Junior medical student performed focused cardiac ultrasound after brief training to detect significant valvular heart disease☆

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ABSTRACT

Background: Focused cardiac ultrasound (FOCUS) examination using a portable device is increasingly used for bedside diagnosis of cardiovascular diseases. This is a 4-week pilot project aiming to teach medical students to perform FOCUS to detect valvular heart lesions.
Methods: Patients undergoing routine transthoracic echocardiography (TTE) were recruited by third year medical students who performed physical examination (PE) and FOCUS after 6-hour training to detect significant (moderate-to-severe) valvular lesions. Performance of FOCUS and PE was compared to TTE as reference using kappa statistics.
Results: 10 medical students performed 212 PE and FOCUS on 107 patients with mean age 63.7 ± 14.9 years. TTE detected 126 significant valvular lesions of which FOCUS correctly identified 54 lesions ($\kappa = 0.45$) compared to 32 lesions by PE ($\kappa = 0.28$, $p < 0.01$). FOCUS was better than PE in identifying mitral stenosis ($\kappa = 0.51$ vs. 0.17), aortic stenosis ($\kappa = 0.45$ vs. 0.16) and tricuspid regurgitation ($\kappa = 0.39$ vs. 0.09, all $p < 0.01$). Students became more proficient in performing FOCUS examination with time.
Conclusions: Teaching junior medical students to perform and interpret FOCUS was feasible after brief training and better than PE in detecting significant valvular lesions. Further studies are warranted to determine the utility of incorporating this new technology into mainstream medical training.

1. Introduction

Physical examination (PE) is a time-honored clinical skill which takes years to become proficient. Errors in the detection and interpretation of clinical signs are common among medical students [1,2]. The diagnosis of valvular lesions based on auscultation of heart sounds is especially challenging for the inexperienced medical students [3,4]. Echocardiography is considered the gold-standard for the diagnosis and assessment of valvular heart disease. However, standard echocardiogram machines are bulky, expensive and not readily available. In recent years, focused cardiac ultrasound (FOCUS) examination using portable pocket-sized ultrasound has been increasingly used for bedside diagnosis of cardiovascular diseases [5]. Combining traditional PE and FOCUS has the potential to improve bedside diagnostic accuracy as well as a tool to improve clinical skills [6–8]. A number of medical schools in the United States have integrated cardiac ultrasound skills as part of the curriculum with very positive student feedback and results [9]. This study aimed to teach medical students how to perform FOCUS to assess valvular heart disease in a 4-week student project and to evaluate the agreement between students performed FOCUS and PE to formal echocardiography.

2. Methods

2.1. Medicine year 3 selected study modules (SSM)

Ten medical students participated in this 4-week project as part of a Year 3 Selected Student Module (SSM) designed to stimulate in-depth study on topics of their own interest during the medical program and help equip students with a basic understanding of scientific research and related methods. Each SSM project is guided by an academic project supervisor.

2.2. Study population

We recruited 107 patients who underwent clinically indicated transthoracic echocardiography (TTE) at the Prince of Wales Hospital over two 4-week periods from April to May in 2014 and 2015. Standard TTE was performed by trained nurses or cardiologists using either Philips iE33 (Philips Medical, Best, Netherlands) or GE E9x machines (GE Healthcare, WI, U.S.A.). Valvular lesions of moderate to severe severity were considered significant in this study based on the assumption that moderate to severe lesions detected by TTE could be detected by PE, whereas mild lesions were assumed to be undetectable by auscultation. Each recruited patient was examined by more than one student to determine inter-observer variability. A brief medical history and PE of the cardiovascular system was performed by each student. History included the presenting symptoms and past medical history of the patient. PE was standardized to include inspection (jugular venous pressure, peripheral pitting edema, peripheral stigmata of endocarditis), palpation (arterial pulse, apex, right parasternal for ventricular lift, hepatomegaly), cardiac (quality of heart sounds, added heart sounds, murmurs), and lung (crepitations, wheeze, dullness) auscultation. PE was performed before FOCUS. The study was performed in accordance with the Declaration of Helsinki and approved by the Joint Chinese University of Hong Kong – New Territories East Cluster Clinical Research Ethics Committee (The Joint CUHK-NTEC CREC). All the participants had signed the consent form before taking part in this study. Only patients who were in stable condition and given informed consent were enrolled in the study.

