

Pocket-Sized Transthoracic Echocardiography Device for the Measurement of Cardiac Chamber Size and Function

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Background: A pocket-sized portable transthoracic echocardiographic (pTTE) imaging device is commercially available, but its feasibility and accuracy in the assessment of cardiac chamber size and function has not been fully compared with the results of standard TTE (sTTE) examination.

Methods and Results: The target population comprised 125 unselected patients who underwent sTTE and pTTE examinations. The left ventricular (LV) diastolic and systolic dimensions, fractional shortening (FS), the thickness of the interventricular septum (IVS) and of the LV posterior wall (PWT), left atrial (LA) dimension, and ascending aorta diameter were measured. Echocardiographic measurements were completed for both pTTE and sTTE in all patients (feasibility 100%). LV dimensions, FS, IVS, PWT, LA dimension, and aorta diameter obtained by pTTE showed excellent correlation and agreement with sTTE ($r=0.87-0.98$, all $P<0.001$). Observer variabilities for these measurements were similar between pTTE and sTTE.

Conclusions: In the present study, pTTE with the Acuson P10 was feasible and accurate for assessing cardiac chamber size and function. (Circ J 2009; 73: 1092–1096)

Key Words: Echocardiography; Imaging; Ventricular function

Technological advances in electronic miniaturization have resulted in the creation of small, portable transthoracic echocardiographic (pTTE) devices. The major advantage of a portable device is being able to provide immediate information both within and, for the first time, outside the hospital setting. Previous studies have reported that pTTE is superior to physical examination, and comparable with complete standard TTE (sTTE) as a diagnostic tool in clinical practice.¹⁻³ Physical examination is recognized as an initial screening method, but the skill set required to perform physical examinations has unfortunately deteriorated over the past 2 decades as medical technology has advanced.⁴⁻⁶ Therefore, visualizing the heart as well as being able to calculate limited quantitative measurements of the cardiac chambers and their function, may result in improved patient care and/or understanding.

Compared with a stethoscope, previous portable devices were too large and heavy (≈ 2.5 kg) for physicians to carry while making rounds. A pocket-sized imaging device has better portability and agility, enhancing the use of pTTE.⁷ We investigated the feasibility and accuracy of pTTE for assessing cardiac chamber size and function.

Methods

Study Population

The study group consisted of 125 unselected patients (70 males, mean age 70 ± 13 years) who were scheduled for sTTE to evaluate left ventricular (LV) function: 65 patients with coronary artery disease (24 with a history of myo-



Figure 1. The pocket-sized transthoracic echocardiography device, Acuson P10, showing the body of the system (Left) and the transducer (Right).

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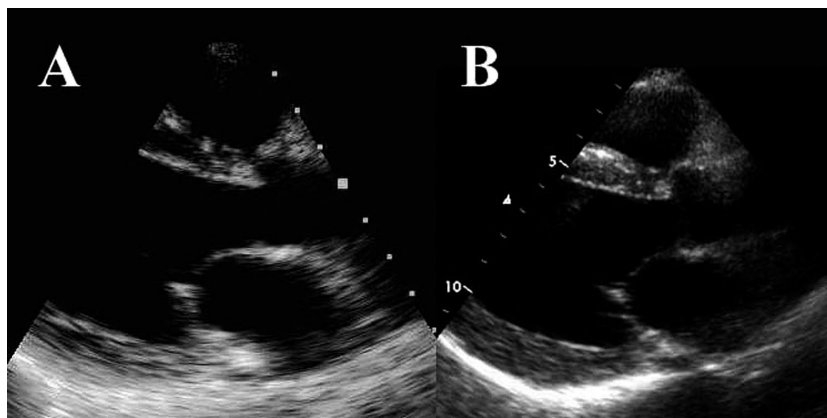


Figure 2. Parasternal long-axis view: (A) portable transthoracic echocardiography and (B) standard transthoracic echocardiography.

cardial infarction), 21 patients with hypertension, 11 with valvular heart disease, 8 with dilated or hypertrophic cardiomyopathy, 10 with pulmonary hypertension, and 10 with arrhythmia. Initially, 90 patients had pTTE immediately after sTTE. Both echocardiographic examinations were done in the echocardiographic laboratory by expert sonographers. In the later 35 patients, pTTE was performed by the physician at the bedside and those patients had their sTTE examination in the echocardiographic laboratory 3±4 days later. Stable hemodynamic conditions were confirmed during this period.

