# Focused Cardiac Ultrasound in Out of Hospital Cardiac Arrest: A Literature Review


## Abstract

Focused Cardiac Ultrasound (FoCUS) is emerging in emergency medical systems, particularly in the context of prognostication in out of hospital cardiac arrest (OHCA). However, FoCUS has not been formally incorporated into UK guidelines due to a lack of evidence. Furthermore, concerns have been raised regarding the distraction FoCUS can have on other essential and evidenced elements of care. This broad literature search aims to shed light on the practice of FoCUS in cardiac arrest by reviewing articles related to in-hospital and out of hospital practice. The findings are conspicuous by the lack of high-quality studies, particularly regarding prognostication. Association between ultrasound findings and outcome are asserted as is the feasibility of paramedic use of FoCUS, although the evidence is from small and non-randomised studies and subject to bias.


## Introduction

Although prehospital Focused Cardiac Ultrasound (FoCUS) is becoming increasingly available to emergency medical services (EMS) in the UK and worldwide, there are concerns about the quality of evidence justifying its use. UK guidelines (Resuscitation Council (UK), 2015) state that when available, FoCUS may be of benefit in identifying resuscitations associated with the identification of poor cardiac contractility indicative of poor survival. However, this diagnostic skill has not yet been incorporated into prehospital guidelines largely due to the paucity of high-quality evidence (Quinn and Price, 2017). Indeed, following a more recent systematic review, numerous knowledge gaps and low certainty of evidence for using ultrasound in cardiac arrest has been highlighted (Reynolds, Issa and Nicholson et al., 2020).

It has been recognised that intra-arrest ultrasound can detract from other essential elements of care, especially high-quality chest compressions (Gardner et al., 2017). Deakin and Koster (2016) highlight the significance of chest compression pauses being associated with decreased chances of survival. Recently the European Society of Cardiology produced a position statement on handheld ultrasound devices (HUD) for FoCUS (Cardim et al., 2019). Limitations concerning the ability to make quantifiable assertions with HUDs are asserted. They also highlight the need for specific training in using these devices and education in image acquisition and interpretation. However, they do acknowledge potential use in prehospital and emergency settings within their recommendations.

It is important that the current literature regarding FoCUS is appreciated in order to help evaluate this emerging component of out of hospital cardiac arrest (OHCA) care and guide future research. A literature search was conducted with the aim of informing the subject area through critical appraisal and synthesis of the current body of knowledge.

## Methods

Although the use of ultrasound is well established within hospitals it did not emerge into the prehospital environment until the 1990's in the USA. Furthermore, paramedic use of ultrasound has only arisen in the past seven years, and mostly in physician led systems (Walker, 2017). This awareness informed a strategy to search inclusively for literature related to ultrasound use in cardiac arrest from both in and out of hospital settings, and not limited to paramedic practice. Although a systematic approach was adopted, the search falls short of a systematic review. However, during the literature search the principles of critical appraisal were applied (CASP, 2019).

The search strategy of databases and key findings are summarised in table 1 of the results. The date ranges were chosen to capture results from 2010 (up to 2018), thereby ensuring a more contemporaneous search. 'Any Field' was selected to mitigate for non-specific titles or abstracts in the assumption that the terms used in this search would likely appear somewhere within the article. In addition to studies – editorials, opinion pieces and guidelines were included to facilitate a hand search of references.

The primary filtering of results involved excluding articles based on title. Secondary filtering involved exclusion/inclusion after reading abstracts (or whole articles in the case of short editorials and commentary). Articles were chosen based on their likely relevance to the area concerning the use of FoCUS or POCUS (Point of Care Ultrasound) in cardiac arrest.