2.3. Student performed pocket ultrasound

The V-scan (GE Healthcare, WI, U.S.A.) mobile pocket-sized ultrasound device was used in this study. The device can obtain two-dimensional imaging in B-mode and color flow Doppler. It also allows image storage and calipers for linear measurements. Ten Year 3 medical students with no prior knowledge and experience in echocardiography underwent 6 h of training by a cardiologist including 2-hour tutorial on echocardiographic anatomy, examination views and simple evaluation of valvular lesions; 1-hour case studies of valvular heart disease and 3-hour hands-on training on patients with different valvular heart diseases including aortic stenosis, aortic regurgitation, mitral stenosis, mitral regurgitation and tricuspid regurgitation. For this study, FOCUS examination was performed using 4 views: parasternal long- and short-axis, apical 4-chamber and subcostal views in B- and color Doppler-mode to detect significant (moderate or severe) aortic, mitral and tricuspid valve regurgitation or stenosis. Duration of the FOCUS examination was recorded.

2.4. Statistical analysis

Categorical and continuous data were presented as percentage and mean ± SD, respectively. Chi-square test was used to compare sensitivity and specificity of the students' PE and FOCUS findings using TTE as the reference standard. Kappa (κ) statistic was used for assessing agreement between the students' PE and FOCUS findings and TTE results. Kappa values < 0 indicated no agreement and 0–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1 as almost perfect agreement. Inter-observer agreement was also assessed between students examining the same patient. SPSS version 22 (SPSS Inc., Chicago, IL, USA) was used for data analyses and 2-tailed p-value < 0.05 was considered significant.

3. Results

3.1. Patient demographics

Patients' demographics were summarized in Table 1. The majority of patients were outpatients (61.7%). Indications for TTE included chest

Table 1
Patient characteristics and transthoracic echocardiography results.

Baseline characteristics	Patients (n = 107)
Age, mean ± SD, years	63.7 ± 14.9
Inpatient	41 (38.3%)
Outpatient	66 (61.7%)
Men	69 (64.5%)
Presenting symptoms	
Chest discomfort/pain	21 (19.6%)
Palpitation	20 (18.7%)
Shortness of breath	27 (25.2%)
Past medical history	
Coronary artery disease	29 (27.1%)
Heart failure	21 (19.6%)
Congenital heart disease	3 (2.8%)
Valvular heart disease	25 (23.4%)
Hypertension	61 (57.0%)
Diabetes mellitus	28 (26.2%)
Hyperlipidaemia	31 (29.0%)
Smoking	25 (23.4%)
Transthoracic echocardiography results	**Cases (n = 211)**
Mitral regurgitation	
Normal or mild	161 (76.3%)
Moderate or severe	50 (23.7%)
Mitral stenosis	
Normal or mild	201 (95.3%)
Moderate or severe	10 (4.2%)
Aortic regurgitation	
Normal or mild	193 (91.5%)
Moderate or severe	18 (8.5%)
Aortic stenosis	
Normal or mild	200 (94.8%)
Moderate or severe	11 (5.2%)
Tricuspid regurgitation	
Normal or mild	174 (82.5%)
Moderate or severe	37 (17.5%)

pain (19.6%), palpitation (18.7%) and shortness of breath (25.2%). Many patients have known cardiovascular diseases including hypertension (57.0%), coronary artery disease (27.1%), valvular heart disease (23.4%), heart failure (19.6%) and congenital heart disease (2.8%). Among the 107 patients, 6 were examined by 1 student, 99 by 2 students and 2 by 4 students. Therefore, a total of 212 sets of student PE and FOCUS were collected for analysis. One TTE result could not be retrieved and therefore was excluded from analysis.

