Resuscitation 131 (2018) 69–73

Contents lists available at ScienceDirect

Resuscitation

journal homepage: www.elsevier.com/locate/resuscitation

Clinical paper

Implementation of the Cardiac Arrest Sonographic Assessment (CASA) protocol for patients with cardiac arrest is associated with shorter CPR pulse checks☆

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ARTICLE INFO

Keywords:
Cardiopulmonary resuscitation
Point-of-care ultrasound

ABSTRACT

Objective: We aim to evaluate whether implementation of the "Cardiac Arrest Sonographic Assessment" (CASA) protocol reduces the duration of interruptions in CPR during resuscitation of cardiac arrest (CA) compared to the pre-intervention period.
Methods: This was a quasi-experimental pre and post intervention study completed over 19 months in an urban Emergency Department. CA resuscitations were filmed and analyzed with respect to pulse check duration and use of point-of-care ultrasound (POCUS). After one year, an intervention was implemented: ED residents and faculty were taught the CASA protocol and instructed on how to implement it within CA resuscitation. The primary outcome was the difference in CPR pulse check duration between the pre and post intervention period. Videos from pre and post intervention CA resuscitations were coded by two reviewers.
Results: Data was collected prospectively for 267 sequential cardiac arrests. 38 pre-intervention and 45 post-intervention resuscitations were videoed and included in analysis. Both groups had a median of 3 pulse checks and 2 POCUS exams performed per code. CPR pulse checks involving POCUS exams were 4.0 s (95%CI 1.7–6.3) shorter in the post-intervention group than in the pre-intervention group. CPR pause durations were 3.1 s (95%CI 0.7–5.6) shorter when the ultrasound probe was placed on the chest before stopping CPR compared to placement after stopping CPR, and 3.1 s (95%CI 0.6–5.6) shorter when an ED ultrasound fellowship trained faculty was present compared to non-ultrasound fellowship faculty. The proportion of pulse checks with ultrasound use increased from 64% before the intervention to 80% after the intervention.
Conclusion: In this pre and post-intervention study, the implementation of a structured algorithm for ultrasound use during cardiac arrest significantly reduced the duration of CPR interruptions when ultrasound was performed.

Introduction

Management of patients with cardiac arrest (CA) with pulseless electrical activity (PEA) is primarily focused on the identification and treatment of reversible causes, and patients with non-shockable rhythms continue to have a poor prognosis. The American Heart Association recommends the use of point-of-care ultrasonography (POCUS) in CA, and many emergency physicians (EP) employ POCUS to evaluate for reversible causes of CA [1–5].

Point-of-care ultrasonography can be a powerful tool for detecting reversible causes of CA, and some studies have shown that the duration of ultrasound can be ≤10 s when performed by trained providers [4,6]. However, recent prospective cohort studies examining CPR pause duration, a more patient oriented outcome, found that CPR pauses involving the use of POCUS are significantly longer than pauses without the use of POCUS [7,8]. These findings are concerning given that maintaining high quality CPR is paramount for maximizing the likelihood of return of spontaneous circulation (ROSC) [9–11]. In an effort to reduce the length of CPR pauses involving POCUS, we developed and published the Cardiac Arrest Sonographic Assessment (CASA) protocol for ultrasound use during CA resuscitation for patients with non-shockable rhythms [12]. In this pre and post intervention study, we

☆ A Spanish translated version of the abstract of this article appears as Appendix in the final online version at https://doi.org/10.1016/j.resuscitation.2018.07.030.

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https://doi.org/10.1016/j.resuscitation.2018.07.030
Received 20 May 2018; Received in revised form 19 July 2018; Accepted 25 July 2018
0300-9572/

evaluated the effect that implementation of the CASA exam in a single emergency department (ED) had on the duration of CPR pulse checks in which POCUS was performed.

Methods

Study settings

We conducted a quasi-experimental, pre and post intervention study to evaluate if teaching emergency medicine residents and faculty the CASA protocol reduced CPR pause duration with ultrasound. This study was performed at an urban emergency department (ED) with a four-year emergency medicine residency program and an ED ultrasound fellowship. The ED has ~70,000 annual visits. The hospital's institutional review board approved this study.

Participants

All adult, non-trauma patients presenting with CA or experiencing CA in the ED were eligible. The pre-intervention period occurred from July 2016 to July 2017, and the post-intervention period occurred from September 2017 to January 2018. CASA protocol education occurred in August 2017. Exclusion criteria included traumatic arrests, patients with sustained ROSC prior to ED arrival, if no CPR pauses occurred, or if the resuscitation was not video recorded. CA resuscitation run by Physicians' Assistants (PA) were excluded because they did not participate in the CASA didactics. Cardiac arrest codes were included regardless of initial rhythm since we did not have access to the cardiac rhythm associated with each CPR pulse check.

