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Left ventricular hypertrophy screening using a hand-held ultrasound device

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Aims To test the diagnostic potential of a hand-held ultrasound device for screening for left ventricular hypertrophy in a hypertensive population using a standard echocardiographic system as a reference.

Methods One hundred consecutive hypertensive patients were enrolled. An experienced investigator performed measurements of the thickness of the anterior septum and posterior wall using the parasternal 2D-long axis view and the end-diastolic dimension of the left ventricle with both imaging devices. Left ventricular hypertrophy was defined as an increase in left ventricular mass $\geq 134\ g \cdot m^{-2}$ for men and $\geq 110\ g \cdot m^{-2}$ for women, when indexed for body surface area and $\geq 143\ g \cdot m^{-1}$ for men and $\geq 102\ g \cdot m^{-1}$ for women, when indexed for height.

Results Sixty-five men and 35 women were studied (age 60 ± 11 years); mean duration of hypertension: 13 ± 11 years; mean blood pressures: systolic 150 ± 20 mmHg and diastolic 89 ± 11 mmHg. The anterior septum and posterior wall were visualized in all patients with both imaging devices. The standard echocardiographic system identified left ventricular hypertrophy by body surface area in 18 (18%) patients and by height in 26 (26%) patients. The agreement between the standard echocardiographic system and the hand-held device for the assessment of left ventricular hypertrophy was 93%, kappa: 0·77 (left ventricular mass/body surface area) and 90%, kappa: 0·76 (left ventricular mass/height).

Conclusions We conclude that hand-held devices can be effectively applied for screening for left ventricular hypertrophy in hypertensive patients.
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Key Words: Left ventricular hypertrophy, left ventricular mass, hand-held ultrasound device.

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Introduction

Left ventricle hypertrophy which expresses end-organ damage from hypertension, is an independent potent marker of cardiovascular risk in arterial hypertension[1–3]. It is considered as an asymptomatic pre-clinical stage of the cardiovascular disease, that may lead to cardiac events[4]. Also, reversal of left ventricular hypertrophy can improve the patient's outcome[5]. Early identification of left ventricular hypertrophy and treatment is therefore the cornerstone of appropriate management. The electrocardiogram (ECG), although commonly available and inexpensive has proven insensitive in detecting the presence of left ventricular hypertrophy[6–8]. Echocardiography is a sensitive means for measurement of left ventricular thickness and has comparable accuracy to the magnetic resonance imaging (MRI) especially in patients with normal left ventricular geometry[9–10]. New and small echocardiographic devices are now becoming available which could be used as screening tools for various pathomorphologies of the heart.

The aim of the present study was to evaluate the potential and diagnostic accuracy of a recently developed portable hand-held ultrasound system for screening for left ventricular hypertrophy in hypertensive patients using a standard two-dimensional echocardiographic system as a reference.

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Table 1 Patients characteristics

Age (years)	60 ± 11
Male, n (%)	65 (65%)
Years of HT	13 ± 11
Heart rate (beats . min^{-1})	71 ± 11
SBP (mmHg)	150 ± 20
DBP (mmHg)	89 ± 11
BMI (kg . m^{-2})	27 ± 4

HT=hypertension; SBP=systolic blood pressure; DBP=diastolic blood pressure; BMI=Body Mass Index.

Study patients and methods

Study population

One hundred consecutive hypertensive patients visiting the outpatient clinic (65 men, mean age 60 ± 11 years) were enrolled in the study. Patient characteristics are presented in Table 1.

Study design

The study protocol consisted of an echocardiographic examination by means of a standard echocardiographic system, Hewlett Packard (Sonos 5500; Andover, Mass, U.S.A.) or Vingmed (System V; Horten, Norway), and an echocardiographic examination by means of a hand-held device. Both studies were performed within 10 days (range 2–7 days) by the same investigator with experience in echocardiography. The order of the second visit was arranged by a study coordinator unaware of the results.

For the evaluation of the intra-observer variability the same observer performed the same test in 30 patients within a week after the last examination, provided they had unchanged characteristics. For the evaluation of inter-observer variability, a second observer, who was blinded to the results of the other investigator, performed the echo study with the hand-held device in 30 patients.

