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Original Article

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Handheld Echocardiography in a Clinical Practice Scenario: Concordances Compared to Standard Echocardiographic Reports

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ABSTRACT

BACKGROUND: The purpose of this study was to assess the utility of a handheld device (HH) used during common daily practice and its agreement with the results of a standard echocardiography study (STD) performed by experienced sonographers and echocardiographer.
METHODS: A prospective follow-up was conducted in an adult outpatient echocardiography clinic. Experienced sonographers performed the STD and an experienced echocardiographer performed the HH. STD included 2-dimensional images, Doppler and hemodynamics analysis. Hemodynamic assessment was not performed with the HH device because the HH does not include such technology. The images were interpreted by blinded echocardiographers, and the agreement between the reports was analyzed.
RESULTS: A total of 108 patients were included; and the concordance for left ventricle (LV) ejection fraction (EF), wall motion score index, LV and right ventricle (RV) function, RV size, and mitral and aortic stenosis was excellent with κ values greater than 0.80. Wall motion abnormalities had good concordance (κ value 0.78). The agreement for LV hypertrophy, mitral and aortic regurgitation was moderate, and tricuspid and pulmonary regurgitation agreements were low (κ values of 0.26 and 0.25, respectively).
CONCLUSIONS: In a daily practice scenario with experienced hands, HH demonstrated good correlation for most echocardiography indications, such as ventricular size and function assessment and stenosis valve lesion analyses.

Keywords: Transthoracic echocardiography; Ultrasonography; Cardiovascular diagnostic techiniques; 2D echocardiography

INTRODUCTION

Echocardiography is a relatively innocuous and inexpensive diagnostic tool. These characteristics may lead to an excessive number of unnecessary examinations. Due to this

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Conflict of Interest
The authors have no financial conflicts of interest.

Author Contributions
Conceptualization: Blume GG, Clausell N; Formal analysis: Berro PG; Methodology: Lechinewski LD, Vieira IP, Tsang T; Project administration: Blume GG, Moura LAZ, Tsang T; Supervision: Clausell N; Visualization: Moura LAZ; Writing - original draft: Blume GG, Vieira IP; Writing - review & editing: Bertinato GP, Machado Júnior PAB.

fact, echocardiography laboratories in most public hospitals have long waiting lists and overly stressed physicians and technicians.[1)2)] This dilemma leads us to an inquiry on how to effect rapid assessment of valvular and left ventricular function in clinical practice without overwhelming the echocardiography laboratories.

Technical evaluation has rapidly evolved during the last decades, and hand-held (HH) echocardiography devices have gained widespread acceptance in their use not only by physicians, but also by untrained professionals.[3-11)] HH echocardiography has already proved to be a reliable tool in clinical examination and for the screening of several cardiovascular disorders.[3)5-7)9)11-31)] Although the initial intuitive reaction is that the HH device would be significantly useful, its image quality does not match that of high-definition machines, which may affect study quality. Other limitations for its broad use center on the fact that the knowledge about this technique derives from small studies with unselected patients and limited scope of diagnostic comparison.[19)23)25)32)33)]

Critical assessment of HH is imperative for its clinical use as there exists some anxiety in the medical community toward the broad use of HH. New research is necessary to establish how well this new technology conforms to the standard of care. The aim of our study was to assess the usefulness of one new miniaturized HH device model in a common daily practice and compare its concordances with standard (STD) high-definition echocardiography studies performed by experienced sonographers and echocardiographer.

METHODS

The study was approved by the Research Ethics Board of the University of British Columbia and Vancouver Coastal Health Research Institute. A prospective follow-up was made in a 2-week period between April and May of 2016. Patients that presented to a routine comprehensive echocardiographic assessment with the STD device (Philips iE33; Philips Ultrasound Inc., Bothell, WA, USA) at the outpatient Echocardiography Laboratory of the Vancouver General Hospital (Vancouver, BC, Canada) were also scanned with a HH scanner (Vscan; GE Vingmed Ultrasound AS, Horten, Norway) by an experienced echocardiographer. The STD examination was performed as daily practice, first by an experienced sonographer and then rechecked and reported by an experienced echocardiographer. Each examiner was blinded to the results of other examinations.

The analysis for Vscan HH was made at the scanner. Parasternal long axis, parasternal short axis at multiple levels, and apical four and two chamber views were acquired. The clinician that interpreted the HH device and STD had access to the patient's medical record and the indication for the study. Assessment of chamber size, function and hypertrophy from the HH device was made visually. The STD analysis data were transferred to a computer and analyzed offline by the cardiologist.

