Training paramedics in focussed echo in life support

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Objectives The aim of this study was to determine whether paramedics can be trained to perform and interpret focussed Echo in Life Support (ELS) for the assessment of cardiac movement and the recognition of reversible causes of cardiac arrest.

Methods This study is a prospective observational pilot study. Data were collected during a 1-day course training 11 paramedics to perform ELS scans on healthy volunteers. The students were assessed on image acquisition skills and theoretical knowledge (including interpretation). Level 1 ultrasound-trained emergency medicine physicians undertook the training and assessment.

Results All paramedics could obtain images in the parasternal and subxiphoid views. When performing scans in the 10-s pulse check window, 88% of attempts in both views were successful (subxiphoid mean image quality 3.8 out of 5, parasternal 4.0). Theoretical knowledge improved (mean precourse score 54%, postcourse score 89%; $P<0.001$). There was no apparent association between theoretical and practical performances. At 10 weeks, theoretical knowledge was nonsignificantly reduced (82%; $P=0.13$) but less when compared with practical performance (75% subxiphoid success, mean quality 3.0; 25% parasternal success, mean quality 4.0).

Conclusion Paramedics can perform focused ELS, integrate attempts into simulated cardiac arrest scenarios and retain some of this knowledge. Further work is required to assess the feasibility of incorporating this into real-world cardiac arrest management. *European Journal of Emergency Medicine* 00:000–000 Copyright © 2015 Wolters Kluwer Health, Inc. All rights reserved.

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Introduction

There are an estimated 60 000 out-of-hospital cardiac arrests (OHCAs) annually in the UK, with a survival rate to hospital discharge of around 5–10% [1–3]. Although 70–85% of cardiac arrests (CAs) have a cardiac cause, the prognosis is extremely heterogeneous [3]. Patients with a witnessed arrest, in which there is a ventricular arrythmia, have a survival rate of 30% [3], whereas circulation is restored in just 2% of those with no detectable ventricular wall movement [4]. Therefore, distinguishing between subgroups of CA patients can guide resuscitation efforts and help identify patients in whom aggressive resuscitation attempts are more likely to be successful [5]. The treatment of asystole and pulseless electrical activity relies upon identifying the cause of CA, which involves screening for reversible conditions: the four 'T's' [tension pneumothorax, thrombosis (cardiac or pulmonary), cardiac tamponade and toxins] and the four 'H's' (hypothermia, hypovolaemia, hypoxia and hypo/hyperkalaemia or other metabolic causes) [6]. Ultrasound scanning can provide real-time information about cardiac function and be a part of the clinical examination to screen for these reversible causes.

Focussed echocardiography in life support (ELS) is a bedside screening tool commonly used in the Emergency Department (ED) [4]. It is a noninvasive, quick and easy examination that can provide ongoing information about a patient's condition and is well established in the European system of physician-led prehospital care [7]. Critically, it can provide information related to a reversible aetiology for CA or identify the presence of subtle cardiac function when a pulse is not detected. Ultrasound can be performed at the bedside, providing real-time information without interrupting resuscitation efforts [5]. Images taken in the prehospital setting could be transmitted to the receiving ED, providing clearer clinical information before the patient arrives [8].

However, there are drawbacks to the use of ultrasound. It is a user-dependent technique and relies upon an operator's ability to capture and interpret images [7]. In the context of a CA, ultrasound has a very narrow window of use and must be performed in the 10-s pulse check to ensure that chest compressions are not interrupted [6]. In addition, the use of prehospital ultrasound could delay

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Table 1 A summary of key characteristics, findings and limitations of previous studies in this area

