ECHOCARDIOGRAPHY-DOPPLER

Hand-Held Echocardiographic Devices:
What Do They Add to the Initial Cardiovascular Evaluation?

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Introduction and objectives. Hand-held echocardiographic devices have recently become available. Our objective was to determine, on the basis of clinical data and basic diagnostic techniques, whether hand-held devices offer additional information useful not provided by the initial cardiovascular diagnosis.

Patients and method. We prospectively studied the presence and severity (absent, mild, significative) of 7 frequent heart diseases (aortic or mitral stenosis-regurgitation, tricuspid regurgitation, and left ventricular systolic dysfunction-hypertrophy) in 36 consecutive patients (50% men; mean age 68 ± 12 years) with 3 different methods: clinical examination and basic complementary exams, hand-held echocardiography with 2D and color Doppler imaging (OptiGo™, Philips Medical Systems, The Netherlands) and a standard, last-generation transthoracic echocardiogram (Sonos 550™, Philips Medical Systems, The Netherlands). We compared the results obtained with the first two methods, and combined the results of both to compare these findings against the results obtained with standard electrocardiography. Percentage agreement and Somer's D, a measure of association between ordinal variables, were calculated.

Results. The hand-held device obtained better results than clinical examination (agreement 87 vs. 65%; D = 0.79 ± 0.04 vs. 0.19 ± 0.53) and identified severe lesions that were classified incorrectly by clinical examination in 39% (14/36) patients. However, in 8 patients (10 evaluations) it misclassified severe lesions.

Conclusions. In experienced hands, a hand-held echocardiographic device offers additional information not obtained from an initial cardiovascular diagnosis for common cardiovascular disorders, but it is no substitute for complete echocardiographic examination.

Key words: *Echocardiography. Diagnosis. Aortic stenosis. Aortic regurgitation. Mitral stenosis. Mitral regurgitation. Tricuspid regurgitation. Heart diseases. Heart failure.*

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Ecocardiograma portátil: ¿qué añade a la valoración cardiovascular inicial?

Introducción y objetivos. Desde hace poco tiempo disponemos de nuevos sistemas portátiles de ecocardiografía. Nuestro objetivo es determinar si un ecocardiograma portátil aporta información suplementaria al diagnóstico cardiovascular inicial, basado en datos clínicos y técnicas diagnósticas básicas.

Pacientes y método. Estudiamos prospectivamente la presencia y severidad (ausente, leve, significativa) de 7 cardiopatías frecuentes: estenosis-insuficiencia aórtica y mitral, insuficiencia tricuspídea y disfunción-hipertrofia ventricular izquierda en pacientes consecutivos mediante 3 técnicas distintas: valoración clínica junto con pruebas complementarias básicas, ecocardiograma portátil con imagen 2D y Doppler color (Optigo®, Philips Medical Systems) y ecocardiograma estándar de última generación (Sonos 5500®, Philips Medical Systems). Comparamos los resultados obtenidos mediante las primeras 2 técnicas y combinando los resultados de ambas, respecto al ecocardiograma estándar, mediante el porcentaje de concordancia y la medida de asociación D de Somers.

Resultados. Estudiamos a 36 pacientes (50% varones; edad, 68 ± 12 años). El ecocardiograma portátil obtuvo mejores resultados que la valoración clínica (concordancia del 87 frente al 65%; D = 0,79 ± 0,04 frente a 0,19 ± 0,53) e identificó lesiones significativas incorrectamente valoradas por la clínica en un 39% (14/36) de los pacientes; sin embargo, en 8 pacientes (10 valoraciones) valoró erróneamente lesiones significativas.

Conclusiones. El ecocardiograma portátil, en manos experimentadas, aporta información adicional al diagnóstico inicial de enfermedades cardiovasculares comunes, pero no resulta equivalente a un diagnóstico ecocardiográfico completo.