The quality of the endocardial segmental border delineation was categorized as 0 = not possible, 1 = poor, and 2 = good for HH scans. The image quality from the HH device was categorized as 0 = terrible, 1 = bad, 2 = average, and 3 = good. Assessment of regional wall motion was defined as 1 = normokinesia, 2= hypokinesia, and 3 = akinesia. Global systolic function was analyzed with visually estimated EF by the HH device and visually estimated or calculated by the Simpson biplane method on STD. EF was graded as 1 = normal, 2 = mild, 3 = moderate, and 4 = severe

LV dysfunction. LV dimensions were graded according to the severity of the enlargement as 1 = normal, 2 = mild, 3 = moderate, and 4 = severe. LV hypertrophy was grade as 1= normal, 2= mild, 3= moderate or 4= severe hypertrophy. Left atrial size, right atrial size and right ventricle dimension and function were analyzed in the same manner. Grading of the severity of valve regurgitation or stenosis was based on visual interpretation of cardiac morphology and color Doppler on the HH analysis (0 = none, 1 = minimal, 2 = mild, 3 = moderate, and 4 = severe). On the STD analysis the reviewer was able to use routine echocardiography methods to grade the regurgitation or stenosis such pressure half time, proximal isovelocity surface area, the continuity equation or mean gradient.

The HH imaging acquisition protocol was similar to the standard protocol but limited to 2D visualization as this device model does not include continuous or pulsed wave Doppler assessment. After completing the exam, a file describing endocardial border, wall motion analysis, left and right anatomy, valve anatomy and presence or absence of pericardial effusion and rheumatic disease was filled. The agreement between the reports were analyzed.

Concordant findings

The STD and the HH reports were compared to identify the degree of agreement of the findings. STD reports were considered as the gold standard method. The echocardiography findings of the HH device were considered as concordant with those of STD when the variables analyzed had:

- The same grade for regurgitant valvular heart disease,
- The same grade for ventricular or atrial enlargement,
- The same grade for dysfunction or hypertrophy,
- Level of severity agreement,
- Agreement of results for presence or absence of stenotic valvular heart disease, and
- Agreement of results for presence or absence of wall motion abnormalities.

Data analysis and statistics

Continuous variables were reported as the mean (standard deviation); categorical variables were reported as the number (%) of the total group. Categorical variables from the HH device and STD reports were grouped into 2 or 3 levels. For continuous and normally distributed data, paired t tests were used; for non-normally distributed data, Wilcoxon's signed-rank tests were used. Agreement was defined by κ statistic for categorical variables with 2 levels and weighted k statistic for categorical variables with 3 levels. κ statistics of 0.41 to 0.6 were considered moderate agreement, 0.61 to 0.8 as good agreement, and 0.81 or greater as excellent agreement.[34] Continuous measurements were compared using Spearman's correlation, Pearson correlation, Lin correlation and Bland-Altman analysis. Statistical analyses were performed using PASW (SPSS, Inc, Chicago, IL, USA).

RESULTS

One hundred ten patients were enrolled in the study. Two were excluded because of incomplete images, and data from the remaining 108 patients were analyzed. The mean age was 62.4 ± 16.7 years and the mean duration of the HH study was 263 ± 90 seconds. Mean body surface area was 1.86 ± 0.25 cm^2, with a mean height of 1.69 ± 0.11 cm and a mean weight of 75.3 ± 18.3 kg. The main characteristics of our study population are demonstrated in **Table 1**.

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Table 1. Baseline characteristics of the study population

Characteristic	Value
Age (years)	62.4 ± 16.7
Height (cm)	1.69 ± 0.11
Weight (kg)	75.3 ± 18.3
Wall motion abnormalities	21 (19.4)
LV dysfunction	22 (20.4)
LV enlargement	23 (21.3)
LV hypertrophy	39 (36.1)
RV enlargement	15 (13.9)
RV dysfunction	10 (9.3)
LA enlargement	78 (72.2)
RA enlargement	69 (63.9)
Any degree of mitral regurgitation	108 (100.0)
Any degree of aortic regurgitation	64 (59.3)
Any degree of pulmonary regurgitation	92 (85.2)
Any degree of tricuspid regurgitation	108 (100.0)
Any degree of mitral stenosis	4 (3.7)
Any degree of aortic stenosis	20 (18.5)

Values are presented as mean ± standard deviation or number (%).
LV: left ventricle, RV: right ventricle, LA: left atrium, RA: right atrium.