All patients had a baseline electrocardiogram performed. The ECGs were examined for evidence of left ventricular hypertrophy using the Sokolow–Lyon (the sum of the amplitudes of the S wave in V_1 and the R wave in V_5 or V_6, 35 mm) and the sex-specific Cornell criteria (the sum of the amplitudes of the S wave in V_3 and the R wave in aVL, >20 mm in women and >24 mm in men)[11].

All patients were known hypertensives. Blood pressure was measured in the supine position. For the study, we took the average of 12 measurements over 60 min with a 5 min interval using a semi-automatic device (Accutor 2, Datascope, Datascope Corp. CA, U.S.A.).

Echocardiographic methods

Linear measurements of the thickness of the anterior septum and posterior wall and the left ventricular end-diastolic dimension were obtained at the parasternal, two dimensional long axis view with both devices on-line, according to American Society of Echocardiography recommendations[12]. The measurements reported are the mean of five cycles.

Left ventricular mass was calculated from the Devereux-modified American Society of Echocardiography (ASE)-cube equation[10]: 0·80 (1·04 [(IVST+PWT+LVED)^3 − LVED^3]+0·6g. The left ventricular mass index (g . m^{-2}) was calculated by dividing the left ventricular mass by body surface area. Since this index can fail in identifying left ventricular hypertrophy in obese individuals[13] a second index was calculated by dividing the left ventricular mass by height (g . m^{-1}). Body surface area (m^2) was derived from the Du Bois formula[14]: $0{\cdot}007184 \times (\text{weight [kg]}^{0{\cdot}425} \times (\text{height [cm]})^{0{\cdot}725}$. Body mass index (kg . m^2) was derived from the average weight and height.

Left ventricular hypertrophy was defined as an increase in the left ventricular mass index ≥134 g . m^{-2} for men and ≥110 g . m^{-2} for women, when indexed for body surface area[15–17], or ≥143 g . m^{-1} for men and ≥102 g . m^{-1} for women, when indexed for height[13,16].

The inter- and intra-observer variability was 96% and 98%, respectively.

The ultrasound stethoscope

The SonoHeart™ (SonoSite Inc., Bothell, Washington, U.S.A.) hand-held ultrasound system (weight 2·4 kg, Fig. 1) was used in this study. It is equipped with a small 2–4 MHz phased array broadband transducer and operates on a rechargeable lithium ion battery or AC power. The two-dimensional control settings are comparable to a standard echocardiographic device and a caliper is integrated in the unit for linear measurements. SonoHeart™ has a storage memory of 50 images and can be connected to a video-recorder, a printer or an external monitor. Colour power Doppler flow mapping is also integrated into the system.

Statistics

Descriptive statistics were reported as mean ± SD or by frequency percentages. The difference between the measurements of the left ventricular mass indexed for body surface area and the height of those two devices can be appreciated from Fig. 2 (a) and (b) with the Bland-Altman[18] plot graphic.

The agreement for the measurements between the two examination techniques was assessed from 2 × 2 tables using weighted kappa statistics. Kappa values <0·4, between 0·4 and 0·75, and >0·75 were considered to represent poor, fair to good and excellent agreement, respectively, based on Fleiss's classification[19].