References	Location	Study type and aims	Population trained	Key findings	Study limitations
Taylor *et al.* [8]	USA and Canada	Cross-sectional survey Aim: describe the use of ultrasound in North American EMS	Survey of 222 EMS directors	4% of EMS providers use ultrasound. 50% of these use paramedics, 63% physicians, 13% paramedics/nurses with further training, 13% rescue medics	Selection bias: 30% recall rate (voluntary response bias: more likely to respond if they had invested in the topic – that is, already used ultrasound). Small sample size of those using ultrasound (9 centres)
Chin *et al.* [13]	USA	Prospective, educational interventional study Aim: to determine whether prehospital care providers can learn ultrasound	20 emergency medical technicians from the fire department. Scanned human models	2-h training session plus assessment. Mean image interpretation score was 91%. Able to perform protocol and recognize pneumothorax, pericardial effusion and cardiac standstill. Struggled most in recognition of cardiac standstill. 16/20 attained views of the heart in < 10 s. No association between image acquisition and image recognition scores	Training programme, not applied to resuscitation practice. Assessment of prerecorded high quality images, not those produced by the paramedics. No assessment of skills retention. Classroom setting. All these aspects reduce external validity
Heegaard *et al.* [14]	USA	Case study	Paramedic. Scanned a 41-year-old male stabbing victim	Identified a pericardial effusion on ultrasound, which altered decision making (immediate transportation). Took less than 1 min to obtain and facilitated immediate treatment on arrival	Case study
Heegaard *et al.* [15]	USA	Prospective observational study Aim: to determine whether paramedics could be trained to perform ultrasound in prehospital environment	40 paramedics trained, 104 patients had scans undertaken	6 h training session with ongoing refresher education. Unable to obtain adequate images in 7.7% of attempts. Of those with adequate views, 100% agreement between paramedics and reviewing sonographers. All performed during transportation and did not increase transfer time	High risk of selection bias with prospective convenience selection (nonrandomized). Fairly high dropout rate (38%) over training and follow-up period, with no analysis of those lost to follow-up. Excluded patients who were too unstable to avoid risk of neglect of other care delivery (selection bias). Selection bias of paramedics (volunteered: high-motivation group)
Backlund *et al.* [16]	USA	Prospective observational study Aim: assess the ability of basic life supporters to be educated to perform ultrasound to assess cardiac activity	12 Army National Guard health care specialists performed 48 scans on four volunteers	5-min lecture + hands on training + practice (total = 4 h). 92% were able to visualize 'partial ventricle' or better (sufficient to assess for movement). Median time to completion: 5.5 s (IQR 3.7–10.9)	Does not assess their ability to interpret images. Very basic training limiting external validity. Selection bias, as the guards volunteered. Healthy volunteers, so extrapolation to cardiac arrest situations may be limited, and it was not a sample representative of the population
Garrett *et al.* [10]	USA	Prospective observational study Aim: assess whether ultrasound during patient transport and sending to receiving hospital for interpretation are feasible	Technician-performed, physician-guided ultrasound. 32 scans on 11 volunteers	Ultrasound performed by EMS technicians during transit, images obtained within 3–5 min and transmitted for cardiologist interpretation. Successful transmission in 88% of images. 66% of technician-performed scans were equivalent in terms of interpretability to their physician conducted equivalents	Accompanied by a physician who gave guidance, performed on healthy volunteers. Not directly testing the paramedic's ability to independently produce images. Classroom environment so external validity is limited
Heegaard *et al.* [17]	USA	Prospective observational study Aim: develop a training programme and assess the success of ultrasound in the following year	Air medial nurses and paramedics. 100 scans performed in the year following training (91 cardiac scans)	7 h of lectures and practical courses + 8 h of supervised practice on patients. Written knowledge test: mean score of 82% 6 weeks after course, 71% 1-year after course. Practical skills: 87% could produce images on live models at 6 weeks, 94% at 1 year. In the field scans: an adequate cardiac view obtained in 95%; 100% agreement between MD and student interpretations	Convenience sampling method (nonrandomized). Limited number of positive scans, so to draw conclusions that for this subgroup a larger sample would be needed. Highly experienced students; hence, may not be applicable to the wider paramedic population

ED, emergency department; EMS, emergency medical service; IQR, interquartile range.

appropriate transfer to the hospital, and therefore place the patients at a higher risk of harm [8].

