

## Focused cardiac ultrasound (FOCUS) by emergency medicine residents in patients with suspected cardiovascular diseases

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### Abstract

**Introduction** Few studies have assessed the value and accuracy of focused cardiac ultrasound (FOCUS) performed by emergency physicians. The aim of the present study was to evaluate the diagnostic accuracy of FOCUS performed by emergency medicine residents compared to echocardiography performed by a cardiologist in emergency department (ED) patients suspected of cardiovascular disease.

**Methods** The research involved a prospective observational cross-sectional study enrolling patients over 18-years old suspected of having cardiovascular disease who required an echocardiograph. For each patient, a FOCUS test was conducted by a trained emergency medicine resident. The diagnostic accuracy of ED performed FOCUS was compared to echocardiography performed by a cardiologist (gold standard) in the ED. Sensitivity, specificity, positive and negative predictive values, and likelihood ratios were calculated for FOCUS. The agreement of EM residents and

cardiologists on each finding was evaluated using Cohen's kappa coefficient with 95% CI.

**Results** Two hundred and five patients, with a mean age of  $61.0 \pm 17$  years (50% male), were included in this study. Agreement between FOCUS performed by an emergency medicine resident and echocardiography performed by a cardiologist in measuring ejection fraction of the left ventricle was 91% ( $\kappa = 0.85$ ; 95% CI = 0.79–0.91). Reports of the two groups for identifying right ventricular enlargement showed 96% agreement ( $\kappa = 0.86$ ; 95% CI = 0.82–0.90). The agreements for right ventricular pressure overload, wall motion abnormality and pericardial effusion were 100% ( $\kappa = 0.83$ ; 95% CI = 0.77–0.89), 92% ( $\kappa = 0.83$ ; 95% CI = 0.76–0.90), and 96% ( $\kappa = 0.83$ ; 95% CI = 0.77–0.89), respectively.

**Conclusion** FOCUS performed by emergency medicine residents is comparable to echocardiography performed by cardiologists. Therefore, it could be a reliable tool and

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screening test for initial testing of patients suspected of cardiac abnormalities.

**Keywords** Ultrasonography · Diagnostic test approval · Diagnostic techniques · Cardiovascular · Cardiac tamponade · Pericardial effusion

### Sommario

**Introduzione** Pochi studi hanno valutato il valore e l'accuratezza dell'ecocardiografia eseguita da medici dell'emergenza (*focused cardiac ultrasound, FOCUS*). Lo scopo del presente studio è di valutare l'accuratezza diagnostica della FOCUS eseguita da medici dell'Emergenza confrontata con l'ecocardiografia eseguita da cardiologi nel Dipartimento di Emergenza in pazienti con sospetta malattia cardiovascolare.

**Metodi** Si tratta di uno studio osservazionale, prospettico, *cross-sectional* che ha arruolato pazienti sopra i 18 anni con sospetta malattia cardiovascolare in cui era indicata un'ecocardiografia. L'accuratezza diagnostica della FOCUS eseguita dal medico dell'Emergenza è stata confrontata con l'ecocardiografia eseguita dal cardiologo nel Dipartimento di Emergenza (gold standard). Sono stati calcolati per l'ecografia FOCUS la sensibilità, la specificità, i valori predittivi positivo e negativo e il grado di confidenza. La concordanza del medico dell'Emergenza con il cardiologo per ogni parametro sono stati valutati con l'indice K di Cohen con il 95% di Indice di Confidenza.

**Risultati** Sono stati inclusi nello studio 205 pazienti con età media di  $61,0 \pm 17$  anni (50% maschi). La concordanza tra il medico dell'Emergenza ed il cardiologo nella misurazione della frazione di eiezione del ventricolo sinistro è stata del 91% ( $k = 0,85$ ; 95%CI = 0,79-0,91). I referti dei due specialisti nell'identificare dilatazione del ventricolo destro hanno mostrato un 96% di concordanza ( $k = 0,86$ ; 95% CI = 0,82-0,90). La concordanza per il sovraccarico pressorio del ventricolo destro, le anomalie del movimento di parete ed il versamento pericardico è stata del 100% ( $k = 0,83$ ; 95% CI = 0,77-0,89), 92% ( $k = 0,83$ ; 95% CI = 0,76-0,90), e 96% ( $k = 0,83$ ; 95% CI = 0,77-0,89) rispettivamente.

**Conclusioni** FOCUS eseguita da medici dell'Emergenza è comparabile a quella eseguita dai cardiologi. Quindi può essere considerata un mezzo affidabile ed un test di screening per l'iniziale valutazione dei pazienti con sospetta patologia cardiaca.