Table 2. HH and STD average grade for each assessed variable

Variable	HH grade (average)	STD grade (average)
Endocardial segmental border delineation	0.36	NA
Image quality	2.61	NA
Wall motion	1.10	1.07
Global LV function	1.24	1.27
LV dimension	1.29	1.21
LV hypertrophy	1.47	1.20
RV size	1.13	1.06
RV function	1.05	1.05
LA size	2.15	2.38
RA size	1.81	2.23
Mitral regurgitation	2.83	2.52
Aortic regurgitation	3.00	1.44
Pulmonary regurgitation	3.00	1.62
Tricuspid regurgitation	3.25	2.64
Mitral stenosis	0.06	0.02
Aortic stenosis	0.34	0.33

HH: hand-held, LA: left atrium, LV: left ventricle, NA: not applicable, RA: right atrium, RV: right ventricle, STD: standard.

Each variable assessed through HH device and STD echocardiography was graded as described in the Methods section. The average grades for these variables using both echocardiography methods are demonstrated in **Table 2**. Considering STD as the gold standard method, the *Vscan* HH device had similar results for RV function. For wall motion, LV dimensions and hypertrophy, and RV size and function, the portable pocket device tended to overestimate the findings, even though the findings were similar among the devices. However, the HH assessment for LV function and left atrium (LA) and right atrium (RA) size tended to be underestimated, but with similar grades. In the valve analysis, regurgitation tended to be overestimated by the HH device and, although the grades for mitral and aortic stenosis between the two methods were close, HH tended to reveal higher scores.

Regarding the sensitivity and specificity, the *Vscan* HH device showed a greater benefit in the assessment of LV systolic dysfunction with the sensitivity ranging from 73% to 100% and specificity from 64% to 96%. Additionally, evaluation of chamber dimensions, pericardial

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Table 3. Agreement between HH and STD echocardiography

Variable	No. of patients	Echocardiography, mean ± SD		Agreement (95% CI)
		STD	HH	
LV ejection fraction (%)	108	57 ± 8	58 ± 8	0.86 (0.80–0.90)
Wall motion score index	108	1.1 ± 0.2	1.1 ± 0.3	0.84 (0.78–0.89)
Wall motion score index*	20	1.36 ± 0.2	1.53 ± 0.2	0.72 (0.46–0.88)
Wall motion abnormalities (present vs. absent)	108	NA	NA	0.78 (0.66–0.90)
LV dimension (normal, mild, moderate or severe enlargement)	108	NA	NA	0.77 (0.70–0.84)
Global LV function (normal, mild, moderate or severe dysfunction)	108	NA	NA	0.85 (0.78–0.92)
LV hypertrophy grade (normal, mild, moderate or severe hypertrophy)	108	NA	NA	0.60 (0.53–0.67)
RV size (normal, mild, moderate or severe enlargement)	108	NA	NA	0.83 (0.75–0.91)
RV function (normal, mild, moderate or severe dysfunction)	108	NA	NA	0.82 (0.71–0.92)
LA size (normal, mild, moderate or severe enlargement)	108	NA	NA	0.42 (0.35–0.49)
RA size (normal, mild, moderate or severe enlargement)	108	NA	NA	0.42 (0.35–0.49)
Mitral regurgitation (none, mild, moderate or severe)	108	NA	NA	0.42 (0.35–0.48)
Aortic regurgitation (none, mild, moderate or severe)	108	NA	NA	0.56 (0.49–0.62)
Pulmonary regurgitation (none, mild, moderate or severe)	108	NA	NA	0.25 (0.17–0.32)
Tricuspid regurgitation (none, mild, moderate or severe)	108	NA	NA	0.26 (0.20–0.33)
Mitral stenosis (none, mild, moderate or severe)	108	NA	NA	0.96 (0.87–1.05)
Aortic stenosis (none, mild, moderate or severe)	108	NA	NA	0.82 (0.75–0.88)

κ statistics for dichotomous variables, weighted *K* for multilevel variables and as Linn concordance correlation for continuous variables.
CI: confidence interval, HH: hand-held, LA: left atrium, LV: left ventricle, NA: not applicable, RA: right atrium, RV: right ventricle, SD: standard deviation, STD: standard.
*Wall motion agreement for patients with wall motion abnormalities only.

effusions and blood volume estimations were possible by evaluating the dimensions of the inferior vena cava.