3.2. Transthoracic echocardiogram results

126 significant valvular lesions of moderate to severe severity were detected on TTE (Table 1): 23.7% (n = 50) mitral regurgitation, 4.2% (n = 10) mitral stenosis, 8.5% (n = 18) aortic regurgitation, 5.2% (n = 11) aortic stenosis, 17.5% (n = 37) had tricuspid regurgitation.

3.3. Physical examination agreement

Overall agreement between student PE and TTE was fair with κ value of 0.28 (Table 2 and Fig. 1). Agreement was highest for mitral regurgitation (κ = 0.39) which was fair. Agreement for other lesions was worse with κ values ranging from 0.09 to 0.20.

3.4. Focused cardiac ultrasound agreement

Overall agreement between FOCUS and TTE (κ = 0.45) was moderate and better than PE for all lesions (Table 2 and Fig. 1). Agreement for mitral stenosis (κ = 0.51), mitral regurgitation (κ = 0.48) and aortic stenosis (κ = 0.45) were all moderate. Agreement for tricuspid (κ = 0.39) and aortic regurgitation (κ = 0.23) was fair.

Table 2
Agreement between student FOCUS and PE with TTE as reference.

TTE finding	FOCUS				PE				[a]p$_1$	[b]p$_2$
	Intra-agreement (κ$_1$ value)	Inter-agreement with TTE (κ$_2$ value)	Sensitivity	Specificity	Intra-agreement (κ$_1$ value)	Inter-agreement with TTE (κ$_2$ value)	Sensitivity	Specificity		
All lesions	0.41	0.45	62%	90%	0.41	0.28	38%	90%	1	<0.01
MR (n = 50)	0.41	0.48	76%	79%	0.50	0.39	64%	79%	0.45	0.34
MS (n = 10)	0.34	0.51	70%	96%	−0.04	0.17	20%	97%	0.02	0.06
AR (n = 18)	0.49	0.23	39%	90%	0.24	0.20	22%	95%	0.23	0.83
AS (n = 11)	0.51	0.45	82%	92%	0.48	0.16	45%	86%	0.86	0.03

FOCUS: Focused cardiac ultrasound; PE: physical examination; TTE: transthoracic echocardiography; κ: Kappa; MR: mitral regurgitation; MS: mitral stenosis; AR: aortic regurgitation; AS: aortic stenosis; TR: tricuspid regurgitation.
[a] p$_1$ refers to the p value of inter-agreement between FOCUS and PE.
[b] p$_2$ refers to the p value of the difference on the inter-agreement with TTE (κ$_2$ values) between FOCUS and PE.

3.5. Student PE and FOCUS inter-observer agreement for the same patient

Inter-observer agreement was assessed in cases where more than one student evaluated the same patient (Table 2). Overall inter-observer agreement was similar for FOCUS and PE. However, inter-observer agreement for mitral stenosis was very poor with PE (κ = −0.04) compared to FOCUS (κ = 0.34, p = 0.02).

3.6. Improvement of student PE and FOCUS over time

Performance of student PE and FOCUS during the first 2 weeks of the study period was compared with the second 2 weeks. Students became more proficient in completing FOCUS examination with time. Mean time improved from 8.9 ± 2.2 min in the first 2 weeks to 7.1 ± 1.6 min in the second 2 weeks of the study (p < 0.01). Agreement of student PE and FOCUS compared to TTE also improved during the study period (Table 3).

4. Discussion

Our study demonstrated that (i) agreement between student PE and TTE diagnosis of significant valvular heart disease was poor; (ii) teaching medical student to perform and interpret FOCUS was feasible after brief training; (iii) agreement between student FOCUS and TTE was better than PE for the diagnosis of many valvular lesions, especially for mitral and aortic stenosis and tricuspid regurgitation; (iv) performance of student FOCUS improved over a short period and (v) inter-observer variability in FOCUS was less compared to PE for mitral stenosis. We

anticipate that a longer study period and more intense and formal training could yield even better results.