The UK model of emergency care is paramedic led; hence, feasibility assessments must be evaluated from a nonphysician perspective. There is little evidence surrounding the success of training paramedics to undertake focused ultrasound examinations, as well as on whether these skills could be maintained through their current opportunities for operational exposure in the field [7]. Several studies have tested the feasibility of paramedic-conducted ultrasound, which is overseen by a physician based at the receiving hospital. This involves live streaming of images to an awaiting doctor for interpretation, alongside guidance to the paramedic sonographer [9,10]. Although this system allows real-time interpretation of ultrasound images and facilitates preparation at the receiving ED, it requires a dedicated physician and relies on effective image transmission. In the UK-based system, the acquisition and interpretation of ultrasound images by paramedics would have a more immediately useful application, potentially guiding the treatment of the patient before or during transit. Therefore, there is a need to establish the feasibility of teaching paramedics to conduct and interpret ELS in the prehospital environment.

A review of the literature surrounding paramedic ultrasound (not specific to cardiac ultrasound) reported a paucity of data in this area, with no published research surrounding paramedic ultrasound in a system of prehospital care similar to the UK system [7]. A further systematic review of ultrasound in nontrauma patients was unable to assess the effect of ultrasound on clinical outcomes due to a lack of reliable studies, and reported that the articles currently available are at a high risk of bias and present wide heterogeneity [11]. In 2012, Brooke *et al.* [12] undertook a 2-day training programme to teach 10 ultrasound-naive paramedics to conduct and interpret lung ultrasound scans to identify a pneumothorax. There was a 100% success rate for producing images of adequate quality in a simulated environment, and the accuracy of interpretation of prerecorded scans was comparable to the levels attained by certified emergency medicine ultrasound practitioners.

A review of the literature that focussed on cardiac ultrasound by paramedics revealed seven relevant studies (Table 1). These studies are extremely heterogeneous, each with different objectives, definitions, scanning protocols and requirements for image quality. Although all the studies focussed on emergency care providers, some included military personnel, others nurses and others paramedics. One was a case study describing an incident in which paramedic ultrasound affected patient management [14], one assessed the feasibility of paramedic-performed physician-interpreted ultrasound scans during patient transit [10] and one only reported the results of a survey of current ultrasound use, rather than the introduction or assessment of paramedic use [8].

The remaining four studies described training programmes on cardiac ultrasound for ultrasound-naive emergency care providers [13,15–17]. These articles varied in their scope and methods. Training ranged between 2 and 7 h, with ongoing refresher training [13,15,17]. All the studies reported successful skill acquisition among their students, with between 87 and 100% of students being able to perform a cardiac ultrasound [13,15–17]. One study reported that 80% of their students could attain cardiac views in less than 10 s [13], with another reporting a median of 5.5 s taken to scan [16]. Three studies taught their students interpretation skills. The study by Chin *et al.* [13] reported that paramedics scored well (mean of 91%) at recognizing pathologies on prerecorded video clips. The 2010 study by Heegaard *et al.* [15] reported 100% agreement for the interpretation of images between newly trained paramedics and a reviewing sonographer. The same system was used to assess newly trained air ambulance nurses and paramedics, with a mean score of 87% initially after the course and 94% a year later [17].

The aims of this pilot study are therefore to assess whether paramedics can be trained to perform and interpret ELS and to assess whether there is an association between the paramedics' ability to attain practical versus theoretical knowledge.

Methods

Within the Scottish Ambulance Service staff based in Edinburgh, there is a subgroup of paramedics with advanced training in the management of CA. The Resuscitation Rapid Response Unit (3RU) was set up in 2011 and consists of 12 paramedics who respond to OHCA calls. A 3RU paramedic works alongside the conventional ambulance staff in attendance and leads the resuscitation effort [18]. This provides a unique opportunity to assess the feasibility of paramedic ELS in a group with high exposure to CAs.