Commercially available echocardiographic systems were used for the sTTE examination, including Sequoia 512 (Siemens Medical Solutions, Mountainview, CA, USA), Aplio SSA-770 (Toshiba Medical Systems, Tokyo, Japan), and Vivid 7 (GE Medical Systems, Milwaukee, WI, USA). This study was approved by the Ethics Committee of the Osaka Ekisaikai Hospital.

pTTE

The pTTE was performed with the Acuson P10 (Siemens Medical Solutions) (**Figure 1**), which has a 64-element phased array transducer with a frequency range of 2–4 MHz. The device has tissue harmonic imaging, as well as automatic time gain compensation and digital storage capabilities. The total weight of the system, including the transducer, 3.7 inch display and control panel, is 0.725 kg. The size of the unit and transducer are 56 mm and 33 mm in height, 97 mm and 48 mm in width, and 145 mm and 136 mm in length, respectively. The rechargeable batteries are fully charged in 2.5 h (75% charge in 1 h), and the set-up time for the image acquisition is less than 10 s. The device has measurement packages that include linear measurement caliper capabilities.

The parasternal long-axis view was obtained with pTTE and sTTE (**Figure 2**). The following echocardiographic parameters were measured according to the recommendation of the American Society of Echocardiography:⁸ LV end-diastolic and end-systolic dimensions (LVDd, LVDs), the thickness of the basal interventricular septum (IVS) and posterior wall (PWT) at end-diastole, left atrial dimension (LAd), and ascending aorta diameter. LV fractional shortening (FS) was then calculated as (diastolic dimension–systolic dimension)/diastolic dimension×100.

In addition, the presence or absence of LV regional wall motion abnormalities (RWMA) and pericardial effusion were assessed by pTTE and sTTE, respectively. RWMA was defined as a segment with hypokinesis, akinesis or dyskinesis. The pericardial effusion was diagnosed as an

echo-free space within the pericardial layers.

Statistical Analysis

Continuous values are expressed as mean±standard deviation (SD). Comparisons between 2 groups for the parametric data were made using the t-test. Correlations between the sTTE and pTTE results were obtained using least squares fit linear regression analysis. Differences were considered significant at $P<0.05$. Differences between sTTE and pTTE results were also compared with the mean values obtained by sTTE and pTTE using the Bland-Altman method,⁹ with the limits of agreement defined as $\pm 2SD$ of the difference between the 2 methods.

Inter-observer variability for the LV dimensions, FS, IVS, PWT, LAd, and aorta diameter was obtained by analysis of 30 random patients by 2 independent blinded observers. Intra-observer variability was performed by analysis of the other 30 patients by the same observer at 2 different time points. The results were analyzed by the Bland-Altman method.

Results

Echocardiographic measurements were completed for pTTE and sTTE in all patients (feasibility 100%). The range of echocardiographic parameters by sTTE was 31–67 mm for LVDd, 19–60 mm for LVDs, 10–51% for FS, 7–15 mm for IVS, 7–15 mm for PWT, 20–59 mm for LAd, and 20–38 mm for aorta diameter. In the 90 patients who had pTTE and sTTE performed in the echocardiographic laboratory, correlations between the measurements by pTTE and sTTE were excellent (**Figure 3**) and there were no significant differences between them for any echocardiographic parameter. Bland-Altman plots demonstrated small systematic differences, or mean bias, between the pTTE and sTTE measurements, with close limits of agreement (**Figure 4**).