## Results

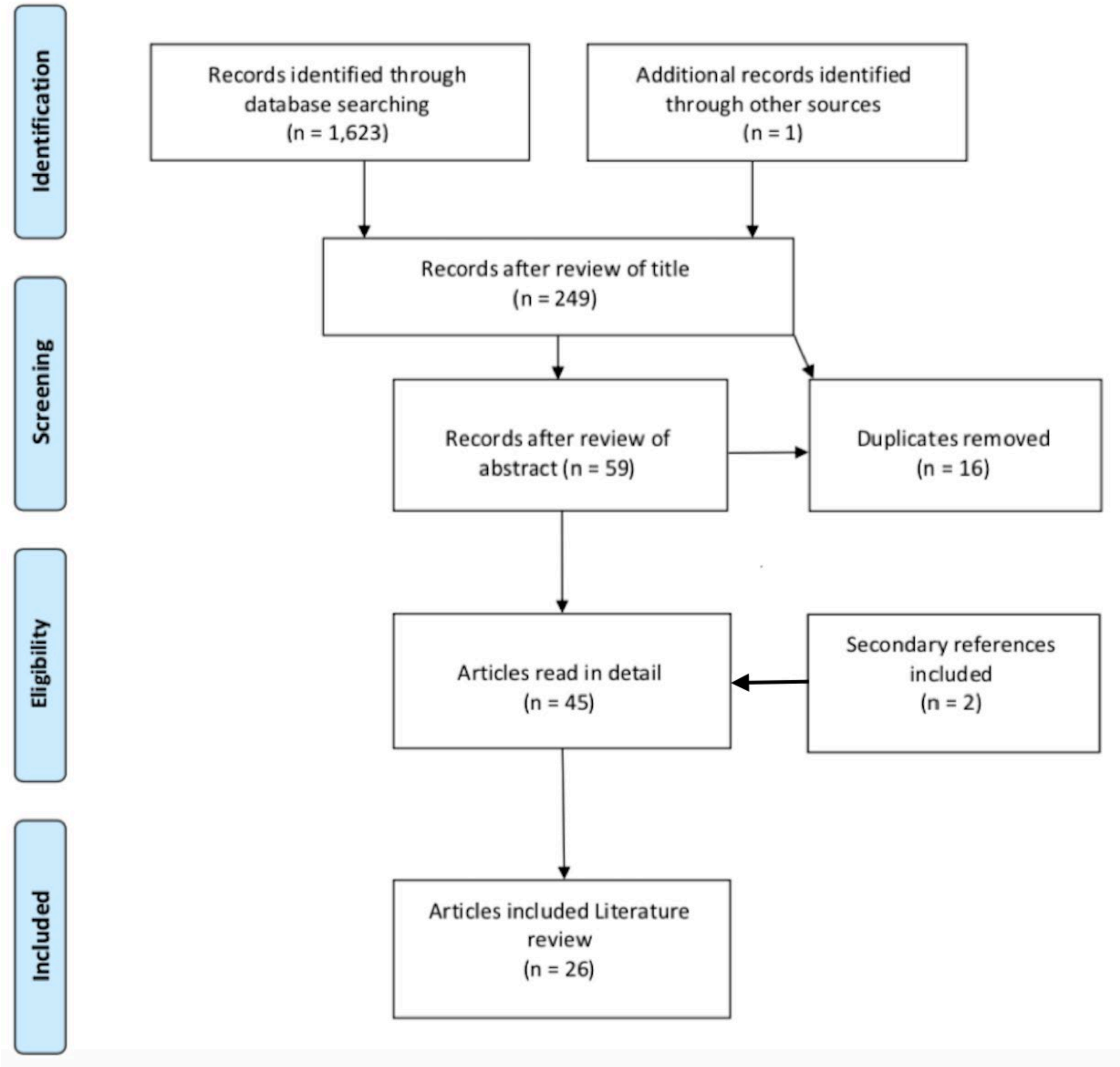
After secondary referencing, forty-seven articles were acquired and read in detail. A final figure of 26 articles were identified as being relevant to paramedic use of FoCUS in OHCA. This process is summarised in figure 1. After full text reading of included articles, it became apparent there were three clear themes emerging from the literature: Prognostication, Feasibility and Interruption.