Concordant findings

The results from concordant findings in both ultrasound methods are described in **Table 3**, which shows the mean values and correlation coefficients for continuous variables on STD and *Vscan* HH studies.

There was an excellent correlation for the assessment of the LV ejection fraction; the κ statistic agreement value was 0.86 (95% confidence interval [CI], 0.80–0.90). A Bland-Altman plot of LV ejection fraction distribution differences between methods is shown in **Figure 1**, and a correlation plot of LV ejection fraction by STD and HH device is represented in **Figure 2**.

The wall motion score index also showed an excellent correlation at 0.84 (95% CI, 0.78–0.89) when all patients were considered. When only the patients with wall motion abnormalities were considered, the concordance for the wall motion index was good, with the agreement of 0.72 (95% CI, 0.46–0.88). The correlation for the detection of wall motion abnormalities (yes or no) was good at 0.78 (95% CI, 0.66–0.90) and for global estimated LV function was

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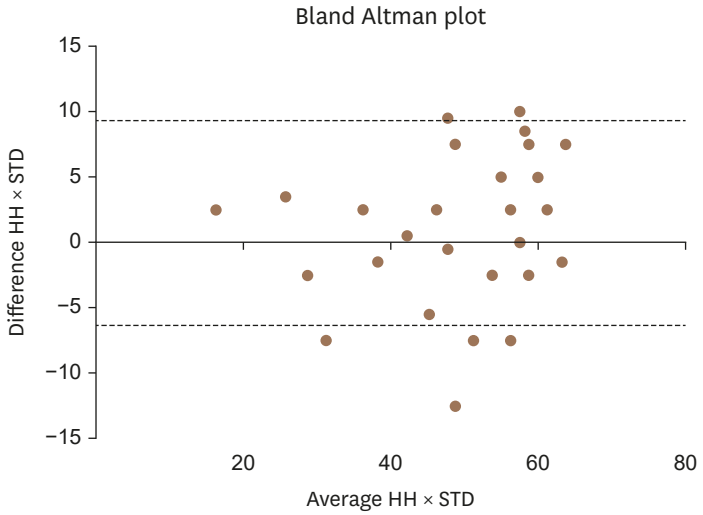

Figure 1. Distribution of LVEF differences between the methods.
HH: hand-held, LVEF: left ventricle ejection fraction, STD: standard.
*Tolerance of 5% difference.

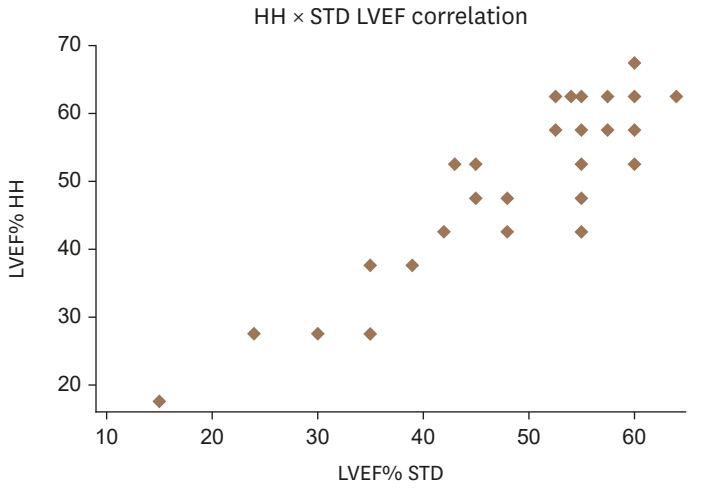

Figure 2. Correlation of LVEF by the methods.
HH: hand-held, LVEF: left ventricle ejection fraction, STD: standard.

excellent at 0.85 (95% CI, 0.78–0.92). Assessment of LV dimension had a good correlation at 0.77 (95% CI, 0.70–0.84). There was only a moderate agreement on grading of LV hypertrophy with a correlation of 0.60 (95% CI, 0.53–0.67). The agreement for left and right atrium size was also only moderate at 0.42 (95% CI, 0.35–0.49) for both. Right ventricle analyses showed an excellent agreement for both size and function, 0.83 (95% CI, 0.75–0.91) and 0.82 (95% CI, 0.71–0.92), respectively. All ventricular devices were detected on both echocardiography methods.

