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Pocket-size echocardiograph - a valuable tool for non-experts or just a portable device for echocardiographers?

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ABSTRACT

Purpose: The diagnostic value of examinations performed with the use of pocket-size echocardiograph by medical professionals with different levels of experience remains to be determined. The aim of this study was to assess the diagnostic value of bedside echocardiographic examinations performed with the use of pocket-size echocardiograph by experienced cardiologist and medical students.

Material/Methods: The study group comprised 90 patients (63 men, 27 women; mean age 64±14 years) admitted to the cardiac intensive care unit and 30 patients from an out-patient clinic (21 men, 9 women; mean age 62±17 years). All patients underwent bedside echocardiographic examination performed with pocket-size echocardiograph by two briefly trained medical students (n=90 patients) or cardiologist (n=30 patients). Major findings were recorded using a simplified questionnaire. Within 24 hours standard echocardiographic examination was performed in all patients by another cardiologist using a full sized echocardiograph.

The study group was divided into 4 subgroups: A / B – first / second half of in-patients examined by students, group C – in-patients examined by cardiologist, group D- out-patients examined by students.

Results: The agreement between standard transthoracic echocardiography (sTTE) and major findings on bedside transthoracic echocardiography (bTTE) was fair to moderate (kappa 0.293-0.57) in group A, moderate to very good (kappa 0.535-1.00) in group B, good to very good (kappa 0.734-1.00) in group C and moderate to very good (kappa 0.590-1.00) in group D.

Conclusions: Pocket-size echocardiograph enables an expert echocardiographer to perform reliable bedside examinations. When used by briefly trained medical students it provides an acceptable diagnostic value with notable learning curve effect.

Key words: pocket-size echocardiograph, medical student, transthoracic echocardiography

INTRODUCTION

Echocardiographic examination is universally accepted as a non-invasive, side-effect-free procedure, providing a "visual supplement" to physical examination, enabling quick and thorough assessment of patient's cardiovascular status. Moreover, in emergency situations it enables immediate bedside evaluation of patients' status. However, conventional high-end systems, even though designed as mobile, in reality prove difficult to transport. The necessity for bedside examination, results in a time-consuming and impractical transfers of heavy and vulnerable devices. Portable ultrasound

devices, being the size of a laptop and battery powered, were meant to be the answer to the problems mentioned above [1.2]. The properties of portable echocardiographs facilitated transport, however, they were still too large and too heavy to be constantly available to a physician.

The next level of miniaturization led to the creation of even smaller, pocket – size echocadiographic devices, which to certain extent embody the concept of the visual stethoscope created by Roelandt *et al.* in 1978 [1,2]. Due to their size and weight, which result in ultraportability, physicians can carry them during an entire shift and use them for bedside monitoring of patients' status and screening for major abnormalities. Maximum simplicity of operation potentially allows different groups of medical professionals to perform basic echocardiographic examination. An important issue arises regarding the training requirements and level of experience necessary for proficient use of such personal imaging device. Hence, the question about the accuracy of such an examination and possible improvement of its diagnostic value along with gained experience needs to be answered.

MATERIAL AND METHODS

Study population

The study group consisted of 90 unselected patients (63 men, 27 women; mean age: 64±14 years) admitted or referred to the cardiac intensive care unit and 30 patients from an out-patient clinic referred for scheduled echocardiographic examination (21 men, 9 women; mean age: 62±17 years) by their treating doctor. Main reasons for mentioned referral were hypertension, stable angina, suspected valve disease, monitoring of patients suffering from chronic heart failure, heart function assessment prior to scheduled non-cardiac surgery. As for patients examined in the intensive care unit, the main reasons for hospitalization were: chest pain, pulmonary thrombosis, exacerbation of chronic heart failure, symptomatic arrhythmias. Patients in unstable condition were excluded from the research if their participation in this study could delay the standard treatment procedures.

Study protocol

The group of patients admitted or referred to the cardiac intensive care unit underwent bedside transthoracic echocardiographic (bTTE) examination performed by two medical students, with no previous practical experience in echocardiography, who have completed a brief training program created for the purpose of this study (n=60 patients) or by a cardiologist specialized in echocardiography (certified by Polish Society of Cardiology, with ten-year experience and volume load of examinations/year larger than 250) (n=30 patients) with the use of the pocket-size echocardiograph (Acuson P10; Siemens Medical Solutions USA, Inc.). The out-patients (n=30 patients) underwent similar examination performed by two medical students. In all examinations performed by them, both of the students were present and the interpretation was a result of consensus, but images were acquired by the same student in all patients.

