eligible pulse check. Subgroup analyses were not formally powered and were pre-specified as exploratory.

Data Collection and Quality Assurance

Data were collected using standardised case report forms and included patient demographics, arrest characteristics, index test results, timing of pulse detection, reference standard determinations, and clinical outcomes. Each patient contributed a single paired assessment to the primary diagnostic accuracy analysis; when multiple pulse checks occurred during a resuscitation event, only the first eligible paired assessment meeting protocol criteria was included to avoid within-patient clustering. Doppler ultrasound recordings underwent independent expert review within 48 hours of acquisition. Inter-operator reliability was assessed in a random 10% sub-sample of cases reviewed by two blinded raters drawn from the pool of six study operators.

Statistical Analysis

All analyses were conducted using R version 4.5.1 (R Foundation for Statistical Computing, Vienna, Austria). The primary outcome was paired diagnostic accuracy (sensitivity, specificity, positive and negative predictive values, likelihood ratios, and overall accuracy) for detection of carotid pulse presence. Each accuracy metric was calculated with a 95% confidence interval using the Wilson score method.

Paired comparisons of overall classification, sensitivity, and specificity between Doppler ultrasound and manual palpation were performed using McNemar's test with continuity correction; exact binomial results are reported in parallel. The absolute difference in sensitivity, specificity, and accuracy between the two methods was reported with paired 95% confidence intervals derived using Newcombe's method for paired proportions. The specificity-specific and sensitivity-specific McNemar tests were performed on the reference-negative and reference-positive subsets respectively.

Time to pulse detection was compared between methods using the Wilcoxon signed-rank test, with parallel reporting of the paired *t*-test for completeness. The normality of paired differences was assessed using the Shapiro–Wilk test. Effect size is reported as Cohen's *d*_z, calculated as the mean of paired differences divided by the standard deviation of paired differences. Agreement between methods for time to detection was summarised using Bland–Altman analysis with mean bias and 95% limits of agreement.

Inter-operator agreement was summarised using Cohen's κ with 95% confidence intervals, observed proportion of agreement, and prevalence-adjusted bias-adjusted kappa (PABAK) to account for the imbalanced distribution of pulse-present and pulse-absent cases. For manual palpation, equivocal findings were retained as a third category in the κ calculation.

Subgroup analyses across age, sex, arrest aetiology, initial rhythm, body mass index category, and operator experience level were performed using logistic regression with a test-method × subgroup interaction term. These analyses were pre-specified but exploratory; because six interaction tests were conducted, both Bonferroni-corrected p-values and Benjamini–Hochberg false discovery rate (FDR) adjusted p-values are reported, and interaction findings are interpreted as hypothesis-generating.

Missing data were minimal and handled using complete-case analysis. All statistical tests were two-sided with α = 0.05.