In the 35 patients who had pTTE performed at the bedside by the physician, there were excellent correlations between the measurements by pTTE and sTTE for LVDd ($r=0.97$) and LVDs ($r=0.98$), FS ($r=0.93$), IVS ($r=0.90$), PWT ($r=0.88$), LAd ($r=0.93$), and aorta diameter ($r=0.85$) (all $P<0.001$). Bland-Altman analysis showed small systematic differences and limits of agreement between pTTE and sTTE for LVDd (−0.3 mm, 1.1 mm) and LVDs (0.1 mm, 1.0 mm), FS (−0.7%, 2.7%), IVS (0.1 mm, 0.6 mm), PWT (0.2 mm, 0.6 mm), LAd (0.0 mm, 1.4 mm), and aorta diameter (0.1 mm, 1.1 mm). These values were comparable with the results for sTTE and pTTE obtained in the echocardi-

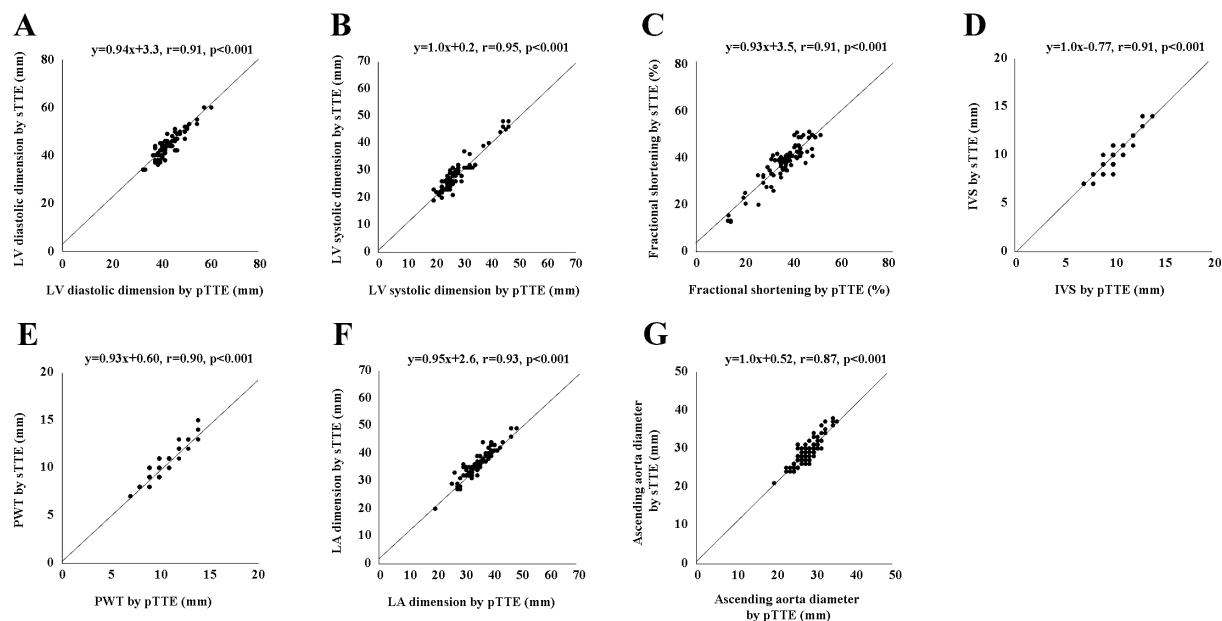


Figure 3. Regression plots showing the correlation between portable transthoracic echocardiography (pTTE) and standard transthoracic echocardiography (sTTE) measurements for left ventricular (LV) diastolic (A) and systolic (B) dimensions, fractional shortening (C), interventricular septum (IVS, D), posterior wall thickness (PWT, E), left atrial (LA) dimension (F), and aorta diameter (G). The solid line represents the regression lines between the pTTE and sTTE measurements.