Table 1 – Literature Search Strategy and Findings

| **Search Terms/ Search Engine** | **Hunter** | **PubMed** | **Science Direct** | **Cochrane** | **CINAHL** |
|---|---|---|---|---|---|
| **‘Cardiac Arrest’ AND ‘Ultrasound’** | 4,272* | 2,590* | 130 | 39 | 137 |
| **‘Cardiac Arrest’ AND ‘POCUS’** | 97 | 20 | 73 | 0 | 12 |
| **‘Cardiac Arrest’ AND ‘POCUS’ AND ‘Paramedic’** | 8 | 1 | 10 | 0 | 0 |
| **‘Cardiac Arrest’ AND ‘Prehospital’ AND ‘Ultrasound’** | 327 | 45 | 474 | 1 | 9 |
| **‘Cardiac Arrest’ AND ‘Focused Echocardiography’** | 11 | 57 | 2,218* | 8 | 10 |
| **‘Cardiac Arrest’ AND ‘Focused Echocardiography’ AND ‘prehospital’** | 23 | 4 | 125 | 0 | 2 |

* indicates that these article references were not searched due to the high numbers deemed unmanageable and very likely diluted in terms of relevancy

Figure 1 – Flow Chart



## Discussion

Prognostication

In their current Adult ALS Guidelines, the Resuscitation Council (UK) (2015) states that although no studies have demonstrated improved outcome, the absence of spontaneous cardiac motion (SCM) on ultrasound exam is highly predictive of death. Although all four references are older than a decade there has been more recent investigation.

Tsou et al. (2017) conducted a meta-analysis investigating POCUS in assessing short term survival of 1695 patients in cardiac arrest over 15 studies. The authors concluded that echocardiography was effective in identifying reversible causes and identifying patients with a low likelihood of survival by noting the absence of SCM. However, many of the studies included were descriptive and small and the lack of case/control studies reflects the dearth of higher-level evidence. Indeed, all studies used cohort sampling and four were retrospective. Heterogeneity marked much of the evidence base with five different FoCUS protocol approaches used and a variation in ultrasound array setting. Ten of the 15 studies were in-hospital and operator designation and skill varied, raising concerns regarding (unreported) inter-rater reliability and making comparison to paramedic practice difficult.

Despite the limitations, the authors highlight consistency between all but one study (with less stringent criteria) in terms of the predictive outcome of no SCM. The authors state that this systematic review is the largest to that date with three times as many patients involved as Blyth et al. (2012). They report likelihood ratios of 0.06, 95% CI: 0.01-0.39 for return of spontaneous circulation (ROSC) and 0.13, 95% CI: 0.07-0.24 for hospital admission in the absence of SCM, and that no SCM on FoCUS is therefore predictive of failure of resuscitation.

Not included in the Tsou et al. (2017) meta-analysis was work by Gaspari et al. (2016). This was a large USA based multi-centre, prospective, single-protocol driven observational study involving six geographical regions, 20 study sites and 793 patients. Patients were enrolled if they presented to the emergency department (ED) with an OHCA or in-ED arrest and were found to be in PEA or asystole. FoCUS was carried out at the beginning of ALS once in the ED and at the end of resuscitation without interruption of CPR. SCM was the variable most associated with survival although 3 patients (0.6%) survived to hospital discharge despite no SCM.

Although the methodology involved convenience sampling and no randomisation took place, study design was uniform across multiple sites with a large sample size. Additionally, ROSC was not the sole end point and as such hospital admission and discharge were also included. However, long term outcomes and quality of life measures were not reported. Of further note is the fact that treating physicians were not blinded to the ultrasound findings which raises the potential question of predictive bias related to decision making, although somewhat mitigated by the exclusion of resuscitations less than five minutes in duration.