Patients with CA were identified from a list of EMS "ring downs" for high acuity patients, triage ESI level 1 patients, documented chief complaints of "cardiac arrest", and final dispositions to morgue, ICU, or cardiac catheterization lab. In the pre-intervention period, two resuscitation rooms had video capability, and in the post-intervention period, four resuscitation rooms had video capability. Codes were recorded 24 h a day, 7 days a week, when turned on by a staff member. Videos of the resuscitations were stored in a secure hospital database.

Intervention

The CASA protocol is a three-step POCUS protocol that evaluates for reversible causes of CA from non-shockable rhythms and for cardiac activity [12]. Sequentially during the first three CPR pauses, the operator evaluates for cardiac tamponade (1st pause), pulmonary embolism (2nd pause), and cardiac activity (3rd pause). During CPR, the operator assesses for pneumothorax and hypovolemia (inferior vena cava [IVC] and FAST). The order of the protocol was chosen to mirror prevalence of the etiology. Evaluation of cardiac activity is the final step of the protocol, as prognostication based on cardiac standstill improves with longer cardiac arrest time [13,14]. In addition, we believe that pseudo-PEA would be easily visualized while evaluating for pericardial effusion in the first step. The protocol asks binary questions for each pause in an effort to simplify POCUS use. We purposefully chose to evaluate only one condition during each ultrasound because our initial data demonstrated that POCUS (and associated CPR pauses) frequently lasted longer than 10 s even in the hands of the most experienced ultrasonographers [7].

During August 2017, all residents and attendings were taught the CASA protocol in small group educational sessions. In addition, they received online handouts and monthly reminders of the protocol. The protocol was posted in the ED resuscitation bays. While encouraged, utilization of POCUS and the CASA protocol remained optional throughout the study period.

Study outcomes and measures

The primary outcome was the difference in CPR pulse check duration when POCUS was performed between the pre and post intervention periods. CPR pauses were defined as any interruption in CPR greater than 3 s after which CPR was resumed (excluding moments of obvious intermittent ROSC). CPR pulse checks included any CPR pause where palpation of the pulse was visible or recorded in nursing flow sheets.

For secondary outcomes, the pre and post intervention groups were evaluated for the difference in CPR pause duration without POCUS, the effect of ED ultrasound fellowship training, procedures (central venous access, intubation, tube thoracostomy, pericardiocentesis and arterial line), resident year, and placement of the ultrasound on the chest prior to stopping CPR. We also collected demographic data (age, sex, comorbidities) and code data (initial rhythm, whether the arrest was witnessed, and survival). Sustained ROSC was defined as ≥ 20 min of not requiring chest compressions to sustain circulation [15]. Survival with good neurological outcome was defined as a Cerebral Performance Category Scale score of 1 or 2 at discharge as determined by chart review. Survival data was abstracted by two reviewers and a Kappa statistic was calculated for good neurological outcome (CPC 1 & 2), poor neurological outcome (CPC 3 & 4), and death (CPC 5).

Data was collected on a standardized abstraction tool that was used during a previous study [7]. All study videos were reviewed by two reviewers and coded for CPR pause duration, reason(s) for pause, whether ultrasound was performed during the pause, automated compression device use, and procedures (intubation, tube thoracostomy, central venous access, and arterial line). All coding differences were rewatched for consensus.

Statistical analysis

We performed multivariable linear regression to evaluate the primary outcome. The dependent variable was CPR pulse check duration when ultrasound was performed. Independent variables included pre or post intervention period, attending ultrasound fellowship training, resident training year, if a procedure was performed, if the ultrasound was placed on the chest prior to stopping CPR, and if the same provider led the code and performed the ultrasound. These variables were included because they were previously demonstrated to be associated with or were postulated to be associated with CPR pause length. We used Newey-West standard errors to evaluate for trends in CPR pulse check duration within either study period or for any significant difference in trends between periods [16].

Patient and code characteristics and outcomes were reported as means, standard deviation (SD), medians, interquartile ranges (IQR), and percentages as appropriate. For normally distributed, continuous data, we used Student's *t*-tests, and for non-parametric continuous data, we used Mann-Whitney rank-sum. We used Fisher's exact test for categorical data. All analyses were performed in STATA 12 (StataCorp. 2011. *Stata Statistical Software: Release 12*. College Station, TX: StataCorp LP).

