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RESEARCH REPORT

DEMONSTRATION OF DOPPLER ULTRASOUND PULSE DETECTION BY TRAINED PREHOSPITAL PERSONNEL: A FEASIBILITY STUDY

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ABSTRACT

Background and Aim: Data suggests that finger palpation of the carotid and/or femoral pulses is significantly less sensitive than 100%. In some cases, a patient who does, in fact, have organized cardiac function, may be identified as being in Pulseless Electrical Activity (PEA). Chest compressions performed as indicated by these circumstances may not provide significant therapeutic benefit to those patients and may, in fact, distract from better directed therapies. Doppler Ultrasonography (DUSG) has been shown to be more sensitive than human fingers. This research aims to assess whether EMT-Basics and Paramedics can be quickly and inexpensively trained to use DUSG as a tool for pulse detection.

Methods: Participants viewed a recorded video 4 minutes 18 seconds in length which detailed an anterior-to-posterior fanning technique for assessing presence of a carotid pulse using a doppler ultrasound device. The participants were given a period of time for coached practice and familiarization with the device. Participants were then timed while demonstrating application of ultrasound-conducting gel to a volunteer and using the device to detect a carotid pulse. The time recording ceased when the participant verbalized confirmation of the pulse, and their success or failure was annotated.

Results: Credentialed EMT-Basics and Paramedics, with minimal training, consistently demonstrated the ability to accurately and rapidly assess a carotid pulse using a doppler ultrasound device.

Conclusions: This demonstration suggests that prehospital personnel can be efficiently trained to use available and inexpensive doppler ultrasound devices to determine cardiac pulse status. Furthermore, it suggests that the technique itself can be used to detect the carotid pulse quickly and accurately. Further research in patient care settings should be undertaken to evaluate the utility of doppler ultrasound devices in distinguishing PEA from pseudo-PEA.

BACKGROUND

A replete body of research had been published over the last three decades, including adult and pediatric populations in multiple settings, and has largely found manual palpation of both peripheral and central pulses is non-specific and unreliable (Brearley, et al., 1992; Tibballs & Russell, 2009; Mather, C.,

& O'Kelly, S.,1996). A more recent, and rapidly expanding, body of evidence comparing manual palpation techniques to the use of Doppler ultrasonography (DUSG) and uses of Point-of-Care Ultrasound (POCUS) has further reinforced this notion. Comparative research between the use of technologies has generally found both DUSG and POCUS to be more sensitive and specific for confirmation of the presence of a pulse than manual palpation (Kang et al., 2022; Zengin et al., 2018; Cohen et al., 2022; Badra et al., 2019; Schwartz et al. 2021; Smith et al. 2021; Gaspari et al. 2023; Özlü et al. 2023).

In the context of the potential cardiac arrest victim, the central pulse is checked as a substitute biomarker for direct observation of the presence of cardiac function. When a patient on cardiac monitoring is seen to have organized cardiac electrical activity other than ventricular tachycardia or ventricular fibrillation yet is not found to have a central pulse, clinicians are trained to recognize and categorize this as Pulseless Electrical Activity (PEA) (Oliver, T. I., Sadiq, U., & Grossman, S. A., 2023). The American Heart Association Advanced Cardiac Life Support algorithm suggests chest compressions, positive-pressure ventilations, and directed therapies to reverse the underlying etiology if possible (Panchal et al., 2020).