Palabras clave: *Ecocardiografía. Diagnóstico. Estenosis aórtica. Insuficiencia aórtica. Estenosis mitral. Insuficiencia mitral. Insuficiencia tricuspídea. Enfermedades cardiovasculares. Insuficiencia cardíaca.*

INTRODUCTION

In view of the high prevalence of cardiovascular di-

ABBREVIATIONS

CLI: clinical assessment, supported by electrocardiogram and chest x-ray.
HH: hand-held echocardiography.
TTE: transthoracic echocardiography.
C: percentage of agreement.
D: Somers' D.

seases and the clinical implications they entail, diagnosis should be as fast, accurate and reliable as possible. The clinical cardiologist´s initial opinion is based on data from the medical history, physical examination, electrocardiogram and chest x-ray, and these data can often be successfully used for gaining an approximate idea of the patient´s disease. Nevertheless, situations where a precise diagnosis of the disease is impossible are not infrequent.[1,2]

Echocardiography has brought about dramatic changes in the diagnosis of cardiovascular diseases,[3,4] as the degree of precision it provides was previously available only with invasive techniques. Recent technological advances in the field of echocardiography have overcome most of the initial shortcomings and limitations, although at the cost of significant increases in equipment prices and failure to reduce size. Because of these two factors—among others—large echocardiography laboratories have been organized to ensure efficient utilization of the equipment; thereby resulting in delays in patient screening.In recent years, new portable ultrasound models have been developed. These units are more comprehensive than previous devices (2D, color Doppler ultrasound, color Doppler energy, calibration, image storage, etc.), while also offering the advantages of portability, economy and ease of use, though not yet with all the features of a standard echocardiography unit. Nevertheless, they are initially attractive as an additional screening tool for cardiovascular disease. Because the technique has only recently become available, the exact diagnostic and clinical results to be expected from these models are still uncertain.The purpose of our study was to determine what additional information portable echocardiography devices provide for the initial clinical diagnosis obtained through the usual techniques (medical history, physical examination, electrocardiography and chest x-ray) when assessing a number of common cardiovascular diseases.

PATIENTS AND METHODS

Patients and variables

The study included 36 consecutive patients admitted

to the cardiology ward of our hospital between October 2001 and March 2002. We had no preliminary information on any of the patients with regard to the study variables. The patients' demographic characteristics, reason for hospital admission and list of diseases are shown in Table 1.

In all patients, the presence and grade of aortic stenosis and regurgitation, mitral stenosis and regurgitation, tricuspid regurgitation and left ventricular dysfunction and hypertrophy were evaluated prospectively, then semi-quantified as absent, mild or significant (greater than mild) by three different diagnostic methods: clinical assessment supported by the findings on electrocardiography and plain chest x-ray (CLI), hand-held echocardiography (HH) and standard transthoracic echocardiography (TTE). We also analyzed the combined results of CLI and HH, using the data provided by the latter only when the clinical diagnosis improved according to the semi-quantitative scale used in the study. Transthoracic echocardiography was used for the reference diagnosis in all cases. Additionally, for each patient and disease we recorded which of the two techniques gave the results closest to the final echocardiographic diagnosis.

Clinical assessment

The clinical assessment was performed by the cardiologists normally assigned to the patients admitted to the cardiology ward of our hospital; all specialists had more than 15 years of professional experience. Data obtained from the medical history, physical examination, electrocardiogram and plain chest x-ray were used for this assessment. The HH and TTE re-

TABLE 1. **Patient characteristics and reason for admission**

Number of patients	36
Male sex	18 (50%)
Age, years	68±12
Reason for admission	
Heart failure	9 (25%)
Ischemic heart disease 22 (61%)	
Arrhythmias	6 (17%)
Other	6 (17%)
Diagnostic TTE	
Aortic stenosis, N/M/S	30/3/3
Aortic regurgitation, N/M/S	23/11/2
Mitral stenosi, N/M/S	29/5/2
Mitral regurgitation, N/M/S	29/5/2
Tricuspid regurgitation, N/M/S	17/15/4
LV dysfunction, N/M/S	30/3/3
LV hypertrophy, N/M/S	18/10/8

Values are the number followed by the percentage in parentheses, or the mean±standard deviation.
TTE indicates transthoracic echocardiography; N, normal or none; M, mild; S, significant; LV, left ventricle.

sults were not known beforehand in any of the cases.

Hand-held echocardiography unit

We used the Optigo® system (Philips Medical Systems, Best, The Netherlands), which is equipped with a control unit composed of a liquid crystal display, rechargeable battery, simple control panel (depth, gain, position and color gain) and a system to review, analyze and digitally export the images obtained, as well as a 2.5-MHz transducer. The overall dimensions are 33.02 22.86 8.90 cm and the total weight is 3.36 kg (Figure 1). The system can obtain images in the 2D and standard color Doppler modes.