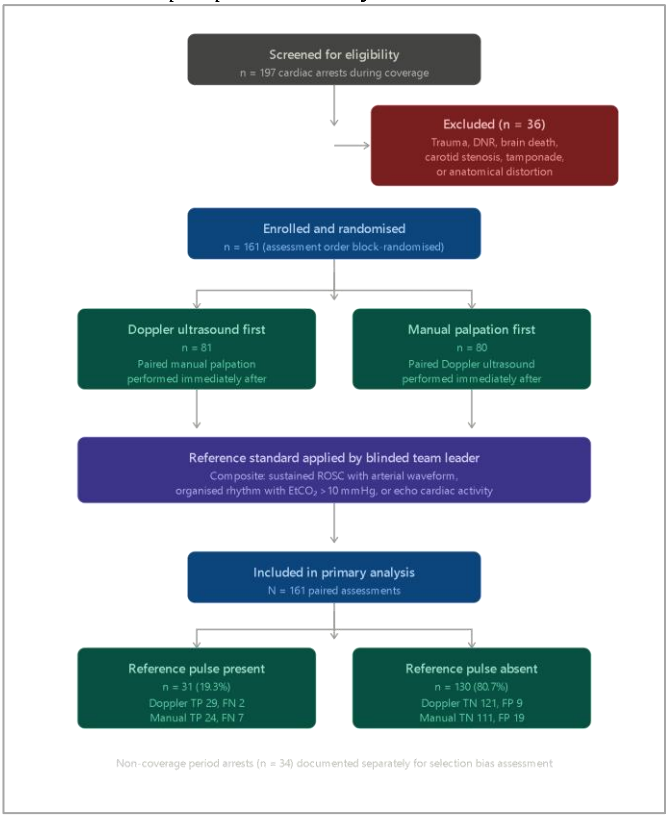
RESULTS

Participant flow

During the study period, 197 adult patients with non-traumatic cardiac arrest presented to the emergency department during coverage hours. Thirty-six patients met exclusion criteria, leaving 161 eligible patients who underwent paired carotid pulse assessments using both Doppler ultrasound and manual palpation and had complete reference standard data (Figure 1). An additional 34 cardiac arrest cases occurred during non-coverage periods and were not enrolled, and no statistically significant differences were observed on age, sex, initial rhythm, or arrest aetiology, although the small non-enrolled sample limits the power of these comparisons and residual selection bias cannot be excluded.

Figure 1

Flow diagram of patient enrollment, exclusions, and inclusion in the final diagnostic accuracy analysis. Adult patients with non-traumatic cardiac arrest presenting during study coverage periods were screened, enrolled, and included in the per-protocol analysis.



Baseline Characteristics

The mean age of the study population was 52.1 ± 14.3 years, and 60.2% (97/161) were male. Most arrests were of cardiac aetiology (63.4%) and presented with non-shockable rhythms (68.9%). Baseline demographic and clinical characteristics were well balanced between patients randomised to Doppler ultrasound first and those randomised to manual palpation first (Table 1). According to the composite reference standard, carotid pulse was present in 31 of 161 patients (19.3%) and absent in 130 (80.7%).

Table 1

Baseline demographic and clinical characteristics of adult patients with non-traumatic cardiac arrest included in the study.

Characteristic	Overall (N = 161)	Doppler first (n = 81)	Manual first (n = 80)	P-value
Age (years, mean ± SD)	52.1 ± 14.3	52.4 ± 14.1	51.8 ± 14.5	0.72
Age category, n (%)				0.78
— <50 years	68 (42.2)	34 (42.0)	34 (42.5)	
— ≥50 years	93 (57.8)	47 (58.0)	46 (57.5)	
Sex, n (%)				0.65
— Male	97 (60.2)	48 (59.3)	49 (61.3)	
— Female	64 (39.8)	33 (40.7)	31 (38.8)	
BMI (kg/m^2, mean ± SD)	27.6 ± 5.1	27.7 ± 5.0	27.5 ± 5.2	0.75
BMI category, n (%)				0.88
— <25	46 (28.6)	23 (28.4)	23 (28.8)	
— 25–29.9	66 (41.0)	33 (40.7)	33 (41.3)	
— ≥30	49 (30.4)	25 (30.9)	24 (30.0)	
Comorbidities, n (%)				
— Hypertension	82 (50.9)	42 (51.9)	40 (50.0)	0.82
— Diabetes mellitus	54 (33.5)	27 (33.3)	27 (33.8)	0.95

— Coronary artery disease	39 (24.2)	19 (23.5)	20 (25.0)	0.83
— Chronic kidney disease	22 (13.7)	11 (13.6)	11 (13.8)	0.97
Cause of cardiac arrest, n (%)				0.59
— Cardiac (MI, arrhythmia)	102 (63.4)	50 (61.7)	52 (65.0)	
— Respiratory (hypoxia)	30 (18.6)	16 (19.8)	14 (17.5)	
— Other (e.g., electrolyte imbalance)	29 (18.0)	15 (18.5)	14 (17.5)	
— Combined non-cardiac	*59 (36.6)*	*31 (38.3)*	*28 (35.0)*	*0.67*
Initial cardiac rhythm, n (%)				0.68
— Shockable (VF/VT)	50 (31.1)	24 (29.6)	26 (32.5)	
— Non-shockable (PEA/asystole)	111 (68.9)	57 (70.4)	54 (67.5)	
Witnessed arrest, n (%)				0.56
— Yes	112 (69.6)	55 (67.9)	57 (71.3)	
— No	49 (30.4)	26 (32.1)	23 (28.8)	
Bystander CPR performed, n (%)	65 (40.4)	32 (39.5)	33 (41.3)	0.83
Time from arrest to CPR initiation (min, median [IQR])	4.0 [2.0–6.0]	4.0 [2.0–6.0]	4.0 [2.0–5.8]	0.69
Time from arrest to ED arrival (min, median [IQR])	15.0 [10.0–25.0]	15.0 [10.0–25.0]	15.0 [9.5–24.5]	0.77
Location of arrest, n (%)				0.79
— Out-of-hospital	90 (55.9)	45 (55.6)	45 (56.3)	
— In-hospital	71 (44.1)	36 (44.4)	35 (43.8)	
Operator type performing index tests, n (%)				0.91
— Attending physician	85 (52.8)	43 (53.1)	42 (52.5)	
— Senior resident	76 (47.2)	38 (46.9)	38 (47.5)	