Eleven of the 12 3RU paramedics were able to attend a 1-day training course on focussed ELS, which included 2 h of lectures, along with 4 h of practical sessions and simulated moulages. Paramedics were trained to undertake two attempts at a subxiphoid view, followed by a parasternal long axis view if unsuccessful. Paramedics were taught to assess images for the following: movement (presence of), function (quality of), rhythm (is there a shockable rhythm unrecognized before ELS?), fluid (presence of pericardial effusion) and chambers (size especially right ventricle). This systematic approach focussed on evaluating the presence and quality of cardiac movement, as well as detecting conditions amenable to therapeutic intervention [i.e. cardiac tamponade, ventricular fibrillation (VF), and pulmonary embolism].

Although rhythm should be assessed by ECG, we taught paramedics to be aware that on occasion VF or ventricular tachycardia may be visible during ELS and should be treated appropriately. A previous study by our group showed that on occasion ED physicians detected VF on ELS that was not recognized on ECG and also VF and ventricular tachycardia that commenced during the pulse check while ELS was ongoing and therefore needed to be defibrillated [19].

To simulate actual OHCA, some scanning was performed on the floor (rather than using the traditional bedside approach), which entails more demanding body and machine positioning.

The course was delivered by Emergency Medicine registrars and consultants who had previously completed College of Emergency Medicine Level 1 ultrasound training. Ultrasound scanning was performed on four healthy volunteers. The participants were asked to complete a precourse questionnaire to establish their baseline knowledge on ultrasound, and the same questionnaire was completed after the course.

In addition, at course completion, each participant was assessed on ELS performance on three volunteers by three faculty members. The assessment had two parts, in which the participants were asked to do the following:

(1) Perform one parasternal and one subxiphoid scan: the time taken to do this and the quality of the image were recorded.
(2) Perform both types of scans in a timed 10-s window simulating the CA pulse check: if successful, the quality of the image assessed.

Image quality was assessed on a scale of 1–5, with 1 being low quality and 5 being high quality. Each participant was assigned a study ID, and data were handled anonymously. All participants submitted a postcourse feedback form. Ten weeks after the initial training, a subset of the 3RU paramedics was retested by way of a repeat questionnaire and a further practical assessment.

Results were entered into a specially designed Microsoft Excel (Microsoft Corporation, Redmond, Washington, USA) database and then analysed using SPSS (SPSS Inc., Chicago, Illinois, USA). Two-tailed paired Student's *t*-tests were used to analyse results where appropriate.

We also wanted to assess whether the same individuals performed well in both theoretical and practical assessments. To do this, a graph was plotted between an individual's postcourse knowledge level, measured on the basis of questionnaire results, and his/her practical ability, as measured by the sum of the average time taken to produce a parasternal view and the average time taken to produce a subxiphoid view.

Results

Theoretical knowledge

Nine participants completed the precourse and postcourse questionnaires. Among the nine students who completed both questionnaires, there was a statistically significant improvement in scores from a mean precourse score of 54% to a postcourse score of 89% ($P<0.001$). The most poorly answered questions before the course referred to technical aspects such as ultrasound modes, probe choices and probe placement. Before the course, 22% of the participants could correctly identify the key structures on a parasternal view, which increased to 73% after the course, with 44% increasing to 100% in a subxiphoid view. After the course, the participants still struggled to name the ultrasound modes (only 46% could identify a fictional mode as incorrect), but all other questions had at least 70% of participants answering correctly.

Practical skills

All participants successfully produced both a parasternal and a subxiphoid view on every attempt during the assessment moulage. A summary of the results is shown in Table 2. In the subxiphoid view, the mean image quality was 3.8 (out of 5), and the mean time taken to attain the view was 13.2 s. The average image quality in the parasternal view was 4.1 (out of 5) and the mean time taken was 13.1 s. During simulated cardiopulmonary resuscitation, in both views 88% of the attempts successfully resulted in an image in the 10-s time frame, with a mean image quality of 3.8 in the subxiphoid view and 4.0 in the parasternal view. All participants successfully obtained images in two out of their three assessment stations.