In the valve analysis, the concordance for regurgitation was only moderate for mitral and aortic regurgitation, with an agreement of 0.42 (95% CI, 0.35–0.48) and 0.56 (95% CI, 0.49–0.62) respectively. As for the estimation of pulmonary and tricuspid regurgitation, the concordance was terrible, with an agreement of 0.25 (95% CI, 0.17–0.32) for pulmonary valve and 0.26 (95% CI, 0.20–0.33) for tricuspid valve. Although the results for valve regurgitation

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were disappointing, better outcomes were observed concerning valve stenosis. The agreement for mitral stenosis was 0.96 (95% CI, 0.87–1.05) and for aortic stenosis was 0.82 (95% CI, 0.75–0.88). Both were considered excellent correlations. Reports for tricuspid and pulmonary stenosis were not mentioned because none of these types of lesions were found in the study population.

DISCUSSION

In the present study, we aimed to analyze the concordances between one HH device model and the STD in routine outpatient practice. Previous studies made the subtle suggestions that the HH technology could substitute for the STD even in the hands of untrained clinicians or students.[6)12)14)24)28)35)36)] Because of those suggestions, a detailed assessment of the technology is imperative, not only to evaluate the benefits of HH device use, but also to compare the results with those of a STD device to determine HH device limitations.

The use of the STD in clinical practice was compared to that of HH devices. An experienced echocardiographer conducted this STD study with no restriction of time or number of images acquired. The main difference from HH data, is that this method images were not reanalyzed offline and no measurements were made on the portable device. Our goal with this approach was to simulate a practical situation in which exams from the pocket devices are readily assessed and decisions are quickly made with just a glance.

The *Vscan* HH revealed a good to excellent correlation with the STD method in the quick evaluation of LV and RV size and function and in the assessment of wall motion abnormalities and valve stenosis. However, in LA and RA size analysis and mitral and aortic regurgitation the concordance was considered only moderate; and in pulmonary and tricuspid regurgitation, agreement was considered poor. We concluded regurgitant lesions and atrial size enlargements were usually underestimated on the HH device.

HH devices lack many features of the STD such as zoom, EKG synchronization, Doppler waves, frequency adjustments and live views. Therefore, valve regurgitation and atrial chamber analyses may be impaired. Because other studies have already shown this discordance between the two methods,[23)32)33)] our results for these lesions were expected.

Prinz and Voigt,[29)] in a previous study, demonstrated HH device success in assessment of regional wall motion and ejection fraction. Liebo et al.[25)] provided evidence that HH could be used in most STD applications, and data from Vourvouri et al.[32)] suggested that 98% of cardiac abnormalities was detectable by HH devices. Galderisi et al.[37)] concluded that pocket-size imaging devices can be useful for detecting subclinical cardiac abnormalities in asymptomatic outpatients.[24)28)31)37)38)]

The HH device model used in our study was demonstrated to be equally sensitive as the STD in assessing most cardiac qualitative parameters evaluated on echocardiography. These parameters include ventricle chambers dimension and hypertrophy, systolic function, wall motion abnormalities and score index and valve stenosis. Because of that, the *Vscan* HH device can be used with the same efficiency as the STD for clinically indicated echocardiographic studies like heart disease sequela, myocardial anatomy and evolution to heart failure.[1)]

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However, to work as a helpful bedside decision-making tool for clinicians, HH devices require adequate training. This is being accomplished at medical universities and teaching hospitals.[39][40] Knowledge of the HH device method's uses and limitations is crucial for obtaining reliable information. This is particularly true in scenarios in which the HH exam may be the only tool available such as in remote rural areas or during natural disasters.[41]

The present study had some limitations. The number of patients presented for routine comprehensive echocardiographic assessment was limited; therefore, these results may not be applicable to the general population. Additionally, the evaluation of the *Vscan* HH device and the STD machine was performed by an experienced echocardiographer; thus, our results may not be applicable to general physicians. More studies with a larger population are needed in order to evaluate the practical use of the HH device by unspecialized physicians in an everyday hospital setting.

In conclusion, our study found good to excellent agreement between the *Vscan* HH device and STD for assessing most of the parameters analyzed at echocardiography routine studies, like LV and RV function and size, wall motion abnormalities and score index and valve stenosis lesions. Since the evaluation of those parameters is the most common indications for echocardiographic studies, the HH device is a potential substitute for STD. However, when clinical conditions suggest valve regurgitation lesions, another diagnostic method should complement HH exam.

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