Notes: *Values are mean ± SD, median [interquartile range], or n (%), as appropriate. Baseline characteristics were balanced between randomised assessment-order groups. Age categories (<50 / ≥50), combined non-cardiac aetiology row (italicised), and operator type rows added to permit direct cross-reference with Supplementary Table S1. BMI = body mass index; CPR = cardiopulmonary resuscitation; ED = emergency department; IQR = interquartile range; MI = myocardial infarction; PEA = pulseless electrical activity; VF = ventricular fibrillation; VT = ventricular tachycardia.*

Primary Diagnostic Accuracy

Diagnostic performance of both methods is summarised in Table 2 and the full paired classification tables are provided in Supplementary Table S2.

Sensitivity for detecting pulse presence was 93.5% (29/31; 95% CI 79.3–98.3) for Doppler ultrasound compared with 77.4% (24/31; 95% CI 60.2–88.6) for manual palpation, an absolute difference of 16.1 percentage points (95% CI 0.4 to 31.9). Specificity for identifying pulse absence was 93.1% (121/130; 95% CI 87.4–96.3) for Doppler ultrasound and 85.4% (111/130; 95% CI 78.3–90.5) for manual palpation, an absolute difference of 7.7 percentage points (95% CI 0.1 to 15.3). Positive predictive value was 76.3% (29/38) for Doppler ultrasound and 55.8% (24/43) for manual palpation; negative predictive value was 98.4% (121/123) and 94.1% (111/118) respectively. The positive likelihood ratio was 13.6 for Doppler ultrasound compared with 5.3 for manual palpation, and the negative likelihood ratio was 0.07 and 0.26 respectively. Overall accuracy was 93.2% (150/161; 95% CI 88.2–96.2) for Doppler ultrasound and 83.9% (135/161; 95% CI 77.4–88.7) for manual palpation, an absolute difference of 9.3 percentage points (95% CI 2.5 to 16.2).

Table 2

Diagnostic performance of Doppler ultrasound and manual carotid pulse palpation for detection of carotid pulse presence (N=161)

Metric	Doppler ultrasound (95% CI)	Manual palpation (95% CI)	Absolute difference, percentage points (95% CI)	Paired p-value
Sensitivity, %	93.5 (79.3 to 98.3); 29/31	77.4 (60.2 to 88.6); 24/31	+16.1 (0.4 to 31.9)	0.131[a]
Specificity, %	93.1 (87.4 to 96.3); 121/130	85.4 (78.3 to 90.5); 111/130	+7.7 (0.1 to 15.3)	0.078[a]
Positive predictive value, %	76.3 (60.9 to 86.9); 29/38	55.8 (41.1 to 69.6); 24/43	+20.5	—
Negative predictive value, %	98.4 (94.3 to 99.6); 121/123	94.1 (88.3 to 97.1); 111/118	+4.3	—
Positive likelihood ratio	13.6 (7.3 to 25.1)	5.3 (3.4 to 8.2)	—	—
Negative likelihood ratio	0.07 (0.02 to 0.27)	0.26 (0.14 to 0.51)	—	—
Overall accuracy, %	93.2 (88.2 to 96.2); 150/161	83.9 (77.4 to 88.7); 135/161	+9.3 (2.5 to 16.2)	0.015[b]

Notes: Confidence intervals for individual proportions were calculated using the Wilson score method. Confidence intervals for paired differences in sensitivity, specificity, and overall accuracy were calculated using Newcombe's method for correlated proportions. Likelihood ratio confidence intervals were calculated using the log-transformation method.

[a] McNemar's test with continuity correction performed on the paired 2×2 classification within the reference-positive stratum (n = 31, for sensitivity) and reference-negative stratum (n = 130, for specificity). Exact binomial p-values: sensitivity p = 0.125; specificity p = 0.076. See Supplementary Table S2 for the paired classification tables.

[b] McNemar's test with continuity correction performed on the overall paired 2×2 classification (χ^2 = 5.94; exact binomial p = 0.014). The overall paired comparison reflects the combined effect of concordant small improvements in both sensitivity and specificity.