Extended follow-up

Four participants were able to attend a follow-up session 10 weeks later. One of them had undertaken supervised ELS scanning of CA patients in the ED during the interim period, and one had had an opportunity for supervised prehospital ELS practice. Three individuals were able to produce a subcostal view in a simulated 10-s pulse check (mean image quality was 3.0 out of 5), and

Table 2 **Practical skill assessment results**

	Mean ($n=9$)	% obtaining view
Perform a subxiphoid view, no time limit		
Image quality (1 = low, 5 = high)	3.8	100%
Time taken to acquire image (s)	13.2	
Perform a parasternal view, no time limit		
Image quality (1 = low, 5 = high)	4.1	100%
Time taken to acquire image (s)	13.1	
Perform a subxiphoid view during a simulated cardiac arrest scenario, 10-s time limit		
Image quality (1 = low, 5 = high)	3.8	87.9%
Perform a parasternal view during a simulated cardiac arrest scenario, 10-s time limit		
Image quality (1 = low, 5 = high)	4.0	87.9%

one was able to obtain a parasternal view (image quality of 4). This small subgroup prevents any firm conclusion from being drawn; however, it confirms that follow-up training and supervised practice are required to retain initial technical skill levels. The four individuals also completed the knowledge questionnaire with a mean score of 82%, a slight but nonsignificant drop from their immediate mean postcourse performance of 89% ($n=4$; $P=0.13$). This suggests that theoretical knowledge also appears to be lost, but less markedly than practical skill.

Assessor narrative feedback

Assessors provided written feedback for the students, pointing out their strengths and areas for improvement. Certain themes predominated, including practical aspects with regard to probe positioning (mentioned nine times), comments with regard to slow speed of scan (mentioned eight times) and specific aspects related to probe handling and technique (mentioned six times). Other pathways of improvement included application of firmer pressure, delegation of counting the 10 s to another team member and setting of reminders to prepare and adjust the depth when changing views.

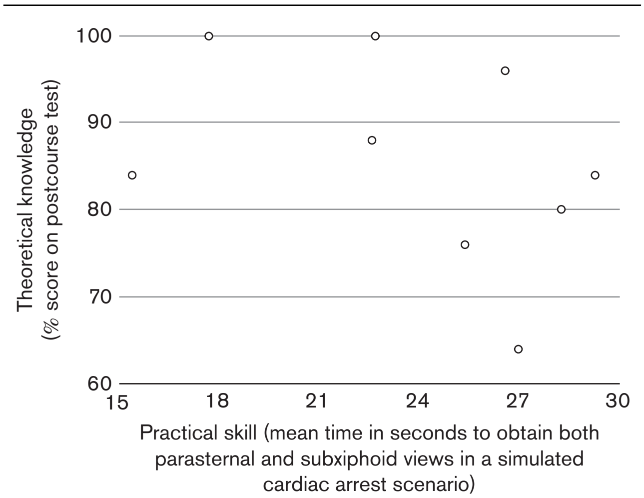
Theoretical skill versus practical knowledge

There was no obvious association between an individual's ability to learn practical ELS and to acquire theoretical knowledge. Figure 1 shows the distribution of each individual's scores on practical and theoretical assessments.

Feedback forms

The participants rated the usefulness of each teaching session (1 = not at all useful, 5 = very useful), with all sessions receiving a rating of 4.6 or higher. They were also asked to rate their confidence at various ELS skills before and after the course. Confidence was increased in all areas. The participants were invited to leave free text comments, in which they mentioned their enjoyment of the course and highlighted the usefulness of the practical sessions, while stating that follow-up training sessions and the opportunity to have real-life experiences were vital next steps.

Fig. 1



Correlation between paramedics' practical skills and theoretical knowledge.