The hand-held echocardiography examination was done by cardiologists with high-level echocardiographic training (performance and interpretation of more than 300 standard studies) who were not aware of the results of the other two techniques.

Data from various slices in the parasternal, apical, subcostal and suprasternal views were assessed for each patient. The following parameters were evaluated to establish the semi-quantitative diagnosis (absent, mild, significant) obtained from HH: for valve stenoses, the valve morphology (thickening, calcification, anatomic abnormalities), movement, area in 2D mode, abnormalities of neighboring chambers, and left ventricular outflow or inflow turbulence; for valve regurgitation, valvular abnormalities in morphology or movement, enlargement of adjacent chambers and vascular structures, and characteristics of the regurgitant jet (vena contracta, width, area and relation to the regurgitant cavity); for left ventricular dysfunction, calculation of the shortening fraction when left ventricular morphology was adequate, and subjective estimate of the ejection fraction in various views, when it was not. The standard method (2D mode) was used for left ventricular hypertrophy, accessible because calibrated linear measurements can be made with the equipment.

Standard transthoracic echocardiography

Transthoracic echocardiography was performed by staff cardiologists with specialized echocardiographic training in the echocardiography laboratory of our hospital. These examinations were made with a late-generation system equipped with the usual imaging systems (Sonos 5500®, Philips Medical Systems, Best, The Netherlands), including 2D imaging with a second harmonic. None of the physicians performed the hand-held echocardiography examination and none were aware of the results from the other two techniques.

Figure 2 shows the quality of the image obtained by the two echocardiography systems after digitization.

Fig. 1. View of the portable system used in the study, indicating the difference in size compared with a normal stethoscope.

Statistical analysis

The results from the three diagnostic techniques were analyzed by measuring the asymmetric association of ordinal variables, Somers' D,[5,6] with transthoracic echocardiography as the independent variable. In this approach, the more similar the results of the technique studied are to those obtained by TTE, the closer the statistical value is to one.[6] The association was considered significant at a *P*-value of less than .05, and was analyzed for all the diseases as a whole, and studied separately. We also calculated the percentages of agreement (C) between the different diagnostic techniques.

RESULTS

Table 2 lists each of the abnormalities found, classified according to the reason for hospital admission. Because some patients had more than one abnormality and more than one reason for hospital admission, the sum of all abnormalities exceeds the number of pa-
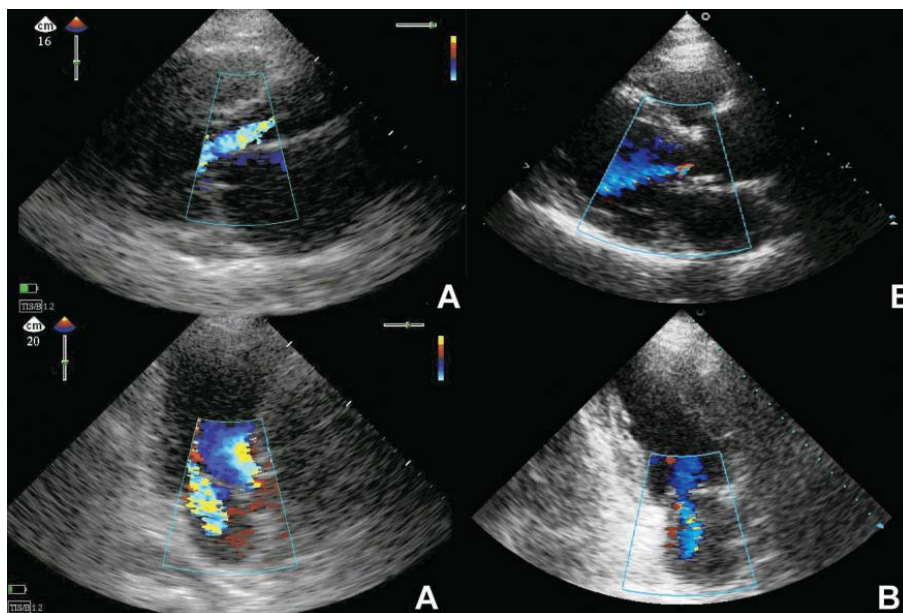
Fig. 2. Images corresponding to patients with aortic (long-axis parasternal view, top) and mitral (2-chamber view, bottom) regurgitation. The images were obtained using 2 echocardiography systems: portable (A) on left, and standard (B) on right.

tients and variables studied.