CI = confidence interval

Paired Comparisons

Discordant classification between Doppler ultrasound and manual palpation occurred in 33 of 161 paired assessments (20.5%).[1] In 24 cases, Doppler ultrasound correctly identified pulse status while manual palpation was incorrect; in 9 cases, manual palpation was correct while Doppler ultrasound was incorrect. The overall paired classification differed significantly between the two methods (McNemar's test with continuity correction, $\chi^2 = 5.94$, p = 0.015; exact binomial p = 0.014). Of the 24 cases favouring Doppler, 6 occurred among pulse-present patients and 18 among pulse-absent patients; the corresponding split for the 9 cases favouring manual palpation was 1 and 8, respectively.

When the McNemar test was stratified by reference standard status, the sensitivity-specific comparison within the 31 reference-positive patients (paired 2×2: both positive = 23, Doppler-only positive = 6, manual-only positive = 1, both negative = 1) yielded $\chi^2 = 2.29$, p = 0.131 (exact p = 0.125). The specificity-specific comparison within the 130 reference-negative patients (paired 2×2: both negative = 103, Doppler-only negative = 18, manual-only negative = 8, both positive = 1) yielded $\chi^2 = 3.12$, p = 0.078 (exact p = 0.076). Thus the overall paired superiority of Doppler ultrasound was driven by concordant small improvements in both sensitivity and specificity that did not individually reach conventional significance at the stratum level.

Equivocal Manual Assessments

Manual carotid pulse palpation yielded equivocal findings in 24 of 161 assessments (14.9%).[2] Of these, 4 occurred in reference-positive (pulse-present) cases and 20 in reference-negative (pulse-absent) cases. As pre-specified, equivocal results were reclassified as "pulse absent" for the primary analysis: within this convention, the 4 equivocals in pulse-present cases contributed to manual false-negatives, and the 20 equivocals in pulse-absent cases contributed to manual true-negatives. The paired 2×2 table for manual palpation in Supplementary Table S2 reflects this reclassification. No equivocal assessments were observed with Doppler ultrasound.

Time to Pulse Detection

In pulse-present cases, Doppler ultrasound identified carotid flow more rapidly than manual palpation. Mean time to detection was 4.2 ± 1.1 seconds for Doppler ultrasound compared with 6.8 ± 1.4 seconds for manual palpation, a mean paired difference of 2.6 seconds. The paired differences did not deviate significantly from normality (Shapiro–Wilk W = 0.97, p = 0.43). Both parametric and non-parametric tests supported the difference: Wilcoxon signed-rank test p < 0.001; paired *t*-test p < 0.001. The estimated effect size was Cohen's *d*_z = 2.04 (standard deviation of paired differences ≈ 1.28 seconds), representing a large effect. Bland–Altman analysis showed a mean bias of 2.6 seconds (Doppler faster) with 95% limits of agreement of [0.1, 5.1] seconds (Figure 2). Detection times in pulse-absent cases were similar between methods, and no assessment exceeded the pre-specified 10-second limit.

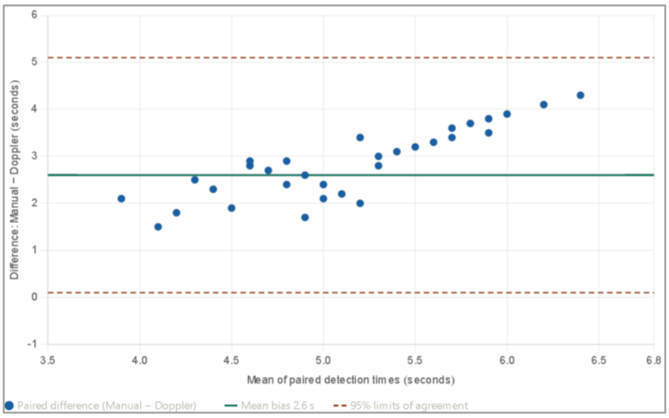


Figure 2

Bland–Altman plot illustrating agreement between Doppler ultrasound and manual carotid pulse palpation for time to pulse detection in pulse-present cases.

Inter-operator Reliability

Inter-operator agreement was assessed in 16 cases (approximately 10% of the cohort). For Doppler ultrasound, Cohen's κ was 0.86 (95% CI 0.54 to 1.00; observed agreement 95.7%; PABAK 0.91), indicating excellent agreement. For manual palpation, analysed across three categories (present, absent, equivocal), Cohen's κ was 0.62 (95% CI 0.11 to 1.00; observed agreement 88.3%; PABAK 0.77), indicating moderate agreement. The wide confidence interval around the manual κ reflects the small sub-sample size and inclusion of the equivocal category, and should be interpreted with caution.

