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Original Article

Point-of-care screening for left ventricular hypertrophy and concentric geometry using hand-held cardiac ultrasound in hypertensive patients

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Abstract: Background: The introduction of the hand-held cardiac ultrasound (HCU) may potentially increase detection of LV hypertrophy in hypertensive patients. However, whether point-of-care screening for LV hypertrophy and concentric LV geometry by HCU in hypertensive patients is feasible and comparable to that of standard state-of-the-art echocardiography (SE) evaluation remains to be elucidated. Methods and Results: Accordingly, one hundred consecutive patients (66 female, mean age=58±13 years, 32% African-American, mean body mass index=31±8 kg/m^2) with the diagnosis of hypertension underwent both HCU and SE examinations in tandem. A cardiology fellow-in-training performed the HCU exam while a cardiac sonographer performed the SE. 37% of hypertensive patients had electrocardiographic LV hypertrophy by Sokolow-Lyon or Cornell voltage criteria. Mean LV mass was 210±42 g with the HCU and 209±40 g with SE. Mean relative wall thickness was 0.45±0.05 by the HCUD and 0.44±0.05 by SE. There was excellent correlation between LV mass and relative wall thickness measurements by HCU and SE (r=0.985, SEE=6.8 g and r=0.762, SEE=0.33, respectively, both p<0.001). The prevalence of LV hypertrophy using prognostically-validated partition values for LV mass/height$^{2.7}$ of 46.7 and 49.2 g/m$^{2.7}$ in women and men, respectively was 76% by HCU and 78% by SE (p=NS), with excellent agreement (92%, κ=0.774, p<0.001). Agreement for detection of concentric LV geometry (relative wall thickness>0.43) was also excellent (88%, κ =0.756, p<0.001). Agreement for LV hypertrophy and concentric geometry detection between the cardiology fellow-in-training and sonographer was excellent (κ =0.786, p<0.001). Conclusion: Point-of-care screening for LV hypertrophy and concentric LV geometry by HCU is feasible and correlates very well with that of SE. HCU may allow for immediate point-of-care assessment and treatment of cardiac target organ damage in hypertensive patients.

Keywords: Echocardiography, left ventricle, hypertension

Introduction

In hypertensive patients, the risk of stroke, myocardial infarction and cardiovascular death is increased in those with left ventricular (LV) hypertrophy [1-3]. It has also been shown by several studies that LV geometry further stratifies risk in hypertensive patients independently of, and more strongly than, blood pressure (BP) and other potentially reversible cardiovascular (CV) risk factors [3-4]. Furthermore, recent studies have shown that regression of LV hypertrophy with antihypertensive treatment has independent prognostic benefits [5-6]. Echocardiographically-derived LV mass has been validated to have good accuracy compared with necropsy-measured LV mass [7] and has been utilized to study LV hypertrophy in clinical and epidemiologic contexts. The introduction of the hand-held cardiac ultrasound (HCU) may potentially increase detection of LV hypertrophy and thus, provide more rapid point-of-care identification and treatment of high-risk hypertensive patients. However, whether point-of-care screening for LV hypertrophy and concentric LV geometry by HCU in hypertensive patients is feasible and comparable to that of standard state-of-the-art echocardiography (SE) evaluation remains to be elucidated.

Methods

Study design

One hundred consecutive patients (66% female, mean age=58±13 years, mean body mass index [BMI] =31±8 kg/m^2) with the diagnosis of hypertension were asked to participate in the study. The Institutional Review Board of Bronx-Lebanon Hospital Center approved the study protocol and all enrolled patients gave informed consent.

The study protocol consisted of an echocardiographic examination by HCU (SonoHeart ™, Bothell, WA) followed by an echocardiographic examination by SE techniques using commercially-available echocardiographs (GE Vivid 7, Milwaukee). Both studies were done in tandem on the same day. A cardiology fellow-in-training performed the examination using the HCU. Cardiac sonographers who were unaware of the results of the previous examination performed the SE examination. The SE measurements were recorded entirely on videotape. To assess performance variability between cardiology fellow-in-training and cardiac sonographer, both scanned 20 randomly selected patients using the HCU. Agreement for LV hypertrophy detection between the cardiology fellow-in-training and cardiac sonographer was excellent (k=0.786, p<0.001).