Table 3 lists the diagnoses obtained with CLI, HH, CLI+HH and TTE. Assessment of the seven variables in the 36 patients with the reference technique yielded 27/252 (11%) significant abnormalities, 62/252 (25%) mild abnormalities and 163/252 (64%) normal findings. Four patients had none of the abnormalities assessed in the study, 17 patients had a significant abnormality and 15 patients had only mild abnormalities.

Figure 3 and Table 4 show the percentages of agreement and the degree of association with the TTE diagnosis, respectively, versus the results obtained by CLI, HH and CLI+HH.

In comparison to CLI, the results of HH were more similar to those of our reference technique. In fact, the results of semi-quantitative assessment of valve stenoses and left ventricular dysfunction were virtually the same as those obtained with TTE. However, we found important discrepancies in the assessment of aortic and tricuspid regurgitation, and fewer discrepancies in mitral regurgitation and left ventricular hypertrophy. If we consider the increase in diagnostic precision of HH over CLI rather than the absolute values, the diseases that benefited most were valve regurgitation, mitral stenosis and left ventricular dysfunction-hypertrophy.

The combined study results for CLI+HH are shown in Figure 4, which indicates the percentage of all abnormalities found in the 36 patients. These figures are based on the seven study variables (n=252) for which each of the two techniques was more similar to the final diagnosis, both globally and for each disease separately. Clinical assessment was the closest technique overall in 3% (7/252), and HH in 26% (66/252) of the cases; the results obtained with the two techniques were similar in 71% (179/252). Table 4 shows the CLI+HH results, which were similar to those obtained with HH alone, both globally and for each study variable separately. (The only initially noteworthy difference, in the case of mitral stenosis, corresponds to discrepancies of one grade on the semi-quantitative scale in only 2 patients.)

When we analyzed the results according to the number of patients, HH detected significant morphological or functional abnormalities that were not properly classified by CLI in 14/36 cases. In 10 of these 14 patients, CLI did not detect 12 abnormalities diagnosed by HH (3 mitral stenosis, 1 tricuspid regurgitation, 2 left ventricular dysfunction, and 6 left ventricular hypertrophy). These 12 abnormalities were classified by TTE as significant in 8 cases and mild in 3. In one pa-

TABLE 2. **Description of final echocardiographic diagnoses, according to reason for admission**

	AS (M/S)	AR (M/S)	MS (M/S)	MR (M/S)	TR (M/S)	LVD (M/S)	LVH (M/S)	Total (M/S)
Heart failure	0/0	3/1	2/1	8/1	6/2	2/3	2/1	23/9
Ischemic heart disease	2/1	5/0	0/0	5/4	8/2	1/1	7/6	28/14
Arrhythmias	1/1	3/1	3/1	5/1	3/2	1/0	0/1	16/7
Other	0/1	2/0	2/1	4/0	3/0	0/0	2/0	13/2

LVD indicates left ventricular dysfunction; AS, aortic stenosis; MS, mitral stenosis; LVH, left ventricular hypertrophy; AR, aortic regurgitation; MR, mitral regurgitation; TR, tricuspid regurgitation; M, mild; other, miscellaneous; S, significant

TABLE 3. **Summary of the findings, according to type of disease and diagnostic method used**

	CLI			HH			CLI+HH			TTE		
	N	M	S	N	M	S	N	M	S	N	M	S
Total	211	28	13	170	59	23	179	53	20	162	62	27
AS	25	8	3	30	3	3	30	3	3	30	3	3
AR	32	2	2	27	7	2	28	6	2	23	11	2
MS	32	1	3	29	3	4	31	3	2	29	5	2
MR	27	7	2	16	18	2	17	16	3	15	16	5
TR	34	2	0	20	15	1	22	13	1	17	15	4
LVD	31	3	2	30	2	4	31	2	3	30	3	3
LVH	30	5	1	18	11	7	20	10	6	18	10	8