Our pre-intervention period included 100 CPR pulse checks in which POCUS was performed with a SD of 10 s (sec) and a mean duration of 19.8 s. We estimated that 100 CPR pulse checks with POCUS use with a SD of 10 s would provide 80% power with an alpha of 0.05 to detect a 4 s difference in CPR pulse checks duration with POCUS performed between the two periods.

Results

In the pre-intervention period, between July 2016 – July 2017, there were 129 non-traumatic CAs resuscitated in the ED, of which 38 were videotaped. In the post-intervention period, between September 2017 – January 2018, there were 47 non-traumatic CAs resuscitated in the ED of which 45 were videotaped (Fig. 1). Results for the first seven

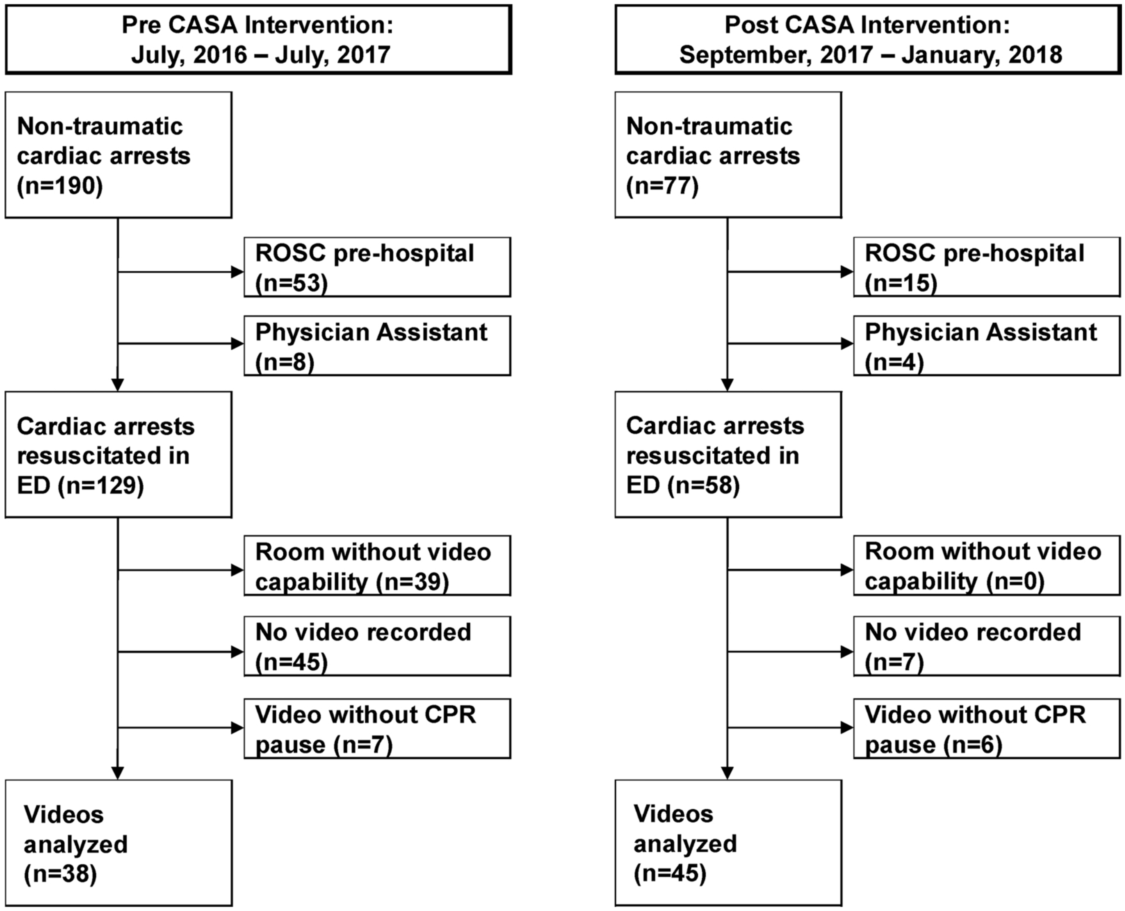

Fig. 1. Consort diagram of participants enrolled in the study.
ROSC: Return of spontaneous circulation.

months of the pre-intervention period (July 2016 to January 2017) were previously published [[7]].