As tools more sensitive and specific in dynamically describing cardiac function in the peri-arrest patient have become available and validated, the term "pseudo-PEA" has come to describe the ostensibly pulseless patient in whom cardiac function is actually present (Cheung, J. C., & Yip, Y. Y., 2021; Rabjohns et al., 2020; Van den Bempt et al., 2021). A patient wrongly determined by a clinician to be pulseless following a manual pulse check, when more sensitive methods would have detected a pulse, is experiencing pseudo-PEA. Several physiologic states could result in pseudo-PEA, including severe distributive shock during which, for some period of time, relatively normal cardiac activity could be present though extremely low pulsatile pressures in the carotid arteries (Smith et al., 2023). Currently, no specific literature has established that chest compressions are capable of meaningfully improving the cardiac output in the presence of such pathologically diminished preload and afterload. Distributive shock states are typically treated with infusion of fluids or blood products to reduce relative hypovolemia and appropriate vasopressors or reversal agents for the particular pathophysiology involved (Smith et al., 2023). For a distributive shock patient in a state of pseudo-PEA, it may be that correct assessment has the potential to steer the patient's treatment down wildly divergent paths one of which may be completely ineffective and therefore counterproductive in the compressed timeframe available for intervention.

POCUS provides direct visualization of cardiac activity by bedside transthoracic cardiac ultrasonography. The use of a color-flow doppler mode also provides the direct real-time visualization of flow in the carotid artery when a probe optimized for superficial vascular viewing is applied to the neck. The disadvantages of POCUS in the EMS context include its expense, as well as the burden of training prehospital clinicians and maintaining continuing skills proficiency. In the context of the peri-arrest victim, the duration of time required to power on and boot up the associated hardware and software also may present a disadvantage.

Doppler ultrasound units appropriate for DUSG are comparatively inexpensive, with units available to consumers and professionals for less than $200. Operation is simple, as they lack images. For basic units, the only operator-influenced mechanisms are a power button, a volume knob/rocker, and the positioning of the probe, while the only outputs are a single LED indicating that the unit is on and the speaker for producing audio signals. Doppler ultrasound units are small, light, and generally boot to full operation status instantly with the press of one button.

Current practices in vascular medicine take for granted the higher sensitivity of DUSG as it is routinely used to check for non-palpable pulses in the dorsalis pedis and posterior tibialis during assessments for peripheral arterial disease, as well as in the fingertips. In the context of cardiac arrest resuscitation, DUSG has consistently shown more sensitive and at least equally specific for the detection of central pulses compared to manual palpation (Kang et al., 2022; Zengin et al., 2018; Cohen et al., 2022; Badra et al., 2019; Schwartz et al. 2021; Smith et al. 2021). Given the previously mentioned advantages of DUSG over POCUS relevant to EMS clinicians, this research seeks to evaluate whether EMT-Basics and Paramedics can be inexpensively and quickly trained to use DUSG for pulse detection.

METHODS

Two populations were specified for study: credentialled EMT-Basics and Paramedics. Inclusion required holding current, unexpired certification or licensure from the National Registry of Emergency Medical Technicians or the Texas Department of State Health Services at the relevant level. No exclusion criteria beyond failing to meet the inclusion criteria were established. In-person solicitation of participation at EMS stations and training events was used to gather a convenience sample. Given the descriptive nature of this effort, convenience sampling strategy, and logistical limitations, no minimum number of participants was determined to be necessary.

After consenting to participation, all participants viewed a training video 4 minutes 18 seconds in duration. It explained the operation of the doppler ultrasound unit, as well as the A-P fanning technique for the detection of the pulse by doppler ultrasound, aided by video demonstration. After viewing the video, participants immediately transitioned to a coached practice and familiarization period totalling no more than 10 minutes per participant.

At the conclusion of the practice and familiarization period, the participants immediately completed a timed demonstration of the technique which they had just been trained to perform. The demonstration began with a supine adult volunteer positioned as a simulated patient and the doppler ultrasound unit turned off with its probe stowed in storage configuration. A stopwatch was started simultaneous to the giving of a start signal to the participant. Participants were required to immediately apply a portion of water-based lubricant functioning as ultrasound-conducting gel to the simulated patient's neck anterior to the sternocleidomastoid. They then immediately picked up the doppler unit, powered it on, and placed the probe on the neck to begin an A-P fanning technique scan for a carotid pulse. The participants were directed to verbalize confirmation of a detected pulse when they believed they had done so. At the participant's verbal confirmation, the stopwatch was stopped.