Echocardiographic techniques and measurements

The parasternal acoustic window was used to record ^{3}5 consecutive beats of 2-dimensional and M-mode recordings of the LV internal diameter and wall thicknesses at or just below the tips of the mitral valve leaflets in long and short-axis views. Correct orientation of planes for imaging and Doppler recordings was verified using standard procedures [8]. All echocardiographic measurements were made by an experienced reader blinded to patient demographics using a digitized review station. HCU measurements were made after completion of the procedure. To avoid recall bias, the SE were batch-read and LV measurements were made at the completion of the study by the same blinded reader.

The LV internal dimension and interventricular septal and posterior wall thicknesses were measured at end-diastole and end-systole according to American Society of Echocardiography (ASE) recommendation (9) on up to 3 cycles. Correctly oriented 2-D linear dimension measurements were made by the leading-edge convention according to ASE recommendation [9]. There was a close correlation (r=0.967, mean difference=0.49 g, SD=10.25 g) between LV mass measurements by M-mode and 2-D echocardiography, as previously reported [10]. End-diastolic ASE LV dimensions were used to calculate LV mass by a formula that yields values closely related (r=0.90, p<0.001) to necropsy LV weight [7] and which showed excellent reproducibility (intraclass correlation coefficient=0.93, p<0.001) between two separate echocardiograms in 183 hypertensive patients [11]. LV hypertrophy was defined as using traditional indexation of LV mass to body surface area (BSA, 116 g/m^2 in men and 104 g/m^2 in women) and also to its allometric relation to height$^{2.7}$ (49.2 g/m$^{2.7}$ in men and 46.7 g/m$^{2.7}$ in women) [12]. RWT was calculated as end-diastolic posterior wall thickness/LV internal radius [3]. Increased RWT was present when this ratio exceeded 0.420, which represents the 97.5th percentile in previously described normal subjects [12-13].

Data handling and statistical analyses

Data management and analysis were performed using SPSS 10.0 (SPSS, Chicago, IL) software. Data are presented as mean±SD for continuous variables and proportions for categorical variables. Simple linear regression analysis was used to obtain correlation coefficients between two methods. Agreement between the HCU and SE measurements was tested according to Bland and Altman method [14]. Agreement to detect LV hypertrophy and concentric geometry between the 2 techniques was asssessed by 2 x 2 tables using weighted k statistics. k values <0.4, 0.4-0.75 and >0.75 represented poor, fair or excellent agreement, respectively [15]. Two-tailed p<0.05 indicated statistical significance.

Results

Subject characteristics

Of the 100 hypertensive patients enrolled in the study, 66% were female. 64% were Hispanic, 32% were African-American, 2% were Asian and 2% was Caucasian. 34% had concomitant dia-

Table 1. Left Ventricular Measurements by Hand-Carried Ultrasound and Standard Echocardiography

Variable	HCU Device Mean±SD (Range)	Standard Echocardiography Mean±SD (Range)
Septal Wall Thickness (cm)	1.15±0.12 (0.90-1.50)	1.15±0.11 (1.00-1.50)
LV Internal Diameter (cm)	4.92±0.36 (4.10-6.20)	4.94±0.47 (4.10-6.40)
Posterior Wall Thickness (cm)	1.09±0.12 (0.80-1.40)	1.08±0.11 (0.90-1.40)
LV Mass (g)	210±42 (123-350)	209±40 (123-330)
Relative Wall Thickness	0.45±0.05 (0.29-0.59)	0.44±0.05 (0.34-0.58)