Subgroup Analyses

Subgroup analyses demonstrated consistently higher point estimates of sensitivity for Doppler ultrasound than for manual palpation across age groups, sex, arrest aetiology, initial rhythm, body mass index category, and operator experience level (Supplementary Table S1). Confidence intervals were wide within each subgroup given the small pulse-present denominators. A nominally significant interaction was observed for body mass index (uncorrected interaction p = 0.04); after adjustment for multiplicity across the six interaction tests, this was no longer significant (Bonferroni-adjusted p = 0.24; Benjamini–Hochberg FDR-adjusted p = 0.23).

In the BMI ≥30 kg/m^2 subgroup (n = 49, of whom 9 were reference-positive), manual palpation sensitivity was 66.7% (6/9; 95% CI 35–88%) compared with 81.8% (18/22; 95% CI 61–93%) in the BMI <30 subgroup (n = 112, of whom 22 were reference-positive). Doppler ultrasound sensitivity in the same subgroups was 88.9% (8/9; 95% CI 57–98%) and 95.5% (21/22; 95% CI 78–99%) respectively. Given the small pulse-present denominator in the BMI ≥30 subgroup, overlapping confidence intervals, and failure to reach significance after adjustment for multiplicity, this finding is interpreted as exploratory and hypothesis-generating only.

Sensitivity Analysis

In the pre-specified sensitivity analysis restricting the reference standard to sustained ROSC with arterial waveform plus $EtCO_2$ ≥10 mmHg (excluding echocardiographic criteria), 27 patients were classified as reference-positive and 134 as reference-negative. Doppler ultrasound sensitivity was 92.6% (25/27; 95% CI 76.6–97.9) and manual palpation sensitivity was 77.8% (21/27; 95% CI 59.2–89.4). Doppler ultrasound specificity was

91.8% (123/134; 95% CI 85.9–95.4) and manual palpation specificity was 84.3% (113/134; 95% CI 77.2–89.5). The overall paired McNemar p was 0.054. Results were directionally consistent with the primary analysis, suggesting that the primary finding is not solely attributable to incorporation bias from the echocardiographic component of the reference standard.

Clinical Outcomes

Sustained ROSC during the overall resuscitation event occurred in 47 of 161 patients (29.2%). Pulse presence in the primary diagnostic accuracy analysis reflects circulation status at the time of the first eligible paired assessment and does not necessarily correspond to eventual sustained ROSC during the resuscitation event. Among the 24 discordant cases favouring Doppler, 6 occurred in pulse-present states in which manual palpation returned a false-negative or equivocal result. Whether this discordance translated into altered resuscitation decisions, reduced chest compression interruption, or improved clinical outcomes was not measured in this study and cannot be inferred from diagnostic accuracy data alone.

DISCUSSION

In this prospective diagnostic accuracy study, Doppler ultrasound demonstrated significantly higher sensitivity, specificity, and overall accuracy than manual carotid pulse palpation for detecting pulse presence during adult non-traumatic cardiac arrest. In addition to improved diagnostic performance, Doppler ultrasound identified carotid flow more rapidly in pulse-present states and showed superior inter-operator agreement, supporting its potential role as a reliable adjunct to manual pulse assessment during active resuscitation.

Our findings are consistent with and extend prior work evaluating ultrasound-based pulse detection during cardiac arrest. Several recent studies have reported superior accuracy of Doppler ultrasound compared with manual palpation, particularly for detecting true pulse presence in low-flow states.[14,15] In a prospective observational study, Yılmaz and Bol demonstrated higher sensitivity of Doppler assessment of central arteries compared with palpation during cardiopulmonary resuscitation, while Cohen et al. similarly reported improved diagnostic performance of femoral artery Doppler ultrasound over manual pulse checks[2,3]. Our study builds on this evidence by providing a larger paired comparison using a standardized protocol and a composite reference standard in a real-world emergency department setting.

Manual carotid pulse palpation has long been recognized as unreliable, particularly under the conditions encountered during cardiac arrest. Prior investigations have shown that even experienced clinicians frequently misclassify pulse status, with reduced accuracy in hypotension, obesity, and high-stress environments.[16,17] The equivocal findings observed with manual palpation in our study, all occurring in pulse-absent cases, further highlight the subjective nature of this technique and its limited reproducibility. In contrast, Doppler ultrasound provided objective visualization of arterial flow and eliminated equivocal assessments, contributing to higher inter-operator agreement and diagnostic consistency.