Within 24-hours of beside examination all patients underwent standard transthoracic echocardiographic (sTTE) examination performed by another experienced echocardiographer using a full sized high-end echocardiograph and all imaging modes (M-mode, grayscale imaging, color Doppler, pulsed wave Doppler, continuous wave Doppler, tissue Doppler imaging).

The study protocol was approved by the Ethics Committee of our institution (approval number RNN/8/10KE) and written consent was obtained from all participants.

Pocket-size echocardiograph

Acuson P10 is a pocket-size echocardiograph – it weighs 700 g including battery and transducer, with dimensions fitting the size of a white coat's pocket. Device is equipped with 3.7" LCD screen and is ready to work after 5-second boot time. It uses a 2-4 MHz probe that enables only grayscale imaging in fundamental and harmonic imaging. Depth, gain and measurements controls are available.

Operators and imaging protocol

Two medical students (10^{th} and 8^{th} semester) with no previous experience in echocardiography completed an intensive 5-day course (5 hours a day) concerning the basics of echocardiography. During the course, the program of which was designed exclusively for the purpose of this study, the students became acquainted with theoretical fundamentals of echocardiography: techniques of obtaining elementary transthoracic views and their assessment in terms of pathologies, left-ventricular systolic function evaluation and heart cavities measurements according to American Society of Echocardiography guidelines [3]. Subsequently, students accompanied an experienced echocardiographer in analyzing recorded echocardiographic examinations in order to distinguish normal heart function and morphology and examples of commonly encountered abnormalities. In the last stage of this course, students underwent hands-on training in obtaining different echocardiographic views and in real-time assessment of basic aspects of cardiac morphology and function (40 examination performed by each trainee). The device used for hands-on training was a pocket-size ultrasonograph, Acuson P10 (Siemens Medical Solutions USA, Inc.). During this last stage the students learned about the device's controls and measurement functions.

During bTTE the acquisition of standard parasternal and apical views was obligatory, whereas use of other views (suprasternal and subcostal) were left to examiners' discretion. The duration of examination was recorded and quality of acquired images was assessed by examiner with the use of

3-grade scale: good/acceptable/unacceptable. Major findings were recorded using simplified questionnaire:

- dilatation of left ventricle (end-diastolic diameter>5.6cm), right ventricle (end-diastolic diameter>2.8cm), left atrium (diameter>4.0cm), ascending aorta (diameter>3.4cm): yes/no
- mitral, aortic valve pathology: yes/no
- left ventricular global systolic function: severely impaired (ejection fraction EF<40%) / moderately impaired (EF 40%-60%) / normal (EF>60%)
- presence of wall motion abnormalities: yes/no
- pericardial effusion: none or minor / major

During bTTE the sizes of cavities were assessed visually, with an option of measurements when regarded necessary by examiner.

The results obtained with bTTE did not affect the course of treatment. However, we have attempted to analyze what possible diagnostic benefit or misdiagnosis could such examination provide. For this reason, the recorded findings of bTTE were then compared with the results of sTTE. Subsequently, the patients' documentation was analyzed in order to assess whether bTTE provided any additional (compared to patient's history and physical examination), clinically significant information. If such additional, clinically significant findings of bTTE were not confirmed by sTTE, these findings were classified as significantly misleading.

Results were analyzed separately in 4 subgroups of patients: group A (n=30 patients) and B (n=30 patients) were respectively first and second halves of cardiac intensive care patients examined by students, group C (n=30 patients) consisted of cardiac intensive care patients examined by an experienced echocardiographer and group D (n=30 patients) – out-patients examined by students.

Statistical analysis:

Continuous and categorical variables are expressed as mean ± SD and as percentages (%), respectively. Kappa statistics were used to determine the concordance between bTTE and sTTE findings. Kappa value 0.81 to 1.0 was considered as a very good strength of agreement, 0.61-0.80–good, 0.41-0.60–moderate, 0.21-0.40–fair and <0.2 as a poor strength of agreement.

RESULTS

Duration of bTTE and quality of images

Mean time of bTTE in groups A, B, C and D was 6.3±1.5 minutes, 5.4±1.1 minutes, 2.8±1.2 minutes and 4.7±1.1 minutes, respectively (all differences observed between groups were statistically significant).

The quality of images in groups A and B were described as acceptable in 39 (65%) patients, good in 20 (33.3%) patients, whereas 1 (1.7%) patient (from group A) was excluded from analysis due to student's inability to acquire images of sufficient quality. In group D, acceptable and good quality images were obtained in 17 (56.7%) and 13 (43.3%) patients, respectively. The experienced echocardiographer (group C) obtained images of good and acceptable quality in 19 (63.3%) and 11 (36.7%) patients, respectively.