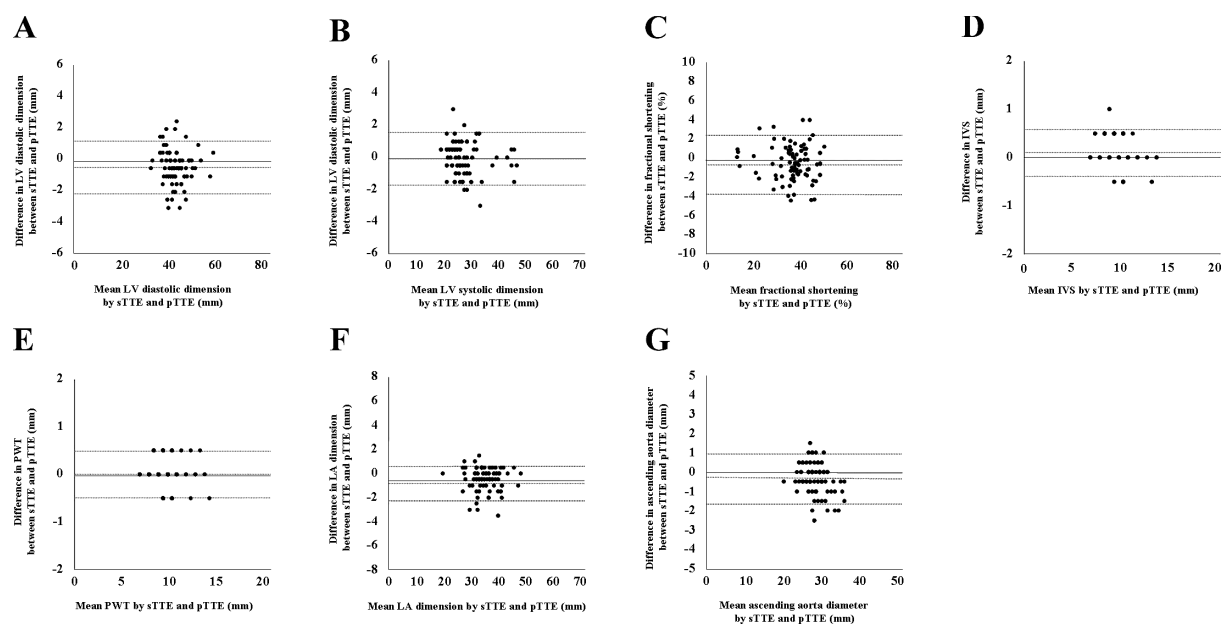


Figure 4. Scatterplot of the differences in the left ventricular (LV) diastolic (A) and systolic (B) dimensions, fractional shortening (C), interventricular septum (IVS, D), posterior wall thickness (PWT, E), left atrial (LA) dimension (F), and aorta diameter (G) between portable transthoracic echocardiography and standard transthoracic echocardiography, showing the mean difference and the limits of agreement (solid lines). pTTE, portable transthoracic echocardiography; sTTE, standard transthoracic echocardiography.

graphic laboratory (Figures 3,4).

In the total patients included in this analysis, sTTE showed RWMA in 33 (26%). There was concordance between sTTE and pTTE for the presence or absence of RWMA in 116 (93%) of 125 patients. The sensitivity and specificity of pTTE for detecting RWMA was 88% and 95%, respectively. Pericardial effusion was detected by sTTE and pTTE

in 5 (4%) of 125 patients.

Observer variabilities were similar between the pTTE and sTTE measurements for the LV dimensions, FS, IVS, PWT, LAd, and aorta diameter (Table).

Table. Intra- and Interobserver Variabilities in Echocardiographic Measurements

	LVDd	LVDs	FS	IVS	PWT	LAd	Ascending aorta diameter
Intra-observer variability							
sTTE	0.7 mm	0.8 mm	1.4%	0.2 mm	0.2 mm	0.7 mm	0.8 mm
pTTE	0.8 mm	1.1 mm	2.0%	0.3 mm	0.4 mm	1.1 mm	1.2 mm
Inter-observer variability							
sTTE	0.8 mm	1.0 mm	2.6%	0.3 mm	0.3 mm	0.9 mm	1.1 mm
pTTE	1.2 mm	1.1 mm	2.6%	0.4 mm	0.4 mm	1.0 mm	1.8 mm

LVDd, left ventricular diastolic dimension; LVDs, left ventricular systolic dimension; FS, fractional shortening; IVS, interventricular septum; PWT, posterior wall thickness; LAd, left atrial dimension; sTTE, standard transthoracic echocardiography; pTTE, portable transthoracic echocardiography.

Discussion

This study demonstrated that the recently introduced pocket-sized echocardiography device can quantify cardiac chamber size and function in the clinical setting.