Other studies have arrived at similar findings. Ozen (2016) in a prospective single centre study in Turkey involving 129 patients, concluded that no cardiac arrest patient without SCM survived, whereas 58% of patients with SCM attained ROSC. The sample included male and female patients who had suffered a cardiac arrest both in and out of hospital with no statistically significant difference in outcome observed. Again, treating physicians varied in terms of training and competence in ultrasound. Furthermore, the ultrasound findings were not scrutinised independently. Interestingly, VT and VF rhythms were included raising concerns regarding the impact on prompt defibrillation and non-interruption of CPR. Significantly, there is no data specifying the duration of resuscitation attempts and at what point FoCUS was undertaken. The longer a patient stays in cardiac arrest the poorer the prognosis (Daya, 2015). FoCUS carried out early will likely result in a higher incidence of SCM. The reverse would seem reasonable if FoCUS is acquired later. Indeed, Andersen, Grossestreuer and Donnino (2018) refer to this phenomenon as ‘resuscitation time bias’ in observational studies involving cardiac arrest.

Kim et al. (2016) conducted a prospective observational study evaluating the correlation between serial echocardiography findings and ROSC in adult OHCA patients. In this Korean study, forty-eight OHCAs (from suspected cardiac aetiology) were included on arrival at the ED. No patients without SCM after ten minutes of arrival survived. The timeline is laid out clearly in the study report and includes average call time to ambulance arrival (7.3 mins) and ED arrival (22.5 mins), bystander CPR (13/48), witnessed arrest (30/48) and initial rhythms (PEA=8, Asystole=39, VF/VT=1). FoCUS was performed during each two-minute rhythm check from arrival at ED for a duration of less than ten seconds. An experienced emergency medicine specialist undertook FoCUS and recorded images which were reviewed later. Treating physicians were not blinded, again raising concerns of predictive bias in decisions to cease resuscitation. Although the authors state usual ALS guidelines were followed, there is no specific protocol described. Indeed, it may vary from UK practice use of European Resuscitation Guidelines (Sour et al. 2015).

Feasibility

Within the Scottish out of hospital environment Reed et al. (2017) reported that although improvements could be made, specialist critical care paramedics with minimal classroom training could successfully use portable ultrasound to inform decisions to stop futile resuscitations. The training is described by Booth et al. (2015) and involved ultrasound trained emergency physicians teaching 11 rapid response unit resuscitation paramedics over one day. Participating paramedics receive advanced training and are targeted specifically to OHCA patients.

Knowledge and practical skills improved from a baseline taken before training. However, after 10 weeks objective measures revealed a significant drop in competence. The opportunity for prehospital consolidation of skills within the 10-week period was not reported.

Prior to data collection for the study paramedics received supervised practice in the field before being ‘passed’ to practice FoCUS independently, although ‘pass’ criteria are not specified. The study reports that in 30/44 (68%) of first attempts paramedics were able to achieve at least a ‘satisfactory’ image, with 8/13 (62%) in repeated attempts. All scans were reviewed by a blinded researcher, although their qualifications are unknown. Additionally, the grading’s are not explained and seem subjective. The overall numbers are small and the video cameras worn to facilitate verification suffered technical difficulties resulting in missing data. However, the study is both unique and relevant in its area of focus and investigation.

Paramedic use of ultrasound in the prehospital setting was examined by Brooke, Walton and Scutt (2010). In a structured review they sought to identify relevant clinical trials, although concluded that most literature identified was expert opinion only and at high risk of bias. Only four primary sources were identified and all are characterised by their small numbers, publication beyond a decade ago, inclusion of both paramedic and non-paramedic groups and based outside the UK.

It is noteworthy that none of the articles in the Brooke, Walton and Scutt (2010) review focused specifically on FoCUS but rather a range of thoracic and abdominal examinations. The authors concluded that given the right education and mentorship, paramedic ultrasound was feasible in order to identify catastrophic pathologies. Despite hypothesising that paramedics may need more training due to lack of anatomical knowledge compared to physicians, they state that training could be as short as a day with 50 formal assessments. Although this assertion seems to fit with established CORE ultrasound training (Royal College of Physicians, 2019), it seems to be drawn from a separate reference (Shackford et al., 1999) cited within the paper, rather than a direct conclusion from the findings.