Agreement between bTTE and sTTE

The vast majority (107/120, 89.2%) of the patients had abnormal examinations. There were only 7 (7.8%) completely normal examinations in the in-patients group (A, B and C) and 6 (20%) normal examinations in group D.

Table 1. **The agreement between standard transthoracic echocardiography and bedside transthoracic echocardiography performed with the use of pocket echocardiograph.**

	Agreement (kappa value)			
	Group A (n=29) 1st half of intensive care patients Student	Group B (n=30) 2nd half of intensive care patients Student	Group C (n=30) Intensive care patients Echocardiographer	Group D (n=30) Out-patients Student
LV enlargement	0.387	0.577	0.927	0.627
RV enlargement	0.346	0.535	0.760	0.590
LA enlargement	0.47	0.795	0.851	0.800
Ao dilatation	0.402	0.553	0.918	0.672
Mitral valve pathology	0.633	0.712	0.889	0.651
Aortic valve pathology	0.293	0.87	0.902	0.630
Wall motion abnormalities	0.449	0.76	0.734	0.865
LV global function	0.57	0.87	0.912	0.840
Pericardial effusion	-	1.0	1.0	1.0

LV- left ventricle, RV- right ventricle, LA –left atrium, Ao-aorta

Agreement between sTTE (considered in this case as a golden standard) and major findings on bTTE performed with a pocket echocardiograph is presented in *Tab. 1*. In group A, the agreement was fair to moderate (kappa values ranging from 0.293 to 0.57), whereas in group B the agreement was moderate to very good (kappa values ranging from 0.535 to 1.00). Similarly the agreement in group D was moderate to very good (kappa values ranging from 0.590 to 1.00). In group C, the agreement was good to very good (kappa values ranging from 0.734 to 1.00).

Additional clinical value

In the study groups A and B, total number of 45 pathologies in 31 patients influencing further treatment plan were recognized. bTTE succeeded in identification of 33 of them in 26 patients. In 6 cases, results of bTTE were considered significantly misleading, indicating the presence of nonexistent pathology.

Majority of diagnosed abnormalities concerned the left ventricle, including wall motion abnormalities with or without left ventricle dilatation and global dysfunction prevailed. Among 24 abnormalities recorded with sTTE, 21 were also identified with bTTE. In 4 cases results of bTTE suggested the presence of wall motion abnormalities whereas as diagnosed with sTTE lack thereof proved to be of significant influence. The remaining significant findings were identified in the following proportion: 6 out of 9 left atrium dilatation, 2 out of 4 aortic dilatation, 1 out of 3 right ventricle dilatation, 2 out of 3 mitral valve pathology, 1 out of 2 aortic valve pathology. One case of pathology concerning the left atrium and 1 pathology related with right ventricle were recorded as significant misdiagnoses.

In group C, all of 21 pathologies present were identified in bTTE, however, 3 (2 wall motion abnormalities and 1 left atrium dilatation) among bTTE results were considered significantly misleading.

In group D, 7 out of 10 present pathologies were diagnosed; non-identified abnormalities were in 2 cases related with mild global dysfunction (which was in 1 case accompanied with left ventricle dilatation) and in 1 patient concerned the mitral valve pathology.

DISCUSSION

Our study is one of the first to present results concerning application of a pocket-size echocardiograph by novice echocardiographers after completion of a brief training program.[4,5] The main finding is that pocket-size echocardiograph enables them to detect major abnormalities with an acceptable diagnostic value, which increases with the number of performed examinations. When used by an experienced sonographer the pocket echocardiograph allows for reliable basic bedside examinations.

The level of availability of echocardiography is constantly rising. However, full-sized high-end echocardiographs are costly and access to standard echocardiographic examinations is limited by manpower and equipment constrains. The introduction of pocket-size ultrasonographs may be another milestone in the quickly evolving world of medical diagnostics. Previous studies with the use of pocket-size echocardiographs showed, that when used by echocardiography specialists, these devices can provide reliable and accurate answers to basic clinical concerns [6-8]. Egan *et al.* [6] showed, that addition of the limited scan assessing the left ventricular size and function to the standard clinical procedures can have an immediate impact on the clinical management. Study by Fukuda *et al.* [7] also showed that the evaluation of cardiac chamber size and function by means of a pocket echocardiograph can be efficient when performed during clinical rounds. Our study also indicates that an experienced echocardiographer can benefit from usage of discussed devices.