It must be noted that for the purposes of this research, specification of a particular approach to the use of DUSG at the carotid site was assessed to be necessary. Given that doppler ultrasound probes "listen" in a linear fashion aligned with the long axis of the probe, variability of the initial alignment of the probe presents significant possibility of missing the carotid artery when placed in the notch anterior to the sternocleidomastoid. This possibility is complicated by variances in patient anatomy and body habitus. Since the technique to be applied for a peri-arrest patient must be both sensitive for the presence of, and specific for the absence of, pulsatile flow in the carotid artery in a limited time frame, the technique employed must be optimized to quickly include and exclude a pulse. Rather than choosing a random initial probe position, this research trains participants in the use of an anterior-to-posterior (A-P) fanning technique.

This technique begins with the probe placed initially into the notch anterior to the sternocleidomastoid and oriented roughly parallel to the coronal plane. In this initial position, the probe is "listening" toward the tracheal rings. While keeping the probe tip in contact with the same point on the skin, fanning the probe from its coronal plane position rearward toward a position parallel to the sagittal plane adjusts the target of its "listening" toward directly posterior. If this fanning motion is continued past its posterior target parallel to the sagittal plane, the target of "listening" becomes lateral. Though this technique has not been previously described or independently validated, this research assumes that an A-P fanning technique of scanning for the carotid pulse is likely more sensitive and specific than a less-directed, non-systematic method of searching for a pulse in the area.

The doppler ultrasound unit employed for the trial was equipped with a 4Mhz probe selected as most appropriate for superficial vascular scanning according to the manufacturer's recommendation. No other equipment variations were assessed.

A data recording instrument recorded a sequentially assigned participant number, the participant's credential, the duration of their demonstration rounded to the nearest second, and "success" or "failure" as determined by the evaluator's corroboration of the detection of a pulse by DUSG at the time the participant confirmed detection. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Expedited approval and institutional activation were obtained from the University of Texas Health Science Center at San Antonio Institutional Review Board as protocol 20220843HU prior to the initiation of research activities and recruitment of participants. Requirement of informed consent was waived due to the low-risk nature of the research, but an approved participant information sheet was made available to all participants to review before participation and keep a copy as desired.

RESULTS

A total of 23 participants, including 10 paramedics and 13 EMT-Basics, were enrolled. All of them were employees of either Acadian Ambulance or San Antonio Fire Department. All participants viewed the video and were given no more than 10 minutes of coached practice time. The specific amount of time spent by each participant was not recorded.

All 23 participants accurately identified a pulse. The mean duration of the timed demonstration by the EMT-Basics was faster than the paramedics at 13.3 seconds compared to

15.2 seconds. The fastest recorded time was an EMT-Basic at 7.0 seconds while the fastest paramedic was 9.0 seconds. The longest time was an EMT-Basic at 31.0 seconds, with the slowest paramedic taking 23.0 seconds.

Partcipant Count	23
Success Rate	**100%**
Mean Duration (seconds)	14.1
Standard Error	1.3
Median	12.0
Mode	8.0
Standard Deviation	6.3
Sample Variance	41.7
Range	24.0
Minimum	7.0
Maximum	31.0
Coefficient of Variation	0.446758211

Table 1. Summary of results from all participants.

Partcipant Count	10
Success Rate	**100%**
Mean Duration (seconds)	15.2
Standard Error	1.5
Median	14.5
Mode	#N/A
Standard Deviation	4.6
Sample Variance	23.5
Range	14.0
Minimum	9.0
Maximum	23.0
Coefficient of Variation	0.302631579

Table 2. Summary of results from paramedic participants.

Partcipant Count	13
Success Rate	**100%**
Mean Duration (seconds)	13.3
Standard Error	2.1
Median	11.0
Mode	8.0
Standard Deviation	7.3
Sample Variance	57.1
Range	24.0
Minimum	7.0
Maximum	31.0
Coefficient of Variation	0.545378097

Table 3. Summary of results from EMT participants.