Auscultating heart sounds is a fundamental but challenging component of physical examination. Even in the best circumstances, these sounds can be difficult to hear, especially the low-pitched 'rumbling' mid-diastolic murmur of mitral stenosis. This was reflected by only slight agreement between PE and TTE for mitral stenosis (κ = 0.17) coupled with high inter-observer variability (κ = −0.04) between students. By contrast, the agreement between FOCUS and TTE was significantly higher (κ = 0.51) and the inter-observer variability was lower (κ = 0.34). This suggested that FOCUS has the potential to be a better screening tool than PE for the diagnosis of mitral stenosis that is easy to learn. Although the prevalence of significant mitral stenosis is becoming rare in Western population as a result of declining prevalence of rheumatic heart disease which is the predominant cause of mitral stenosis, it remains a major public health problem worldwide, including Hong Kong. The use of FOCUS as a screening tool was supported by a recent study by Mirabel et al. in which FOCUS performed by nurses yielded acceptable sensitivity and specificity for rheumatic heart disease detection when compared with standard TTE [10]. Superiority of FOCUS over PE was also observed for the diagnosis of systolic murmurs such as aortic stenosis and tricuspid regurgitation which are often confused by students.

The recent European Association of Echocardiography recommended that dedicated training time should be mandatory on the use of FOCUS for non-accredited echocardiographers but there were little details on specific requirements or duration of training [11]. The American Society of Echocardiography has recommended a total of 150 performed examinations and 300 interpreted studies in order to independently perform and interpret FOCUS [12,13]. This is based on the notion that FOCUS would be used like echocardiography as a stand-alone diagnostic modality. However, this high level of training may be impractical for medical students. Furthermore, FOCUS should not be considered as a replacement of echocardiographic examination but rather as a clinical tool similar to the stethoscope to aid bedside
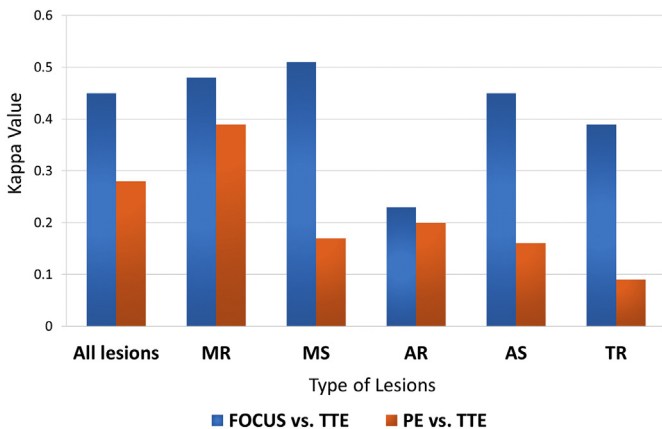
Fig. 1. Agreement between students focused cardiac ultrasound (FOCUS) and physical examination (PE) with transthoracic echocardiogram (TTE) as reference. FOCUS indicates Focused cardiac ultrasound; PE, physical examination; TTE, transthoracic echocardiography; κ, Kappa; MR, mitral regurgitation; MS, mitral stenosis; AR, aortic regurgitation; AS, aortic stenosis; TR, tricuspid regurgitation.

Table 3
Agreement of student FOCUS and PE with TTE over time.