TTE is the standard imaging modality for assessing cardiovascular anatomy, function and physiology in clinical practice.^{10–13} An expensive high-end instrument is used in the echocardiographic laboratory, operated by a skilled sonographer and supervised by experienced physicians. Echocardiographic examination is, therefore, performed several days after the initial physician–patient encounter. However, the indication for TTE depends on the findings of a physical examination, together with patient interview. Limitations in physical examination skills required to diagnose cardiovascular abnormalities have been documented, resulting in misleading diagnostic evaluations, therapeutic plans or patient prognoses.^{4–6} Furthermore, skills in physical examination have declined over the past 2 decades.

Recent advances in electronics have enabled the creation of small, portable imaging devices. Bruce et al¹ and Vourvouri et al² reported excellent correlations between pTTE and sTTE in the measurement of aortic diameter and LV mass. Spencer et al demonstrated that physical examination failed to detect 59% of all cardiovascular conditions and 43% of major findings, which was reduced to 21% by pTTE.³ Previous cost-effectiveness analyses suggest that when pTTE is used as the initial screening of patients with suspected cardiac disease, there is approximately 20% reduction in sTTE indication.^{4,15} Another potential application of pTTE is a limited and focused echocardiographic examination. In the follow-up of many cardiac abnormalities, a limited imaging protocol (ie, few image acquisitions in a short time) is adequate to answer referral questions in clinical practice.^{16,17} Limited quantitative measurements, such as cardiac chamber size and function as assessed in the present study, are suitable and sufficient for a limited and focused echocardiographic examination.¹⁸

The Acuson P10 has recently become commercially available, potentially furthering the construction of a personal imager.⁷ We showed excellent correlations between pTTE and sTTE for the measurements of cardiac chamber size and function in 125 unselected patients, even with the small monitor size and limited image setting. Furthermore, pTTE detected RWMA and pericardial effusion, which are common reasons in clinical practice for referring the patient to sTTE. Therefore, pTTE with the Acuson P10 can be used for initial screening to identify or exclude cardiac abnormalities, or in the follow-up of cardiac diseases. The Acuson P10 is able to be used anywhere as part of the clinical examination. Physicians can carry a pTTE device while making

rounds, just like a stethoscope. From the practical point of view, pTTE with Acuson P10 may be easier to use than the conventional portable devices available during hospitalization of inpatients, as well as outside the hospital setting, including the management of home-care patients. Consequently, there may be widespread use of pTTE as a diagnostic tool supplementing the physical examination, which would strengthen the accuracy of diagnosing various cardiac diseases in clinical practice.

Study Limitations

First, the image quality of the Acuson P10 did not equal that of high-end instruments and the device does not have color Doppler capability. Therefore, pTTE should not replace sTTE and physical examinations.^{19,20}

Second, the datasets were acquired and analyzed by expert sonographers or physician with >2 years of experience in echocardiography with >800 examinations. In the present study 90 patients had pTTE performed in the echocardiographic laboratory by a sonographer, and 35 patients had it performed at the bedside by a physician. Similar correlations between the pTTE and sTTE measurements were obtained for different protocols, suggesting that accurate measurement with pTTE relies on experience in echocardiography rather than where it is performed. In fact, skills in acquiring and interpreting the pTTE images are recommended, even though the device is small in size and easy to use.²¹

Third, unselected patients were enrolled because this study was initially focused on investigating the ability of pTTE to measure cardiac chamber size and function in the clinical setting. We included 33 patients with RWMA, and the ability of pTTE to detect RWMA was demonstrated. However, it remains unclear whether pTTE has the ability to assess other reasons for patient referral for sTTE, because of the relatively small number of patients included. In fact, pericardial effusion was detected in only 5 patients. Further study is necessary to verify the viability of this pocket-sized imaging device in diagnosing other cardiovascular diseases in clinical practice.

Finally, the Acuson P10 comprises the unit and the transducer. The size of the transducer is similar to those of current portable imaging devices, although the body of the system is pocket-sized. For future portable imaging devices, it would be beneficial if the transducer were miniaturized and combined into the body of the system.

Conclusions

This study demonstrated that the evaluation of cardiac chamber size and function by a pocket-sized portable echo-

cardiography device was both feasible and accurate in clinical practice.

Disclosure

The authors have neither a conflict of interest nor financial disclosure.

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