Contrasting findings were observed in two papers explicitly examining feasibility of paramedic ultrasound. Each involved training 20 paramedics with no previous ultrasound experience in different EMS systems in the USA using the PAUSE (Prehospital Assessment with Ultrasound for Emergencies) protocol. Training lasted three hours followed by short practical experience. On testing, Chin et al. (2013) reported that 19/20 paramedics achieved greater than four out of six on a Cardiac Ultrasound Structural Assessment Scale for image acquisition, with a mean interpretation test score of 9.1 out of 10 (95% CI 8.6-9.6). However, Rooney et al. (2016) found that following training only four out of 20 paramedics managed to cross a threshold of an 80% pass rate in a written exam. This raises questions about the efficacy of training between these two paramedic groups and how comparable the paramedics are in terms of prior competence and baseline knowledge.

Rooney et al. (2016) went on to investigate the ability of the four paramedics to acquire images in the prehospital environment. Seventeen of 19 FoCUS examinations were deemed adequate. With low numbers it is hard to draw any conclusions relating to other EMS providers in this or another system. Patient numbers (n=19) were also very low and it is not clear whether this was related to opportunities to undertake ultrasound, the willingness of paramedics or strict protocol. Also, the 17 successful examinations were not undertaken during cardiac arrest but in conditions listed as; dyspnoea, chest pain, trauma and unconsciousness, rather than OHCA FoCUS.

Nevertheless, these two small studies provide limited support to earlier findings of Heegaard et al. (2010) who reported that paramedics with similar levels of training can obtain and interpret ultrasound images. In this case, with reported 100% agreement of a blinded emergency physician who retrospectively reviewed data from 104 patients, although interrater reliability was not reported. Despite the challenges of the out of hospital environment, accuracy of basic image interpretation was maintained. A contributing factor may have been that unlike paramedics reported by Rooney et al. (2016), the 25 paramedics in this study all had refresher training at three and eight months into the study period, although in 7.7% (8/104) of patients, paramedics could not obtain any view, with no reasons for this reported.

Overall, 13 of the 26 papers reviewed refer to the subcostal (SC) probe position being used to gain images, but nowhere is there direct correlation between the probe position used and the speed of image acquisition and its quality. In the review by Tsou et al. (2017) nine of their 15 studies cite the SC view as the primary ‘window’ used with a further five studies using a protocol that includes the SC view. The remaining study did not specify any ultrasound window.

None of the literature in this review focused on costs of training, equipment or governance. However, in the overall assessment of feasibility of paramedic use of HUDs, these factors would need consideration.

Interruption

The Resuscitation (UK) 2015 Adult ALS Guidelines specifies that FoCUS should be carried out within the 10 second rhythm and pulse check windows. This well-reasoned restriction has implications for interpreting results.

Reed et al. (2017) report that only 4/9 (44%) of views obtained by paramedics were within the 10 second pulse check window with a median time off the chest of 17 seconds (IQR 13-20). However, this data is somewhat confounded by technical video recording issues, with incomplete data for the 45 patients scanned. In addition, within the rhythm check window the ECG monitor was only checked in 38% of viewable cases (3/8) and a pulse check carried out in only 22% of viewable cases (2/9). As the study was not randomised there is no comparison to standard care and therefore a high risk of bias.

An investigation that did make comparisons in chest compression pauses between CPR with and without FoCUS was conducted by Clattenburg et al. (2018). The study involved analysing 110 pauses across 24 patients in a prospective single centre cohort study of patients presenting to an ED from OHCA. Similar to Reed et al. (2017) the median chest compression pause was 19.3 seconds (95%CI 15.5-22.0) with FoCUS. They were 14.2 seconds (95%CI 11.1-17.4) without FoCUS. A further reduction of 3.9 seconds (95%CI -8.4-0.7) was reported when ultrasound fellowship trained faculty undertook the procedure. Increased pauses were associated with the ultrasound user being the resuscitation team leader, suggesting a cognitive bandwidth issue with no one to oversee and address extended FoCUS time. Although there is uniformity in results and pauses seem to be distributed amongst all patients, the single study site and small numbers limit generalisability.