The patients in both time periods were similar demographically and with respect to comorbidities. (Table 1). Both groups had a similar proportion of witnessed arrests and out of hospital cardiac arrest (OHCA). A significantly higher proportion of patients in the pre-CASA group, compared to the post-CASA group, had an initial shockable rhythm (26% vs 14%). Both groups had a median of 3 pulse checks and 2 POCUS exams performed per code.

Overall, CPR pulse checks involving POCUS in the pre-intervention period lasted 19.8 s (95%CI 17.9–21.7) and 15.8 (95%CI 14.4–17.2) in the post intervention period: a difference of 4.0 s (95%CI 1.7–6.3) after implementation of the CASA intervention (Table 2). In the multivariable linear regression, which accounted for resident year, any procedure performed during the pause, attending ultrasound fellowship training, and placement of ultrasound probe on the chest prior to pausing CPR, CPR pulse checks involving ultrasound were 3.3 s (95%CI 0.9–5.6) shorter in duration in the post-CASA period (Table 3). In the same multivariable analysis, attending ultrasound fellowship training and placement of ultrasound probe on patient prior to stopping CPR were associated with 3.1 s (95%CI 0.6–5.6) and 3.1 s (95%CI 0.7–5.6) shorter pauses, respectively. Neither resident year nor procedure performed was associated with pause duration. Automated compression device use was not associated with CPR pulse check length. There was no significant trend in the duration of pulse checks with ultrasound over time in the pre or post CASA periods or a significant difference between the two periods (Fig. 2). In the pre-intervention group, 10% of CPR pulse checks with ultrasound lasted ≤ 10 s compared to 19% in the post-intervention group ($p = 0.06$) (Fig. 3).

There was a 2.6 s (95%CI −1.2 to 6.4, $p = 0.18$), non-significant decrease in the duration of pulse checks without POCUS between the pre and post groups. After correcting for resident year, procedure performed, and attending ultrasound fellowship training, there was still no significant association between CASA intervention and CPR pulse check duration for pauses without ultrasound (Appendix Table 1).

In the pre-intervention period, 34% of patients achieved sustained ROSC compared to 43% in the post intervention period ($p = 0.2$). Survival to hospitalization occurred in 29% and 36% ($p = 0.3$) of patients in the pre and post intervention periods, respectively. Survival to discharge with a CPC score of 1 or 2 was present in 6.3% and 5.2% of the pre and post group, respectively. The Kappa statistic was 0.88 indicating "almost perfect agreement" [17].

Discussion

In this pre and post intervention study, we evaluated the effect of teaching the CASA exam to residents in an effort to decrease CPR pulse check duration when POCUS was used in CA with non-shockable rhythms. Introduction of the CASA protocol was associated with shorter CPR pauses involving POCUS (3.3 s in multivariable linear regression). A non-significant decrease in the duration of pulse checks without POCUS was also noted. We noted that the proportion of pulse checks with ultrasound that were ≤ 10 s in duration almost doubled from 10% to 19%. The decrease in pause duration both with and without ultrasound may in part be related to the Hawthorne effect–participants perform better because they are aware that they are being evaluated and not because of the intervention itself. However, in the pre-intervention period, providers were also aware that CA resuscitations were

Table 1
Patient and code characteristics of cardiac arrest codes with and without videos during the pre and post intervention periods.

	Pre-Intervention		Post-Intervention	
	Included Videos (n = 38)	All Codes (n = 129)	Included Videos (n = 45)	All Codes (n = 58)
Age, median (IQR)	63 (56–74)	64 (56–74)	66 (56.5–74)	65 (56–76)
Percent Female, (%)	36.8	38.0	40.5	43.1
Comorbidities, (%)				
HTN	47.2	52.8	60.6	61.2
DM	36.1	29.6	29.4	30.0
CAD	16.7	18.8	18.2	12.2
HLD	16.7	11.2	18.2	20.4
ESRD	13.9	10.4	21.2r	18.8
Initial rhythm, total (%)				
Non-shockable	65.8	70.5	83.3	82.8
Shockable	34.2	26.4	14.3	13.8
Missing EMS documentation	0.0	3.1	2.4	3.5
OHCA n (%)	97.4	86.8	88.1	86.2
Witnessed Cardiac Arrest %	69.4	60.4	63.9	65.9
Sustained ROSC in ED, n (%)	13 (34.1)	44 (34.1)	15 (33.3)	25 (43.1)
Survival to admission	10 (25.6)	37 (28.7)	12 (26.7)	21 (36.2)
CPC 1 or 2	2 (5.3)	8 (6.3)	2 (4.4)	3 (5.2)
Total CPR pauses, n	197		167	
Total pulse checks, n	160		140	
Total POCUS performed, n	100		110	
CPR pauses per code, median (IQR)	4 (2–6)		3 (2–5)	
Pulse checks per code, median (IQR)	3 (2–6)		3 (2–4)	
Number of CPR pauses with POCUS by code, median (IQR)	2 (1–4)		2 (1–4)	

HTN, hypertension; DM, diabetes mellitus; CAD, coronary artery disease; HLD, hyperlipidemia; ESRD, end stage renal disease; OHCA, out of hospital cardiac arrest; ROSC, return of spontaneous circulation; CPC, Cerebral Performance Score.