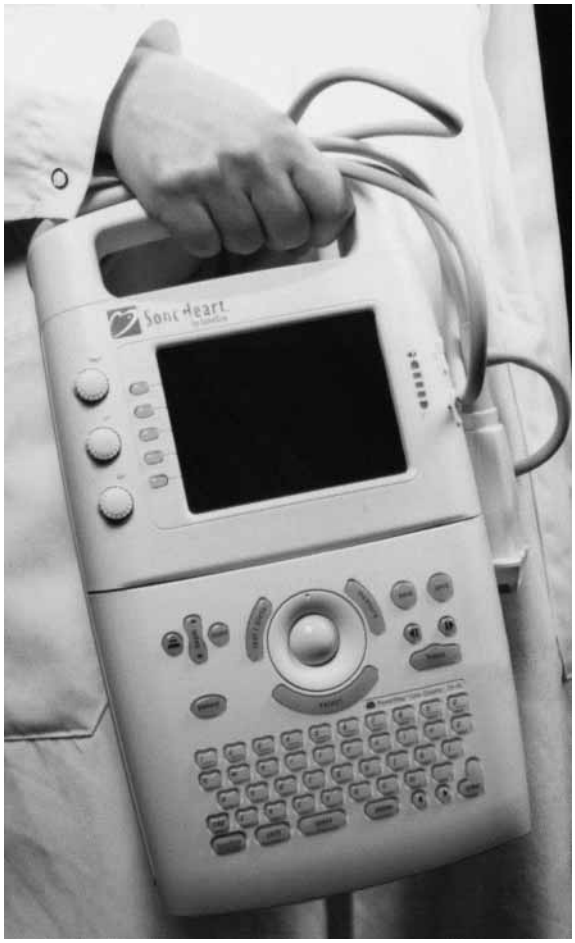


Figure 1 **Photograph of the SonoHeart™ device, a hand-held ultrasound imager, used in this study.**

Results

Clinical characteristics

The mean systolic blood pressure was 150 ± 20 mmHg and the diastolic blood pressure 89 ± 11 mmHg. The mean heart rate was 71 ± 11 beats . min^{-1}.

Electrocardiography

Four patients were found to have left ventricular hypertrophy according to the Sokolov–Lyon criteria and 13 according to the Cornell criteria. The sensitivity of the ECG for the detection of left ventricular hypertrophy was, respectively, 5% and 16% and the specificity was, respectively, 96% and 87%.

Measurements and agreement

Visualization was feasible in all patients with both imaging devices. The results of the measurements of the thickness of the anterior septum and the posterior wall and the dimension of the left ventricle with both examination techniques are summarized in Table 2.

The mean left ventricular mass indexed by body surface area was $96{\cdot}2 \pm 36$ g . m^{-2} with the standard echocardiographic system and 103 ± 33 g . m^{-2} with the hand-held device. Using the threshold of ≥ 134 g . m^{-2} for men and ≥ 110 g . m^{-2} for women the standard echocardiographic system identified left ventricular hypertrophy in 18 (18%) patients (nine women and nine men). The agreement between the two methods was 93%, kappa 0·77 (Fig. 3(a)).

The mean left ventricular mass indexed by height was $111{\cdot}5 \pm 43$ g . m^{-1} with the standard echocardiographic system and 120 ± 40 g . m^{-1} with the hand-held device. Using the threshold of ≥ 143 g . m^{-1} for men and ≥ 102 g . m^{-1} for women the standard echocardiographic system identified left ventricular hypertrophy in 26 patients (13 women and 13 men). The agreement between the two methods was 90%, kappa=0·76 (Fig. 3(b)).

Discussion

The presence of left ventricular hypertrophy, calculated as an absolute left ventricular mass has an independent prognostic value on top of age and blood pressure[3,20,21]. Recent studies have reported good reliability for echocardiographic measurements of left ventricular mass[22,23].

Our study showed that this new, hand-held device could be effectively used for screening for left ventricular hypertrophy in office practice. Recently, we demonstrated in a previous study the efficacy and high accuracy of this small imaging device in assessing the pathomorphology and function of the heart enhancing and extending the physical examination to allow goal-oriented examination, such as screening[24].

Although echocardiography can assess left ventricular hypertrophy accurately compared to the 'gold standard' MRI, the World Health Organisation–International Society of Hypertension (WHO–ISH)[25] and the Joint National Committee on prevention, detection, evaluation and treatment of high blood pressure[26] do not recommend routine echocardiography in all hypertensive patients. Thus, in patients categorized as high risk patients (having cardiovascular risk factors or an end-organ damage), treatment is already indicated and echocardiography results will not change their management[27]. However, echocardiography is recommended in patients with concomitant heart disease[27,28] and in patients with 'stage one' hypertension (patients with high–normal blood pressure who do not have clinical cardiovascular disease, target organ damage or other risk factors). This is recommended in order to avoid misclassification as 'mild' hypertension in patients that have an end-organ damage as left ventricular hypertrophy[25,26,28,29]. Both, Black and Sheps[30,31] support this view introducing limited echocardiographic protocols.