### Introduction

Echocardiography is a reliable imaging modality for the evaluation of cardiac dynamics and diagnosing abnormalities such as heart failure, right-heart strain from pulmonary

embolism, and aortic dissection. While most cardiovascular emergencies requiring echocardiography are time-sensitive, standard echocardiography is not readily available or is associated with significant time delay [1, 2]. In recent years, performing a focused cardiac ultrasound (FOCUS) as the first screening test in emergency department (ED) and intensive care units has been recommended by international organizations to accelerate decision-making on certain cardiovascular emergencies [3]. In 2010, the American Society of Echocardiography and American College of Emergency Physicians reached an agreement on using FOCUS and provided indications for its use [4].

FOCUS allows ultrasonographic evaluation of cardiac anatomy and function at bedside. It is a readily available and rapid diagnostic modality in the ED, which also allows for serial evaluation of dynamic entities [3]. FOCUS complements ED medical history and physical examination but does not replace the standard echocardiography performed by a certified technician or a cardiologist and interpreted by a cardiologist [5].

Some of the indications of using FOCUS are assessing pericardial effusion and systolic function of the left ventricle, evaluation of possible pulmonary embolism, cardiac arrest management, cardiac tamponade evaluation, diagnosis of aortic dissection, and evaluation of myocardial ischemia [6]. This protocol has some limitations. For example, FOCUS has high specificity in diagnosing cardiac diseases, but it is not a sensitive test; therefore, it should be followed by a standard echocardiography. Despite its limitations, FOCUS can accurately differentiate the underlying cause of non-traumatic hypotension and lead to an improvement in clinical outcomes of critically ill patients in the ED [7]. A study reported that this diagnostic test leads to early diagnosis of massive pulmonary embolism, which brings about rapid initiation of anti-coagulant therapy and results in improved patient outcomes [8]. In addition, FOCUS has a high diagnostic value in diagnosing aortic abnormalities compared to a computed tomography (CT) scan [9]. That is the reason why in recent years, emergency medicine (EM) and intensive care physicians have shown great interest in using FOCUS in managing time-sensitive cardiovascular pathologies. Few studies by ED specialists have evaluated the value and accuracy of FOCUS. The present study has been designed to evaluate the accuracy of FOCUS performed by ED physicians in identifying cardiac abnormalities compared to cardiologist-performed echocardiography.

### Methods

#### Study design and setting

The present prospective observational cross-sectional diagnostic accuracy study was carried out in a large

academic hospital from September to December 2014. The study protocol was approved by the ethics committee of Iran University of Medical Sciences. Written informed consent was obtained from all participants prior to enrollment.

### Participants

We enrolled a convenience sample of patients older than 18 years of age who presented to the ED suspected of having a cardiac emergency requiring FOCUS at the discretion of the ED physicians caring for them. Patients were excluded if performing FOCUS would interfere with their treatment.

### Protocol

Seventeen volunteer residents attended a FOCUS workshop in line with the protocol designed by the American Society of Echocardiography [6]. The workshop consisted of two 2-h sessions for theoretical discussions and educational movies and pictures and three 2-h practical sessions. The study subjects underwent FOCUS (SonoAce X8, Samsung Medison Co., Ltd.) by trained EM residents with a 2.7 MHz probe. Then, a standard echocardiography was performed by a cardiologist as soon as possible. The cardiologist performing the echocardiography was not aware of the results of FOCUS performed by EM residents. Echocardiography was performed using an EKO 7 device (Samsung Medison Co., Ltd.) with 2.7 MHz probe by trans-thoracic method in standard views including parasternal long axis, parasternal short axis, apical four chamber, and subxiphoid four chamber.

### Evaluated elements

Ejection fraction (EF) of the left ventricle and function of the right ventricle were measured in each evaluation. The emergency medicine residents calculated ejection fraction of the left ventricle using either the end-point septal separation (EPSS) method or Quinones equation or both. Subsequently, the results were categorized according to three spectrums. If the EF was equal to or more than 50%, the result was recorded as normal systolic left ventricular (LV) function. If the EFs were between 30 and 49% or less than 30%, the results were recorded as mild to moderate or severe systolic LV dysfunction. Cardiologists assessed the EF of the left ventricle by eyeball estimation method before the researchers categorized the cardiologists' reports according to the three research spectrums. The presence of pericardial effusion, cardiac tamponade, and aortic root diameter were also documented.