CLI indicates clinical assessment; LVD, left ventricular dysfunction; AS, aortic stenosis; MS, mitral stenosis; TTE, transthoracic echocardiography; LVH, left ventricular hypertrophy; AR, aortic regurgitation; TR: tricuspid regurgitation; MR, mitral regurgitation; M, mild; N, none; HH, hand-held echocardiography device; S, significant

Fig. 3. Comparison between the percentages of agreement with transthoracic echocardiography (TTE) versus clinical assessment (CLI), hand-held echocardiography (HH) and the combination (CLI+HH) of both.
TOT indicates total of patients; AS, aortic stenosis; AR, aortic regurgitation; MS, mitral stenosis; MR, mitral regurgitation; TR, tricuspid regurgitation; LVD, left ventricular dysfunction; LVH, left ventricular hypertrophy.
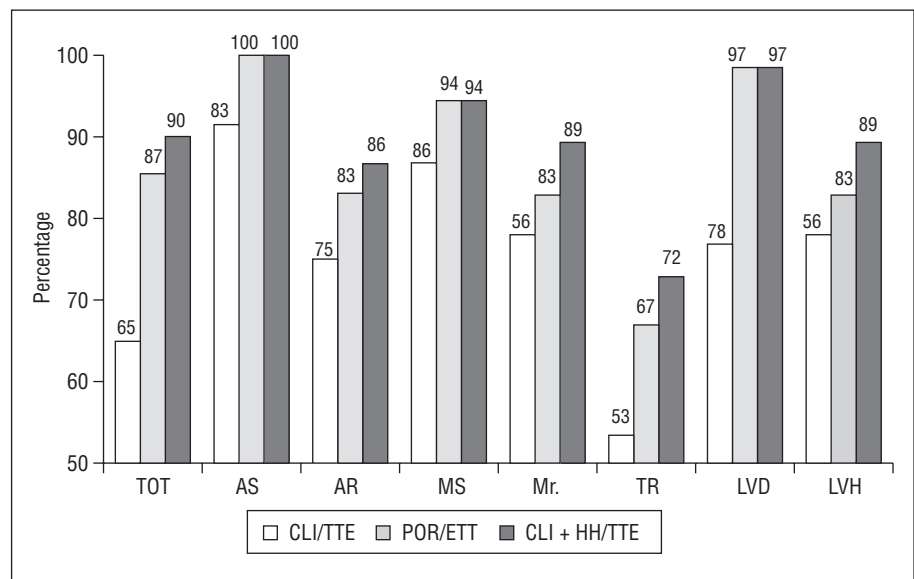
tient, HH identified one case of significant ventricular hypertrophy that was not confirmed on TTE. In the four other patients, CLI categorized the abnormalities as mild (aortic stenosis, 1 mitral regurgitation, 1 left ventricular dysfunction, 1 left ventricular hypertrophy). All of these lesions were later confirmed to be significant (at least moderately severe) by TTE. Similar results were obtained with HH.

Hand-held echocardiography underestimated or overestimated the severity of some lesions in 8 patients. In 4 of them, it underestimated the grade of the lesions (2 mitral regurgitation, 3 tricuspid regurgitation, 1 left ventricular hypertrophy; 6 abnormalities in all). Of these 6 abnormalities, only one was properly classified by CLI: 1 mitral regurgitation assessed by CLI and TTE as significant, but classified by HH as mild. The other 5 abnormalities were judged to be mild by HH but were not detected by CLI. In the other 4 patients, HH overestimated as significant an abnormality found by TTE to be mild or no-

TABLE 4. **Comparison of the degree of association between the results of clinical assessment (CLI), hand-held echocardiography (HH) and combined study (CLI+HH) versus standard transthoracic echocardiography (TTE)**

	CLI vs TTE D±SD	HH vs TTE D±SD	CLI+HH vs TTE D±SD
Total	0.19±0.53	0.79±0.04	0.80±0.04
AS	0.85±0.08	1.00±0.00	1.00±0.00
AR	0.36±0.14	0.61±0.14	0.64±0.13
MS	0.553+0.18	0.98±0.01	0.73±0.16
MR	0.39±0.12	0.77±0.08	0.85±0.06
TR	−0.10±0.66*	0.52±0.11	0.62±0.09
LVD	0.26±0.20*	0.99±0.02	0.84±0.15
LVH	0.16±0.11*	0.77±0.10	0.87±0.06