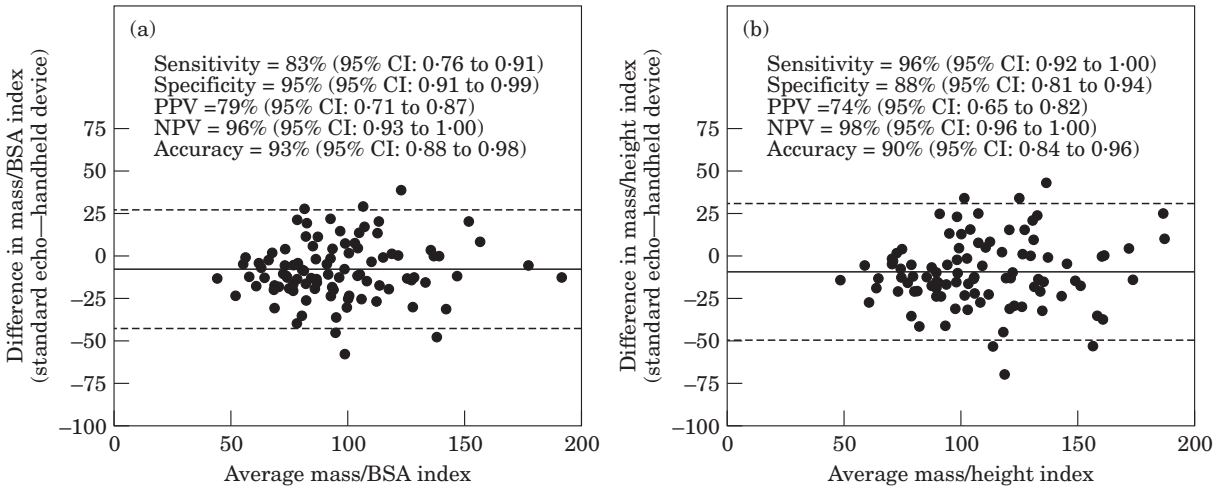


Figure 2 **Bland–Altman plot, demonstrating the magnitude of the difference between the measurements with the two techniques (differences plotted against their mean average) of (a) left ventricular mass indexed for body surface area (BSA) and (b) left ventricular mass indexed for height. SD=2 standard deviations of the mean difference in the measurements of the two devices. Using standard echocardiographic system as the gold standard, the sensitivity and specificity of the hand-held device for screening of the presence of left ventricular hypertrophy were calculated as was the positive predictive value (PPV), negative predictive value (NPV) and accuracy.**

Table 2 Measurements (in cm) of the anterior septum (AS), the posterior wall (PW) and the left ventricular end-diastolic dimension (LVED) with both imaging devices

Type of examination	Mean			SD			Range of measurements		
	AS	PW	LVED	AS	PW	LVED	AS	PW	LVED
Standard echo	1·18	0·92	4·85	0·29	0·20	0·71	0·5–2·2	0·4–1·3	3·4–6·8
Hand-held device	1·21	1·0	4·8	0·26	0·16	0·66	0·7–2·3	0·6–1·4	3·5–6·6
SE-hand-held	− 0·03	− 0·08	0·05	0·03	0·04	0·05	—	—	—

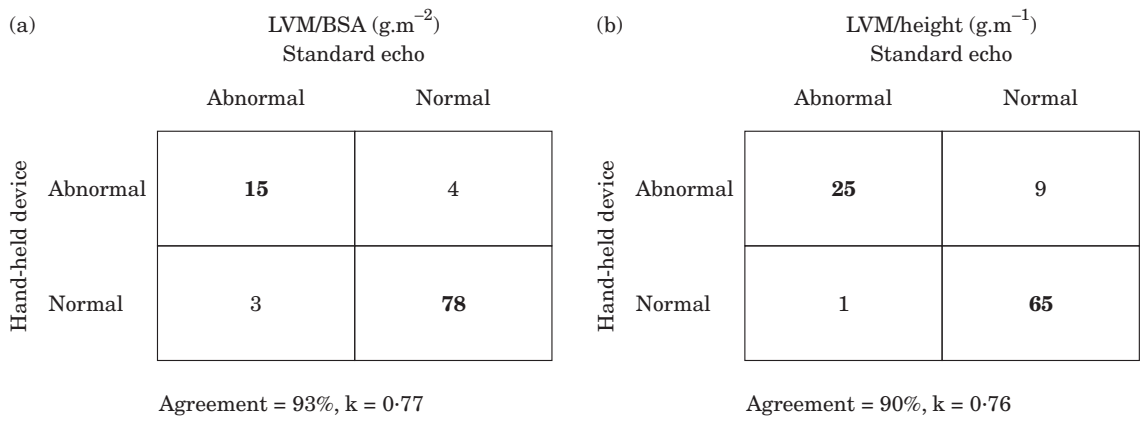
SD=standard deviation; Number of patients:100.