### Statistical analyses

Continuous variables are reported as mean and standard deviation (SD), and categorical variables are reported as percentages with 95% confidence intervals (CI). FOCUS findings were categorized as true positive, true negative, false positive, and false negative using the cardiologist-performed echocardiography as the criterion standard. The sensitivity, specificity, positive and negative predictive value (PPV and NPV), and positive and negative likelihood ratio of FOCUS were calculated. The agreement between EM residents and cardiologists on each finding was evaluated by calculating Cohen's kappa coefficient with 95% CI. A minimum sample size was determined to be 165 by considering 94% minimum specificity, 17% prevalence of pericardial effusion, 4% desired precision ( $d = 0.04$ ), 95% confidence interval (CI;  $\alpha = 0.05$ ), and 90% power ( $\beta = 0.1$ ) [10]. The data were analyzed using STATA 11.0 software.

### Results

During the study period, 205 patients with the mean age of  $61 \pm 17$  years (range: 18–91 years) were included in this study (50% male). Chest pain was the chief complaint in 93 (45%) of the patients, and shortness of breath was reported in 66 (33%). Other chief complains are listed in Table 1.

In the FOCUS evaluation by the residents, 97 (47%) of the patients had  $\geq 50\%$  left ventricular ejection fraction (LVEF), 73 (35%) had 30–49% LVEF, and 35 (17%) had  $< 30\%$  LVEF. These measures were 105 (51%), 67 (32%), and 33 (16%), respectively, in the echocardiography performed by the cardiologist. We did not find any case of aortic root dilatation, and we only found two cases of

**Table 1** Demographic and baseline characteristics of the study cohort

Factor	Frequency (%)
Sex	
Male	103 (50.2)
Female	102 (49.8)
Chief complaint	
Chest pain	93 (45.3)
Shortness of breath	66 (32.2)
Syncope	20 (9.8)
Weakness	14 (6.8)
Angina	6 (2.9)
Stroke	3 (1.5)
Tachycardia	2 (1.0)
Hypotension	1 (0.5)

**Table 2** Abnormal findings reported by the cardiologist-performed echocardiography in the study cohort

Findings	N	% (95% CI)
PE	21/205	10 (7–14)
RVP	6/205	3 (1–6)
RVE	32/205	16 (11–21)
WMA	68/205	33 (27–40)
Low LVEF	100/205	51 (44–58)

PE pericardial effusion, RVP right ventricular pressure overload, RVE right ventricular enlargement, WMA wall motion abnormality, LVEF left ventricular ejection fraction

**Table 3** The agreements of EM resident-performed FOCUS and that of cardiologist-performed echocardiography for each major classification are listed in Table 3

Findings	$\kappa$	95% CI
PE	0.83	0.77–0.89
RVP	1.00	0.98–1.00
RVE	0.86	0.82–0.90
WMA	0.83	0.76–0.90
Low LVEF	0.85	0.79–0.91

tamponade. Therefore, these finding were excluded from the analyses due to their low prevalence.

The findings of cardiologist-performed echocardiography are reported in Table 2.

The agreements between EM resident-performed FOCUS and cardiologist-performed echocardiography for each major classification are listed in Table 3.

The diagnostic performance of FOCUS compared to the gold standard (cardiologist-performed echocardiography) is presented in Table 4.

**Discussion**

The findings of the present study showed that FOCUS performed by EM residents could be used as a reliable screening test for patients with suspected cardiovascular conditions. The results indicate the value of FOCUS in ED. FOCUS is widely available and can be performed in a short time at the patient’s bedside in most EDs. Thus, FOCUS can be used as a device to triage patients with suspected cardiovascular conditions and rapidly identify those in need of urgent treatment.

Performing serial FOCUS can be an adequate replacement for serial standard echocardiography by a cardiologist. It is financially beneficial for both the patient and the health system, and provides similar information regarding function of the left ventricle, identifying pericardial effusion, and assessing intravascular volume for the physicians [4, 11]. A study by Mandavia et al. showed 96% sensitivity and 98% specificity for FOCUS in identifying pericardial

**Table 4** Diagnostic performance of FOCUS compared to the gold standard (cardiologist-performed echocardiography) in the study cohort

Findings	TP	FP	TN	FN	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Accuracy (95% CI)	LR+ (95% CI)	LR- (95% CI)
PE	18	8	176	3	86% (63–96)	96% (91–98)	69% (48–85)	98% (95–99)	95% (91–99)	20 (10–40)	0.15 (0.05–0.40)
RVP	6	0	199	0	100% (52–100)	100% (98–100)	100% (52–100)	100% (98–100)	100% (98–100)	-	0.0
RVE	27	4	172	2	93% (76–99)	98% (94–99)	87% (69–96)	99% (96–99)	97% (93–100)	41 (15–109)	0.07 (0.02–0.27)
WMA	68	17	118	2	97% (89–99)	87% (80–92)	80% (70–88)	98% (94–99)	91% (84–97)	8 (5–12)	0.03 (0.01–0.13)
Low LVEF	93	4	96	12	89% (81–99)	96% (90–99)	96% (89–99)	89% (81–99)	92% (85–99)	22 (8–58)	0.12 (0.07–0.2)