*Non-significant P.
D indicates Somers' D; SD, standard deviation; LVD, left ventricular dysfunction; AS, aortic stenosis; MS, mitral stenosis; TTE, transthoracic echocardiography; LVH, left ventricular hypertrophy; AR, aortic regurgitation; MR, mitral regurgitation; TR, tricuspid regurgitation; HH, hand-held echocardiography device.
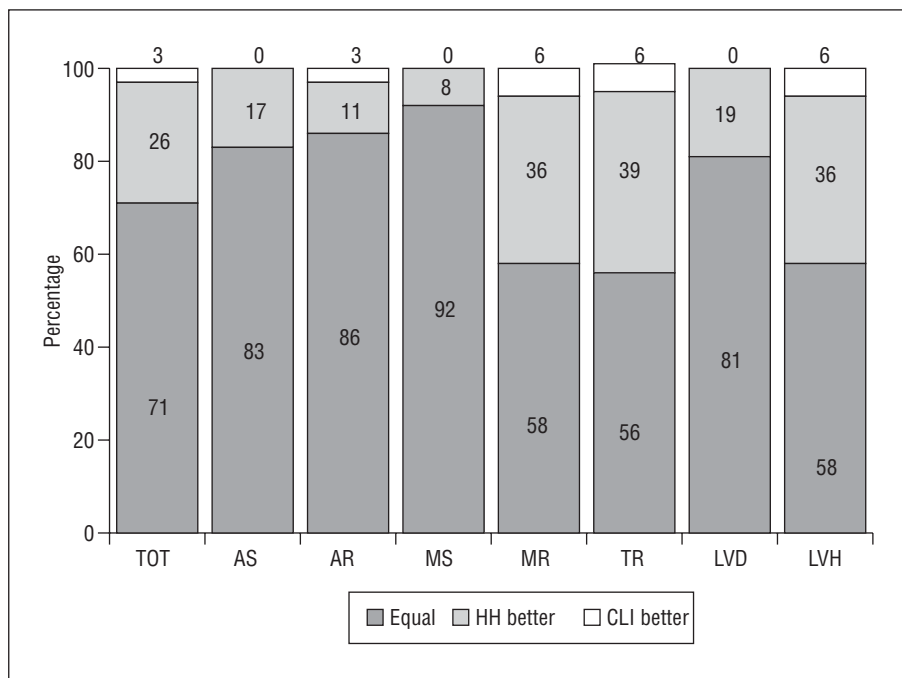
Fig. 4. Graph indicating which technique provides the closest diagnosis to transthoracic echocardiography: clinical assessment (CLI BETTER), hand-held echocardiography unit (HH BETTER) or both the same (EQUAL).
TOT indicates total; AS, aortic stenosis; AR, aortic regurgitation; MS, mitral stenosis; MR, mitral regurgitation; TR, tricuspid regurgitation; LVD, left ventricular dysfunction; LVH, left ventricular hypertrophy.

nexistent (2 mitral stenosis, 1 mild left ventricular dysfunction; 1 absent left ventricular hypertrophy).

DISCUSSION

The use of hand-held echocardiographic instruments was first described in the early 1980's. Nevertheless, the technique did not gain wide acceptance, perhaps because of the technical limitations of the initial models.[7]

Over the last 2 decades steady progress has been made in the miniaturization of echocardiography systems. As a result, techniques such as transesophageal echocardiography and intravascular echocardiography have become available and are now used in daily practice.[8] New portable echocardiography systems have recently appeared, offering several advantages over first-generation systems, including improved basic imaging quality in the gray scale, inclusion of color Doppler ultrasound or color Doppler energy modes, and the capacity for digital image analysis and storage.

Several previous studies compared the diagnostic effectiveness of the new portable ultrasound devices with results obtained from standard echocardiography systems.[9-12] The devices have also been shown to be useful for detecting other diseases not studied here, such as right ventricular dysfunction,[3,9,10] mitral valve prolapse,[10] ventricular septal defect,[10] pericardial effusion,[3] and abnormal regional contractility of the left ventricle.[9] An addition potential application is screening for fetal heart disease and some congenital heart diseases.[13] One of these studies compared the diagnoses obtained from clinical assessment and a portable

echocardiography device similar (but not identical) to the one used in our study. Nevertheless, in that study the same cardiologist performed both the CLI and the HH examinations, and therefore the comparison of these two techniques was not blind[10] as in our study. There are no studies that analyze what information the portable echocardiography unit adds to an expert clinical assessment when the latter includes basic complementary tests.