Huis et al. (2017) reported similar conclusions from their prospective, single-centre, USA based, in-hospital cohort study involving the videoing of 23 cardiac arrest patients and 123 CPR pauses that averaged a mean of 21 seconds with FoCUS and 13 seconds without FoCUS. The study has similar limitations to Clattenburg et al. (2018). Additionally, no detail is provided regarding the skill level of the operator. Interestingly in neither study are indications for FoCUS clearly stated. It is possible that other ultrasound related examinations were being undertaken instead of or in addition to identifying SCM during PEA arrest. Using multiple probe positions could also explain the prolonged chest compression pauses.

In a 23-month prospective single centre study in Denmark, Aagaard et al. (2017) analysed ultrasound images taken by physicians with basic training in 60 patients undergoing ALS. Images were only accepted if the following characteristics could be subsequently determined by expert echo-cardiographers:

1. Right ventricle larger than the left

2. Pericardial fluid

3. Collapsing ventricles

These criteria were met in 72% of patients, but it is not clear how the standards were derived. Indeed, the authors indicate the uniqueness of their study, stating that no prior standard had been set. They conclude that image quality was improved when FoCUS was undertaken during rhythm analysis (67% of 102 images) and ventilations (64% of 103 images) rather than during chest compressions (47% of 160 images). Although this finding could have implications for keeping FoCUS within guideline recommended pauses in chest compressions, the threshold for image quality is very high in this study and differs from the standards of FoCUS practice found in other systems. Significantly, chest compression pauses were not quantified against achieving this new imaging standard.

Of final note in this study is the sole use of the lower SC probe position, thus avoiding the need to access the anterior chest wall during or between active chest compressions. This is arguably important considering the amount of activity surrounding the head and chest of cardiac arrest patients and the need to apply ultrasound gel the skin, both of which may impact on timely resumption of chest compressions.

## Conclusion

There is a growing body of low-quality evidence for the association of no SCM with a poor prognosis in cardiac arrest. Studies concerned with the feasibility of FoCUS undertaken by paramedics in OHCA are small, non-randomised and subject to bias. Evidence for FoCUS comes predominantly from in-hospital settings and physician practice and therefore generalisability to the pre-hospital environment is problematic. Despite obvious weaknesses in the studies reviewed, the risk of prolonged pauses in chest compressions during FoCUS does seem plausible in both hospital and prehospital settings. This is of significant concern when considering their importance to the survivability of OHCA (Deakin and Koster, 2016).

The challenges of undertaking randomised clinical trials involving cardiac arrest patients has been highlighted (Andersen, Grossestreuer and Donnino, 2018). However, in order to better inform guidelines, robust trials need to be undertaken to address the dearth of high-quality literature around the validity of FoCUS to prognosticate in cardiac arrest and feasibility of safe paramedic use in the prehospital setting.

## References


Aargaard, R. et al. (2018) 'Timing of focused cardiac ultrasound during advanced life support – A prospective clinical study', Resuscitation 124, pp. 126-131.

Andersen, L., Grossestreuer, A. and Donnino, M. (2018) 'Resuscitation time bias—A unique challenge for observational cardiac arrest research', Resuscitation 125, pp. 79-82.

Blyth, L. et al. (2012) 'Bedside focused echocardiography as predictor of survival in cardiac arrest patients: a systematic review', Academic Emergency Medicine 2012 (19), pp. 1119–2116.

Booth, K. et al. (2015) 'Training paramedics in focussed echo in life support', European Journal of Emergency Medicine 22 (6), pp. 430-435.

Brooke, M., Watson, J. and Scutt, D. (2010) 'Paramedic application of ultrasound in the management of patients in the prehospital setting: a review of the literature', Emergency Medical Journal 2010 (27), pp. 702-707.

Cardim, N. et al. (2019) 'The use of handheld ultrasound devices: a position statement of the European Association of Cardiovascular Imaging (2018 update)', European Heart Journal 20, pp. 245-252.

Chin, E. et al. (2013) 'A pilot study examining the variability of prehospital assessment with ultrasound for emergencies (PAUSE) protocol', The journal of Emergency Medicine 44 (1), pp. 142-149.