PE pericardial effusion, RVP right ventricular pressure overload, RVE right ventricular enlargement, WMA wall motion abnormality, LVEF left ventricular ejection fraction, TP true positive, FP false positive, TN true negative, FN false negative, PPV positive predictive value, NPV negative predictive value, LR+ positive likelihood ratio, LR- negative likelihood ratio

effusion [12]. Likewise, Torres-Macho et al. noted that FOCUS performed by a physician shows acceptable value in identifying cardiac abnormalities compared to echocardiography [5].

In the present study, the lowest sensitivity calculated was on diagnosing pericardial effusion, which was about 86%. The low sensitivity/high NPV of this test might be due to the pericardial fat pad being mistaken for pericardial fluid or lack of experience in residents in this field. Yet the NPV of the FOCUS performed by the EM residents has been excellent and can, therefore, be used as a rule-out test in diagnosing pericardial effusion, abnormal size and pressure in the right ventricle, and cardiac wall motion abnormalities. It can also be used as a rule-in test in identifying low LVEF in ED. Hence, FOCUS can be of help in ED in this field, especially when cardiologists and echocardiography are not readily available.

In line with this study, previous studies also show that emergency physicians can evaluate systolic function of the left ventricle accurately in patients with hypotension. In a study by Moore et al. on patients with persistent symptomatic hypotension, agreement between emergency physician and cardiologist in evaluation of LVEF was 84%, with a kappa coefficient of 0.61 [13]. In another study by Randazzo et al. the agreement was 78%, with a kappa coefficient of 0.71 [14], while we found 91% agreement and 0.85 kappa coefficient in this study. Dinh et al. believed that emergency physicians could measure cardiac indices such as stroke volume and cardiac output [15].

We should note that bedside ultrasonography is a part of initial and emergency clinical evaluations and cannot replace more accurate and general diagnostic methods that can be performed in specialized departments such as radiology and cardiology. Thus, we should consider FOCUS as a complementary evaluation to medical history and physical examination in an emergency setting and not as a replacement for echocardiography performed by a cardiologist. This evaluation is a complementary method to identify potentially fatal cardiac pathologies such as tamponade and gain basic data such as presence or absence of cardiac abnormality. Cardiologists are not available at all times during the week, and sometimes obtaining an official echocardiograph requires sending the patient to a location outside the ED. In such situations, FOCUS can rapidly be performed to determine the urgency of a cardiology consultation or echocardiography and to confirm whether the patient is stable enough to be transported to the echocardiography suite.

One of the limitations of the present study was the sampling method used, as convenience sampling increases the probability of selection bias. In addition, we used echocardiography performed by a cardiologist as the gold standard. Since the accuracy of this method in diagnosing

cardiac abnormalities is not 100%, using a better gold standard is recommended for future studies. This study has been done on residents of one university, which can affect the external validity of the study. Moreover, there was no aortic dissection and only two cases of cardiac tamponade in this study; therefore, the diagnostic value of FOCUS in identifying these entities could not be assessed. This study also did not assess intravascular volume, which is one of the aims of FOCUS protocol.

## Conclusion

The present study showed that FOCUS performed by EM residents could be a reliable tool and screening test for initial testing of patients with suspected cardiovascular abnormalities in an emergency setting.

## Compliance with ethical standards

**Conflict of interest** The authors declare they do not have any financial or other conflicts-of-interest related to the submission.

**Ethical approval** All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

**Informed consent** All patients provided written informed consent to enrolment in the study and to the inclusion in this article of information that could potentially lead to their identification.

**Author contributions** D.F, S.A, S.H and M.R: Idea, Designed the study. M.J.H, Sa.A and P.H: Registering the study in research center of IUMS, Communicating with the manager of hospitals and arrangement of implementation. D.F, S.A, S.H, M.M and M.J.H: Data collection (visiting the patients, ultrasonography). B.M, Sa.A: Quality control. B.M, M.R, M.M and S.A: Writing the article (search, data bank, primary manuscript). M.R, D.F, and S.A: Analysis by SPSS and Finalizing the article. S.A: takes responsibility for the paper as a whole.

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