However, the question arises, whether the basics of echocardiographic examination should be taught during medical studies and be treated similarly to the other examination skills that need to be mastered? DeCara's *et al.* [9] showed, that 10th semester medical students short course concerning basics of echocardiography and addition of echocardiographic examination to standard physical examination resulted in a significant increase of detection rate of cardiac diseases. Similar findings were observed in internists without formal training in echocardiography [10]. Study by Martin *et al.* [11] indicated, that introducing echocardiography into physical examination procedure performed by a briefly trained clinician significantly improved diagnostic accuracy in cases of left ventricular dysfunction, cardiomegaly and pericardial effusion. Other studies also suggest, that adding brief echocardiographic examination to the traditional physical examination improve the accuracy and offers cost and time saving benefits [12-16]. Extraordinary easiness of operating pocket echocardiograph is undoubtedly its great advantage, which along with ultraportability distinguish them from laptop-size portable echocardiographs. Both these features may result in a possibly wider usage of pocket-size echocardiograph by large and diverse groups of medical professionals. Moreover, progress in technology results in constant improvements in pocket-size imagers. New functions, such as color Doppler, are being added without affecting simplicity and portability. Frederiksen *et al.* [17] reported, that during focus-assessed transthoracic echocardiography pocket echocardiograph enables obtaining images of quality comparable to larger, high quality portable system. Moreover, Culp *et al.* [5] demonstrated, that a cardiology fellow after 2 months of echocardiography training is able to obtain images of satisfactory quality and assess ejection fraction with good agreement with formal reported TTE.

Although recent scientific findings and technical improvements allow us to regard pocket-size echocardiographs as reliable diagnostic tools one should not overestimate their value in highly specialized cardiology. By no means can examinations performed with the use of a pocket-size echocardiograph be perceived as an alternative to complete diagnostic echocardiography; according to European Association of Echocardiography Recommendations they should be rather considered as a part of physical examination [18].

Treated this way, pocket-size echocardiographs could still provide clinicians with plethora of valuable information as a complement to the regular physical examination performed in the coronary or intensive care unit. pocket-size echocardiographs could also allow for first cardiac evaluation in ambulances. Due to its ultra-portability it could also prove useful during cardiac consultations. In the reality of outpatient clinic the inclusion of pocket-size echocardiographs to the screening programs or treating it as a mean of selecting candidates for a complete echocardiographic examination could also be suggested. The question if some of above mentioned clinical procedures could be performed by briefly trained non-expert echocardiographers still remains to be answered, just as a form of the training itself needs to be further established.

The results of our present study should be viewed in the context of widely recognized training guidelines which recommend a 6-month full-time program with at least 350 TTE examinations performed as the training for the basic level in echocardiography [19]. American Society of Echocardiography allows for performing a brief echocardiographic examination with the use of the portable ultrasonographs by level 1 specialists which equals 3 months training with minimum 75 examinations performed [20,21]. Since the usage of a pocket-size echocardiograph by wider groups of medical professionals is a new concept, there are no guidelines concerning the schedule of required pocket-size echocardiograph training. Recently published European Association of Echocardiography recommendations on the use of pocket-size echo devices emphasized the necessity of specific training and certification for all users, but training duration is not explicitly specified. An ad hoc designed training may allow medical students to use pocket-size devices with a high diagnostic yield. However, an appropriate training in echocardiography is deemed necessary for those using these devices and not fully conversant with ultrasound techniques.

Study Limitations

This is a single center study with limited study population. However, 120 examined patients represented relatively wide range of clinical problems. The interpretation of the examination was a result of a consensus achieved between two examiners. Such measures may not reflect conditions of clinical standard, however, they were introduced to average examiners' skill level. The Acuson P10 device enables only a grayscale imaging, whereas newer devices offer also color Doppler imaging. The training protocol was not based on any official guidelines, and was prepared for the purpose of this study only. The assessment of image quality was not based on any objective scale and each of examiners evaluated it subjectively. Medical professionals without formal training in echocardiography were represented only by two medical students. One can assume that if an inexperienced physician underwent a similar training program comparable or better results could be expected.

CONCLUSIONS

Pocket-size echocardiograph enables an expert echocardiographer to perform reliable basic bedside examinations. When used by briefly trained medical student, it provides an acceptable diagnostic value regarding the detection of basic structural and functional findings with notable learning curve effect. Further studies are required to address the issue of training of non-experts in echocardiographic examinations with pocket-size systems.

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