However, the indication of echocardiography in hypertensive patients may be broadened, as this new and inexpensive (∼1/10th of the price of a standard echocardiographic system) hand-held ultrasound device becomes widely available. In our view, such small hand-held imaging devices, reducing the cost and being ultra-portable and easy to use, will allow routinely echocardiographic examination in all hypertensive patients. Performing as an extension to physical examination they will provide the clinician with immediate, valuable information about prognosis and risk classification, assisting him in his decision of therapy. Of course, the initiation of aggressive therapy is dependent on not only the presence of left ventricular hypertrophy but also on other parameters such as cardiovascular risk factors and end-organ damage. Furthermore, it is becoming increasingly clear that we should aim for aggressive treatment in most hypertensive patients.

The efficacy of the selected therapy could be followed with the hand-held device by serial estimation of left ventricular mass with every visit at the outpatient clinic. However, the reliability of left ventricular mass measurements depends on many factors, such as the experience of the operator, the age of the patient, the body habitus or the presence of an abnormal left ventricular geometry or emphysema. Furthermore the amount of regression with therapy also plays a significant role in the likelihood of true changes[23].

By analysing the left ventricular geometric pattern, risk stratification can be carried out: patients with normal left ventricular architecture have the best prognosis, those with concentric remodelling or eccentric hypertrophy have intermediate, and those with concentric left ventricular hypertrophy have the worst prognosis[3,25,32]. Furthermore, echocardiography provides us not only with left ventricular mass determination, but with additional valuable information such as left ventricular systolic function or valvular abnormalities.

The method used most frequently for the diagnosis of left ventricular hypertrophy is still standard electrocardiography. Although the ECG has low sensitivity and specificity in recognising left ventricular hypertrophy, it



Number of patients: 100.
The numbers inside the table express the absolute number of patients
Abnormal = left ventricular hypertrophy

Figure 3 **Agreement of the left ventricular mass (LVM) indexed by body surface area (BSA) (a) and by height (b), measured by the hand-held device and the standard echocardiographic system.**

should not be abandoned in patients with known or suspected coronary artery disease as it provides additional information on ischaemia, previous myocardial infarction and rhythm abnormalities.

Left ventricular mass determination, especially with the M-mode based methodology, can be unreliable in an asymmetric heart. In the presence of such an anatomy, the 3D echocardiogram and the ECG-gated magnetic resonance imaging have a higher accuracy and reliability. However, albeit they are superior compared to conventional echocardiographic methods, they have a higher cost and a varied availability[33].

The study was performed by a cardiologist with experience in echocardiography. We believe that physicians can be trained to use this hand-held device and to recognize and distinguish normal from abnormal findings. In case of an abnormal finding or in case of doubt an echocardiographic study with a standard echocardiographic system performed by an experienced investigator should follow. However, training and licensing for use of these devices by non-cardiologists will become an important issue in the future.

Recently, Goodkin *et al.*[34] studied the use of the hand-held device at the point-of-care and compared it to the physical examination. They reported that the use of this device by cardiologists improved the detection of important cardiovascular findings. However, they pointed out that such a hand-held device cannot be a substitute for the final diagnosis, in case of abnormal findings. This is in concordance with the study performed by Spencer *et al.*[35] in critically ill patients. Moreover, Schiller[36] comments that further evaluation of these devices will improve their practical use.

Limitations

In this study, we calculated the left ventricular mass by the Devereux modified (ASE)-cube equation. Due to the absence of the M-mode feature of the hand-held device the measurements were performed with the use of callipers on the two-dimensional parasternal long axis view according to the American Society of Echocardiography recommendations[12]. The same measuring technique was used for both devices for performance comparison.

The hand-held device used in this study had colour power Doppler flow mapping instead of the traditional colour Doppler. Furthermore, it had no Doppler modalities with which to obtain haemodynamic data. By now, spectral Doppler and colour Doppler are integrated in the new generation of personal ultrasound imagers.

Conclusion

The hand-held ultrasound device, being ultra-portable, and inexpensive could become part of the clinical examination in high-risk patient groups, performing like an excellent screening tool.

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