Discussion

The day-long training course for paramedics with advanced CA training was undertaken to address the need to explore the feasibility and success of paramedic-led prehospital ELS, an area that currently has little published research.

The course received positive feedback from the participants and resulted in a significant improvement in their theoretical knowledge and confidence. Paramedics were able to attain cardiac views within the 10-s pulse check in 87% of cases, similar to the 80% rate attained by fire crews [13]. All of the students in this study were able to attain a cardiac view (mean quality 4.0, mean time taken 13 s), which is comparable to the 87–100% of students able to demonstrate this skill according to the literature [13,15–17]. The study by Heegaard *et al.* [17] tested the students' skill retention at 1 year after the course and reported that, although there was a slight drop in theoretical knowledge test scores (82 to 71%), there was a marginal increase in practical skill, with the proportion of students being able to demonstrate images of live models rising from 87 to 94%. This suggests that if paramedics have the opportunity to use their ultrasound skills, then they are adequately preserved.

A particular strength of our study is the incorporation of practical skill assessment into simulated CA moulages to establish whether performing ELS during a pulse check is feasible. This also encourages the paramedics to consider ELS as part of their strict standard operating procedure when later faced with a prehospital CA situation.

There was no difference in the quality of or the time taken to attain images between the different views, demonstrating that the paramedics can use either a scan according to individual conditions, such as access to the patient's chest due to automatic resuscitation devices. However, students were much better at identifying structures on subxiphoid rather than parasternal images in the knowledge test, suggesting that a subxiphoid view should be the first image sought. The study by Chin *et al.* [13] also found no association between image acquisition (practical skill) and interpretation (theoretical knowledge).

Our study has several limitations. The paramedics trained in this study are part of a specialized unit and have increased knowledge and motivation in the area of CA management; hence, they are unlikely to be representative of the wider paramedic population, limiting the study's external validity. In addition, this study involved scanning healthy volunteers in a classroom environment. Although mastering ultrasound in the classroom is a vital first step in the learning process, there is still much practice needed in a chaotic CA environment, with patients of all shapes and sizes, with pathological findings and while undertaking other advanced life support tasks. The paramedics used the same four volunteers all day, and thus may have picked up the ideal place to scan each individual, a luxury unavailable when scanning a patient. Although we measured their theoretical interpretation skills, treatment of some of these pathologies is not yet possible in the field environment locally (i.e. pericardiocentesis).

Areas for future research

The Edinburgh 3RU group is at a unique position, as OHCAs are currently filmed using the VideoBadge secure video recording system (*http://www.edesix.com*) for service evaluation purposes. Therefore, it should be possible to monitor the use of ELS in CA patients and to see how regularly the scanners are used, whether ELS impacts the prehospital management of patients and whether ELS could provide information that could impact patient management. This is a key factor in establishing whether paramedic ultrasound is a useful adjunct to prehospital care and to assess whether the trained paramedics are able to apply and retain their skills in a real-world environment.

Conclusion

There is currently very little literature surrounding paramedic cardiac ultrasound in the UK. We have shown that paramedics can be trained to perform ELS over a day-long course, with 88% being able to obtain an image with a mean quality of 3.8 or 4 out of 5 during a 10-s pulse check on a healthy volunteer. The ability to interpret basic ELS images increased from 54% before the course to 89% after the course. There was good retention of theoretical knowledge at 10 weeks, with a slight drop in practical ability. There is no apparent correlation between an individual's ability to gain practical versus theoretical knowledge in this area.

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M.J.R. was responsible for the conception of the study; K.L.B. was involved in the analysis; M.J.R., K.L.B., G.R.C. and S.S. were involved in the study design; M.J. R., K.L.B., S.B., G.R.C., R.K., K.L., G.M., D.B.M., E.-B. W. and M.W. were involved in data collection; and all authors were involved in the interpretation of data and in drafting the article.

Conflicts of interest

There are no conflicts of interest.

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