Table 2
Uncorrected CPR pulse check duration differences between the pre and post intervention groups.

	Pre (sec)	Post (sec)	Difference (sec)	p-value
CPR pulse check pause duration, mean (SE)[a]	18.1 (0.8)	15.1 (0.6)	3.0 (1.0–5.0)	0.003
CPR pulse check pause duration with POCUS, mean (SE)[b]	19.8 (1.0)	15.8 (0.7)	4.0 (1.7–6.3)	0.0008
CPR pulse check pause duration without POCUS, mean (SE)[c]	15.4 (1.0)	12.8 (0.7)	2.6 (−1.2 to 6.4)	0.18

[a] pre n = 160; post n = 140.
[b] pre n = 100; post n = 110.
[c] pre n = 60; post n = 30.

being recorded/evaluated since the provider initiated the video recording. This may somewhat mitigate the impact of the Hawthorne effect when comparing the two periods.

After the CASA protocol was introduced, the proportion of pulse checks with ultrasound use increased from 64% to 80%. It is possible that teaching providers the CASA protocol over-emphasized ultrasound use during CA and led to extra and possibly unnecessary POCUS use. It is also possible that the increase in POCUS is related to the increased proportion of codes with non-shockable rhythms in the post-intervention period. Additionally, data from this study (pre and post-intervention) and from Huis, et al. consistently show that pulse checks with ultrasound use are longer than those without ultrasound [7,8]. The aim of the CASA protocol is to limit POCUS use during CA resuscitations, and it may have had the unintended effect of increasing POCUS use and thereby decreasing the potential positive impact of the intervention. Our hope is that the use of the CASA protocol might ultimately decrease CPR pauses during CA resuscitations, by allowing providers to

Table 3
Multivariable linear regression analysis of predictors associated with CPR pause duration for pulse checks with ultrasound performed.

Predictor variable[a]	Coefficient (sec)	SE	p-value
Post intervention time period	−3.3	1.2	0.007
Resident year			
2	REF		
3	1.1	1.4	0.45
4	0.2	1.5	0.89
Attending	−3.0	4.0	0.45
Any procedure performed	1.9	1.8	0.28
Attending ultrasound fellowship trained	−3.1	1.3	0.02
Ultrasound on chest before CPR paused	−3.1	1.3	0.01

POCUS, point-of-care ultrasound.
Controlled for post intervention period, resident year, any procedure performed, and attending ultrasound fellowship training, and placement of ultrasound probe on chest prior to stopping CPR.
[a] Reference is “No” unless otherwise indicated.

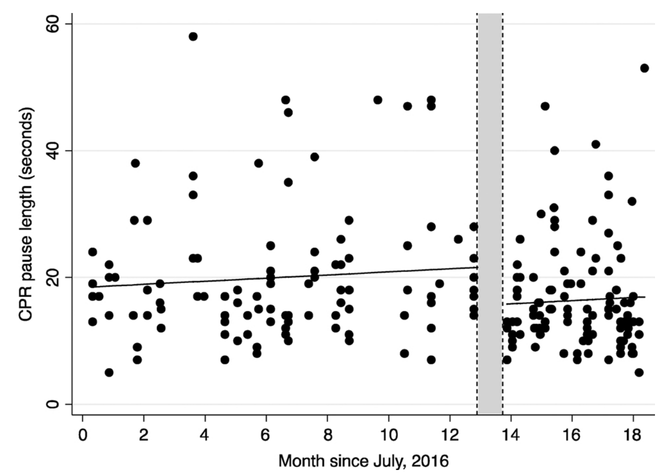

Fig. 2. Scatter plot of CPR pulse check durations with ultrasound performed before and after CASA implementation.
Pre-CASA intervention trend p = 0.56[A].
Post-CASA intervention trend p = 0.67[A].
Interaction term (time since study start * intervention) p = 0.86[A].
[A]Trends calculated with Newey-West standard errors.
Gray bar represents implementation of the CASA exam during August, 2017.