DISCUSSION

It appears feasible to inexpensively and rapidly train EMT-Basics and Paramedics in the use of DUSG at the carotid site for pulse detection/confirmation. This contention rests upon the highly successful, relatively rapid employment of DUSG during the timed demonstrations. Even in the absence of a comparison standard or a pre-determined benchmark for feasibility, with respect to a success rate of 100%, *res ipsa loquitur*. These findings are novel as no previous attempt to characterize the efficiency of educating paramedics and EMT-Basics in the use of DUSG could be identified during literature search, but the results are consistent with previous literature concerning the actual utilization of DUSG.

It is unlikely that further research concerning the efficiency of training EMS personnel in DUSG use is of high utility. Appropriate further research should evaluate the actual use of peri-arrest DUSG carotid pulse checks themselves in clinical settings. Integration of carotid DUSG into care of actual peri-arrest patients should contend mostly with the patient plausibly in PEA where its benefit is most likely to present. An algorithmic approach to use of DUSG by EMS providers might prioritize its use for a patient whose initial or most recent pulse and rhythm check revealed apparent PEA. In following high-performance principles, a user should be trained to power on the unit, apply the lubricant/gel, and place the probe in its initial position while compressions are ongoing such that when the pause is called, only an A-P fanning scan need be performed. Additional protocolized guidance for actions to be taken in the case of identified pseudo-PEA should be provided.

Though it was not formally assessed in the structure of this research, rather was assumed reasonable as described in the methods, the results of this research imply feasibility of the A-P fanning technique of carotid DUSG as a method of employment for DUSG. This implication is limited in strength by the lack of comparison. It may also be that an entirely different form of DUSG technology would optimize the provided advantages while eliminating the drawbacks of clinician operation of the probe. Using a soft collar device to attach a doppler transducer puck device with a broader field of "listening" to the neck may have potential to provide immediate and high-quality "hands-off" feedback less susceptible to minor variations in position. A study looking at porcine models have shown promise with a similar device paired with computerized assessment of the produced signal capable of indicating status of pulselessness or return of spontaneous circulation (ROSC) to an Automated External Defibrillator, while another has shown promise using a doppler puck for feedback during compressions (Yu et al. 2008; Faldaas et al. 2024). Further research would be appropriate to compare undirected scanning efforts and/or alternative scan patterns, such as a posterolateral-to-anteromedial scan or a diverging circular scanning pattern, as well as hands-off probe technology.

With respect to the timed demonstrations, a comparison standard was not formally selected, though a reasonable comparison standard for discussion does exist as this research is centered around the peri-arrest victim. The commonly accepted time interval given for manual palpation of the pulse during a pause in, or in determining the necessity of, chest compressions for a peri-arrest patient is 10 seconds. The mean and median elapsed time to complete the timed demonstration does exceed 10s in the aggregate sample of both populations, as well as in each evaluated population. It should be noted that comparison is being made to a demonstration which includes tasks which could be completed before the pause window in actual clinical practice. During the timed trial, the participants were assigned to complete all the tasks necessary for DUSG, including the application of the lubricant/gel.

Given that this feasibility study does not compare two different interventional arms, it is not immediately apparent what standard against which to compare the data to establish "success" or "failure" of the training given to the participants. During planning, low participation rates and small sample size were considered likely, thus resulting in the choice to employ a convenience sampling strategy with no pre-set minimum. It is also assessed that use of documented sensitivity or specificity rates for manual palpation determined in a setting of actual uncertainty would be an inappropriate comparison for a trial in which DUSG is tested on obviously living volunteers. For this reason of absence of a meaningful available comparison, the data collected is descriptive rather than comparative in nature.

This research acknowledges that the small sample size and convenience sampling are technical limitations to the generalizability, as is the single point of determination of success by corroborative declaration of the evaluator. Additionally, there is no mechanism for blinding participants or the evaluator to the status of the volunteer simulated patient, who was absolutely known in all cases to have a pulse. These limitations were found to be impractical or impossible to mitigate without serious impact to feasibility.

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