TTE finding	FOCUS vs. TTE			PE vs. TTE		
	Week 1 & 2	Week 3 & 4	# p	Week 1 & 2	Week 3 & 4	[a]p
All lesions	0.46	0.50	0.60	0.25	0.30	0.54
MR	0.39	0.65	0.03	0.37	0.39	0.89
MS	0.77	0.56	0.41	0.10	−0.03	0.36
AR	0.41	0.12	0.10	0.12	0.26	0.52
AS	0.44	0.46	0.92	0.05	0.27	0.17
TR	0.37	0.48	0.50	0.21	0.19	0.90

FOCUS: Focused cardiac ultrasound; PE: physical examination; TTE: transthoracic echocardiography; κ: Kappa; MR: mitral regurgitation; MS: mitral stenosis; AR: aortic regurgitation; AS: aortic stenosis; TR: tricuspid regurgitation.
[a] p refers to the p value of the difference on the inter-agreement between TTE and FOCUS/PE at different time points.

clinical diagnosis. In studies which showed improvement in diagnostic accuracy with the use of FOCUS, the training time has been as short as 2 h in the study by Panoulas et al. [14], 3 h in the Duke limited echo assessment project (LEAP) [15], 18 h in the study by Kobal et al. [16] to as long as a 10-day training course [17]. Students in our study underwent 6 h of training and we demonstrated that even in the hands of junior medical students with only minimal training, the diagnostic accuracy of FOCUS was superior to PE similar to findings in previous studies [14,18,19].

Incorporating FOCUS as an adjunct to clinical assessment has potential to enhance students' clinical diagnostic accuracy and skill. In the study by Panoulas et al. [14], 5 final-year medical students and 3 junior doctors assessed 122 patients using history, PE, electrocardiography (ECG) and FOCUS after 2 h of training showed that FOCUS significantly improved clinical diagnosis (0.75 ± 0.28 where maximum $= 1$) over and above history, physical examination and ECG (0.49 ± 0.22, $p < 0.001$). Secondly, FOCUS can be used as a self-teaching aid whereby correlating history and physical findings with a visual image of the pathology can enrich the learning experience, understanding of various cardiac pathologies and confidence that leads to improvement of students' examination skills. In recent years, some medical schools have introduced ultrasound into their medical curriculum [20–23]. In the University of South Carolina School of Medicine, ultrasound teaching has been integrated throughout four years of medical education for almost a decade, not only as a diagnostic tool for senior students but also as a learning tool for junior students to better understand cardiac anatomy and physiology [21]. Student satisfaction was high and felt their ultrasound experience enhanced their medical education. Ultrasound has the potential to change how we teach and practice cardiovascular medicine to the benefit of students and patients but further studies are required to help define the essential elements of ultrasound education for medical students.

4.1. Limitations

This is a single center study with a short study period and limited sample size. The frequency of some lesions such as mitral stenosis and aortic stenosis was low which limited the power of our results. We assumed that only moderate to severe valvular lesions by TTE criteria could be detectably by PE which may not be true. Given the small sample size, we did not differentiate between patients with single and multiple valvular lesions which would bias against PE and not FOCUS. The very low agreement between PE and TTE could be related to inexperience of third year medical students (junior clerkship) compared to final year medical students or junior doctors in other studies [14,18,19]. However, this further highlights the benefit of FOCUS over PE which is quicker to learn and more consistent between students. In regards to FOCUS training, students underwent only 6 h of training prior to the study with minimal feedback and further training throughout the study period. This was a short-term study which does not address the issue of long-term retention of knowledge and skills. A longer and more structured FOCUS training may yield even better FOCUS results.

5. Conclusions

With the availability of affordable hand-held ultrasound devices, there is increasing interest in introducing ultrasound education in medical schools as an adjunct to clinical assessment and platform for medical learning. Our study demonstrated that teaching junior medical students to perform and interpret FOCUS was feasible after brief training. Student performed FOCUS was better than PE in detecting significant valvular lesions. Further studies are warranted to determine the incremental value of FOCUS and the utility of incorporating this new technology into mainstream medical training.

Conflict of interest

The authors declare that they have no competing interests.

Glossary terms

Focused Cardiac Ultrasound (FOCUS) examination uses ultrasound as an adjunct to physical examination to identify the presence or absence of specific ultrasonic findings that represent a narrow list of potential diagnoses. Subjective interpretation of one or several targets of interest is emphasized, with the intent that subsequent referral for formal echocardiography will delineate and measure all findings, including incidental or associated findings unrecognized by FOCUS.

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