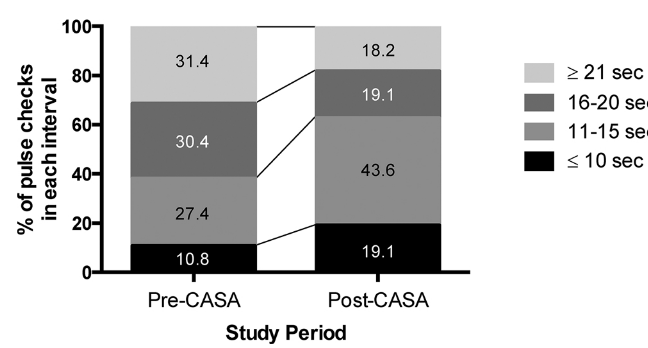

Fig. 3. Proportion of pauses ≤10 s, 11–15 seconds, 16–20 seconds, and ≥21 s by pre and post CASA intervention time periods.

efficiently identify reversible causes. Also, we hope that by simplifying the process of performing ultrasound during CA via a protocol driven approach, clinicians will reduce the need to perform ultrasound at each pulse check.

We noted that attending ultrasound fellowship training and placing the ultrasound probe on the chest before stopping CPR were associated with decreased pause duration. Attendings with additional ultrasound training likely interpret ultrasound views more quickly, and they may place more emphasis on the duration of pauses with ultrasound. When the ultrasound probe is placed on the chest prior to stopping CPR, the provider can find an appropriate echocardiographic window before the pause. A recent paper demonstrated that some echocardiogram views are still useful when CPR is ongoing [18]. This paper and the data from our study suggest that finding an appropriate view prior to halting CPR may shorten CPR pause duration. Contrary to the data that we previously published, when providers ran the resuscitation and performed their own ultrasounds, their pauses were not significantly longer.

While the introduction of the CASA protocol did not yield as substantial a decrease in pause times as we envisioned, we believe that it is still represents an important improvement particularly since the proportion of pulse checks ≤10 s almost doubled. Cardiac resuscitations are often complex and stressful clinical scenarios, particularly for residents in training or for providers working at facilities which rarely receive cardiac arrest patients. The CASA protocol provides a simplified, stepwise approach to defining reversible causes of cardiac arrest in an effort to reduce the clinician's cognitive effort during often stressful resuscitations, while emphasizing the importance of maintaining high quality CPR.

Recently, more attention has been paid to transesophageal echocardiography (TEE) use during CA resuscitation [19]. While there are benefits to TEE, including presumed shorter pulse check duration given improved views and ability to evaluate the quality of CPR in real time, there is little data on the topic. We are unfamiliar with evidence detailing the time needed to place a TEE probe during ongoing CPR, as well as if this can be accomplished in emergency departments where a single clinician runs the resuscitation. In light of this, continuing to reduce transthoracic echocardiography's (TTE)'s association with prolonged CPR pulse checks is paramount. In addition to following the CASA protocol to limit POCUS use, a 6-second video clip timer or a separate 6-second timer operated by the recorder could serve as an audible reminder to restart CPR. This allows for time to restart CPR and maintain pulse checks ≤ 10 s. In our anecdotal experience from viewing numerous resuscitations on video, a verbal countdown of 10 s often is inaccurate, leading to false reassurance and a prolonged CPR pause.

Limitations

This is a pre and post intervention study that was not randomized. Thus, our findings may be subject to be residual confounding. We are not aware of other interventions to improve cardiac arrest resuscitation during this study period, but there may have been temporal changes in practice patterns for which we did not account. The study was unblinded and it is impossible to know what proportion of the findings are related to a Hawthorne effect, and what proportion is related to the intervention. We were unable to correlate POCUS video clips to CPR pulse checks, so there was no way to ensure that residents were performing the protocol in the prescribed order.

Conclusion

In this pre and post intervention study, we found that placing the ultrasound on the chest prior to stopping CPR, having an attending with ED ultrasound fellowship training, and implementing the CASA protocol were associated with significantly shorter CPR pulse checks. Even with the CASA protocol, ultrasound use is still associated with longer CPR pulse checks, and continued investigation is needed to determine the best use of ultrasound during cardiac arrest.

Funding sources/disclosures

None.

Prior Presentations

Preliminary results were presented at SAEM 2018.

Conflicts of interest

There are no conflicts of interest to disclose.

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