In our study, clinical assessment, along with information provided by an electrocardiogram and plain chest x-ray, attained the greatest precision in the semi-quantitative evaluation of stenotic valve lesions, and was slightly less precise for evaluating mitral regurgitation; the results, however, were acceptable only for aortic stenoses. In evaluations of tricuspid regurgitation and left ventricular dysfunction or hypertrophy, the results fell short of those obtained with the final echocardiographic diagnosis.

Nevertheless, with the HH device used in this study (not all current portable systems are equipped for the same image modes) we were able to identify and semi-quantify most of the heart diseases analyzed with a significant degree of similarity with respect to the diagnosis provided by standard echocardiography. (Accuracy was somewhat lower in tricuspid and aortic regurgitation, but was very good in all other lesions.) Because of the limitations of HH (absence of M mode, continuous or pulsed Doppler, second harmonic, etc.), we did not attempt to differentiate between moderate or major disease, but simply combined all cases into the category *significant*.

The combined results of CLI and HH were no diffe-

rent from those obtained with HH alone. In fact, CLI was better than HH in only 3% (7/252) of the cases, whereas the opposite occurred in 26% (66/252).

If we consider the information added by HH (or CLI+HH) to the diagnosis obtained with CLI, the former is most useful for the semiquantitative diagnosis of tricuspid regurgitation and left ventricular dysfunction or hypertrophy, followed by mitral stenosis and mitral or aortic regurgitation. In aortic stenosis, some additional information is obtainable, although not as much as for the lesions just noted. Thus HH identified significant abnormalities in 14/36 patients in whom CLI considered these abnormalities to be mild or even absent. Nevertheless, HH missed significant abnormalities in 8 out of 36 patients.

Despite the positive results obtained in this and earlier studies, portable systems such as the one we used obviously do not provide all the diagnostic tools of standard echocardiography. These shortcomings may explain the discrepancies seen in some of our variables, and also those observed in certain clinical contexts considered in other studies, such as screening of intensive care patients,[11] where the results have not been as good. Specifically, the diagnosis seems to be particularly complex in situations that require precise hemodynamic studies. These situations might include cardiac tamponade, constrictive or restrictive heart disease, diastolic dysfunction, definitive diagnosis of valve disease, inadequate echographic window due to obesity or postoperative period, and diseases such as endocarditis or artificial valve dysfunction, where higher-than-average imaging quality is often needed. In order to evaluate these problems suitably with HH, new advances in the miniaturization of echocardiography systems will be needed. Based on these findings, the American Society of Echocardiography has stated that this technology, when used in portable systems such as the one tested in our study, does not meet the requirements for providing a complete echocardiographic examination.[8]

Despite its problems, the immediacy, simplicity, availability and acceptable results of this technique continue to offer several advantages over standard echocardiography. Therefore, the use of HH in specific situations, e.g., as a complement to the clinical assessment when screening for cardiovascular disease, whether in an out-of-hospital or hospital environment, or in the follow-up for certain previously diagnosed conditions, may be worthwhile.[4] Because of the limitations of HH in its current form, a complete echocardiographic diagnosis should be obtained when the diagnosis is inconclusive. Furthermore, in all existing studies, the echocardiograms were interpreted by physicians with extensive experience or specific, pre-study training in echocardiographic diagnosis. Hence the results are not applicable to studies done by personnel with other types of qualification.

Our study had several obvious limitations, particularly a small sample size, which may affect the reproducibility of our results. Another important limitation was the use of transthoracic echocardiography as the reference technique. Nevertheless, all the TTE studies were done by cardiologists with more than 10 years of experience in echocardiography, using equipment based on the latest technology. Although we are well aware of the limitations of TTE, we can assume that the TTE findings are valid.

CONCLUSIONS

In experienced hands, a hand-held echocardiographic device provides additional information not obtained from a clinical assessment supported by basic complementary tests, thereby greatly aiding the initial cardiovascular assessment. However, the hand-held device still has limitations in comparison with late-generation standard color Doppler echocardiography.

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