Clattenburg, E. et al. (2018) 'Point-of-care ultrasound use in patients with cardiac arrest is associated prolonged cardiopulmonary resuscitation pauses: A prospective cohort study', Resuscitation 122, pp. 65-68.

Critical Skills Appraisal Programme (2019). CASP Checklists. Available at: https://casp-uk.net/casp-tools-checklists/ (Accessed: 13 August 2019).

Daya, M. (2015) 'Out-of-hospital cardiac arrest survival improving over time: Results from the Resuscitation Outcomes Consortium (ROC)', Resuscitation 91, pp. 108-115.

Deakin, C. and Koster, R. (2016) Chest Compression Pauses during Defibrillation Attempts, Current Opinions in Critical Care 22(3) pp. 206-211

Gardner, K. et al. (2017) The Cardiac Arrest Sonographic Assessment (CASA) exam – A standardized approach to the use of ultrasound in PEA. Available at: http://dx.doi.org/10.1016/j.ajem.2017.08.052 (Accessed: 13 August 2019).

Gaspari, et al. (2016) 'Emergency department point-of-care ultrasound in out-of-hospital and in-ED cardiac arrest', Resuscitation 109, pp. 33-39.

Heegaard, W et al. (2010) 'Prehospital Ultrasound by Paramedics: Results of Field Trial', Academical Emergency Medicine 17 (6) pp. 624-630

Huis in 't Veld, M. (2017) 'Ultrasound use during cardiopulmonary resuscitation is associated with delays in chest compressions', Resuscitation 119, pp. 95-98.

Kim, H. et al. (2016) 'Can serial focussed echocardiographic evaluation in life support (FEEL) predict resuscitation outcome or termination of resuscitation (TOR)? A pilot study', Resuscitation 101, pp. 21-26.

Ozen et al. (2016) ‘Assessment of ventricular wall motion with focused echocardiography during cardiac arrest to predict survival’, Turkish Journal of Emergency Medicine 16, pp. 12-16.

Quinn, T. and Price, S. (2017) ‘Where do we go with PoCUS?’, Resuscitation 112, pp. A1-A2

Reed, M. et al (2017) ‘Introduction of paramedic led Echo in Life Support into the pre-hospital environment: The PUCA study’, Resuscitation 112, pp. 65-69.

Resuscitation Council (UK) 2015 Adult Advanced Life Support Guidelines 2015. Available at: https://www.resus.org.uk/resuscitation-guidelines/adult-advanced-life-support/ (Accessed: 13 August 2019).

Reynolds, J. et al. (2020) Prognostication with point-of-care echocardiography during cardiac arrest: A systematic review, Resuscitation 152 (2020), pp. 56-68

Rooney, K. et al. (2016) ‘Pre-hospital assessment with ultrasound in emergencies: implementation in the field’, World Journal of Emergency Medicine 7 (2), pp. 117-123.

Royal College of Physicians (2019) Ultrasound Training. Available at: https://www.rcem.ac.uk/RCEM/Exams_Training/UK_Trainees/Ultrasound_Training/RCEM/Exams_Training/UK_Trainees/Ultrasound_Training.aspx (Accessed: 13 August 2019).

Shackford, S. et al. (1999) ‘Focused abdominal sonogram for trauma: the learning curve of non-radiologist clinicians in detecting hemoperitoneum’, Journal of Trauma 46, pp 553-562.

Sour, J. et al. (2015) ‘European Resuscitation Council Guidelines for Resuscitation 2015, Section 3. Adult advanced life support’, Resuscitation 95, pp. 100-147.

Tsou, P. et al. (2017) ‘Accuracy of point-of-care focused echocardiography in predicting outcome of resuscitation in cardiac arrest patients: A systematic review and meta-analysis’, Resuscitation 114, pp. 92-99.

Walker, E. (2017) ‘Ultrasound: A potential new approach for cardiac arrest management’, Journal of Paramedic Practice 9 (3), pp. 103-107.