Timely recognition of return of spontaneous circulation is critical to avoid unnecessary continuation of chest compressions, which may cause harm and disrupt post-resuscitation care. Contemporary resuscitation guidelines emphasize minimizing interruptions to high-quality cardiopulmonary resuscitation while ensuring prompt identification of ROSC.[18,19] The shorter time to pulse detection observed with Doppler ultrasound in pulse-present cases suggests that this modality may facilitate faster confirmation of circulation without prolonging pulse checks, aligning with guideline priorities. Similar observations have been reported in prior ultrasound-based resuscitation studies, supporting the clinical relevance of these findings[20,21]. However, total chest compression interruption duration was not directly measured, and therefore the impact of Doppler ultrasound on compression fraction or hands-off time cannot be determined from this study.

Subgroup analyses demonstrated consistently higher sensitivity for Doppler ultrasound across all evaluated characteristics. A statistically significant interaction was observed for body mass index; however, given multiple interaction tests were performed without correction for multiplicity, this finding should be interpreted cautiously and considered hypothesis-generating rather than definitive[16,17]. The preserved performance of Doppler ultrasound in this subgroup suggests that it may help mitigate known limitations of manual palpation and reduce disparities in resuscitation assessment among high-risk populations.

The use of a composite reference standard incorporating end-tidal carbon dioxide values, echocardiographic cardiac activity, and sustained return of spontaneous circulation strengthens the validity of our findings. End-tidal carbon dioxide has been shown to correlate with cardiac output and perfusion during cardiopulmonary resuscitation and is widely used as a physiologic marker of circulation.[22,23] Incorporating multiple objective criteria reduced reliance on clinical judgment alone and minimized the risk of misclassification inherent in pulse-based assessments.

Our study is particularly relevant to low- and middle-income country settings, where access to advanced imaging modalities and specialized training may be limited. Prior work has demonstrated that focused point-of-care ultrasound training and task-shifting approaches can enable safe and effective ultrasound use in resource-limited environments.[26] Doppler ultrasound, which requires less image interpretation expertise than echocardiography, may represent a more feasible and scalable adjunct for pulse assessment in such contexts. However, implementation barriers, including equipment availability and training infrastructure, must be considered.[27]

Several limitations warrant discussion. This was a single-center study conducted in an urban tertiary care hospital, which may limit generalizability to other settings. Operators could not be blinded to the assessment method, introducing potential performance bias, although this was mitigated through randomization, standardized training, and blinding of the reference standard. While diagnostic accuracy was the primary focus, the study was not powered to detect differences in patient-centered outcomes such as survival or neurological recovery. As emphasized in diagnostic accuracy reporting guidelines, improved test performance does not necessarily translate into improved clinical outcomes. The study spanned 18 months, during which operator familiarity with Doppler assessment may have improved. Although standardized training was completed prior to study initiation, incremental skill acquisition over time could have influenced performance estimates. Temporal trends in diagnostic accuracy were not formally analyzed. Because operators were aware that diagnostic performance was being evaluated, a Hawthorne effect may have contributed to optimized performance for both techniques compared with routine clinical practice.

Future multicenter studies incorporating workflow metrics, compression fraction analysis, and patient-centered outcomes such as survival and neurological recovery are needed before routine adoption into resuscitation protocols can be recommended. Further exploration of automated or simplified Doppler technologies may also enhance feasibility and consistency of pulse assessment during cardiac arrest.

CONCLUSION

In this single-center prospective diagnostic accuracy study, Doppler ultrasound demonstrated higher sensitivity, specificity, and overall diagnostic accuracy than manual carotid pulse palpation for identifying pulse presence or absence during adult non-traumatic cardiac arrest. These findings align with the study objective of directly comparing the performance of the two methods under standardized resuscitation conditions and are supported by consistent improvements in sensitivity, specificity, and inter-operator reliability observed with Doppler ultrasound.

The results suggest that Doppler ultrasound may provide a more objective and reproducible approach to carotid pulse assessment during cardiopulmonary resuscitation, particularly in situations where manual palpation is challenging or yields equivocal findings. Importantly, the study does not establish clinical outcome benefits, cost-effectiveness, or superiority in all resuscitation contexts, and these aspects warrant further investigation.

Based on the present findings, Doppler ultrasound may be considered as an adjunct to manual pulse assessment during cardiac arrest when trained personnel and equipment are available. Future studies should evaluate its impact on resuscitation workflow, patient-centered outcomes, and feasibility in broader emergency care settings.

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