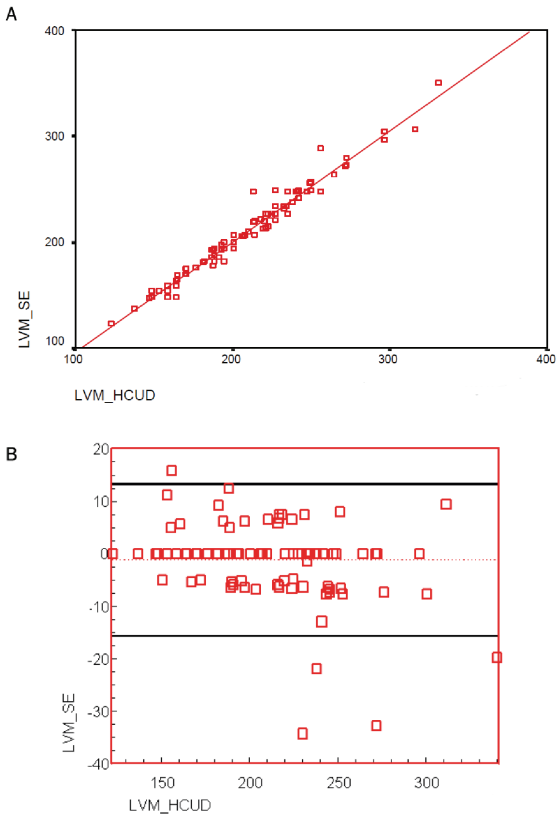

Figure 1. A. Relation between LV mass HCU (x-axis) and LV mass SE (y-axis). The regression model shows a good correlation in LV mass obtained from two methods. (r=0.985, SEE=6.8 g, p<0.001). LVM–left ventricular mass, HCU-hand-carried ultrasound, SE-standard echocardiography, g-gram. **B.** Bland-Altman plot of LV mass obtained from HCU and SE shows a good agreement between two methods. 95% confidential interval of agreement between them ranges from -16 g (5th percentile) to 13 g (95th percentile) with a mean difference of 7 g.

betes mellitus, and 37% had electrocardiographic LV hypertrophy by Sokolow-Lyon or Cornell voltage criteria. They were mostly middle aged (mean age was 58±13 years) and overweight (mean BMI was 31±8 kg/m^2).

HCU LV measurements

LV measurements by HCU and SE are shown in **Table 1**. Mean LV mass/BSA was 111.3±15.4 g/m^2 with the HCU and 111.9±16.6 g/m^2 with SE. Correlation between the two methods, using the linear simple regression analysis was excellent (**Figure 1A**, r=0.985, SEE=6.8, p<0.001). Using LV mass/BSA >104g/m2 in women and >116 g/m2 in men as partition values, agreement to detect LV hypertrophy was 94 % (k=0.876, p<0.001). There was good agreement between the two methods using the Bland -Altman analysis (**Figure 1B**).

Mean relative wall thickness was 0.45±0.05 by the HCU and 0.44±0.05 (0.34-0.58) by SE. Correlation between the two methods by linear simple regression analysis was excellent (**Figure 2A**, r=0.863, SEE=0.33, p<0.001), as was agreement between techniques using Bland-Altman statistic (**Figure 2B**). Agreement to detect concentric geometry (relative wall thickness>0.430) for both techniques was 88% (k=0.756, p<0.001).

As the majority of the hypertensive patients were overweight or obese, LV hypertrophy was also determined by adjusting LV mass to its allometric relation to height (height$^{2.7}$) and using prognostically-validated partition values of 49.2 g/m$^{2.7}$ in men and 46.7 g/m$^{2.7}$ in women to detect LV hypertrophy. Mean LV mass/height $^{2.7}$ was 55.9±9.96 g/m$^{2.7}$ with the HCU and 56.2±10.6 g/m$^{2.7}$ with SE. Agreement to detect LV hypertrophy was 92% (k=0.774, p<0.001).

Discussion

LV hypertrophy has been shown to be an independent predictor of increased cardiovascular morbidity and mortality in hypertensive patients [1-3] and may represent “preclinical cardiovascular disease” [16]. However, its importance in not widely appreciated, in part, because accu-

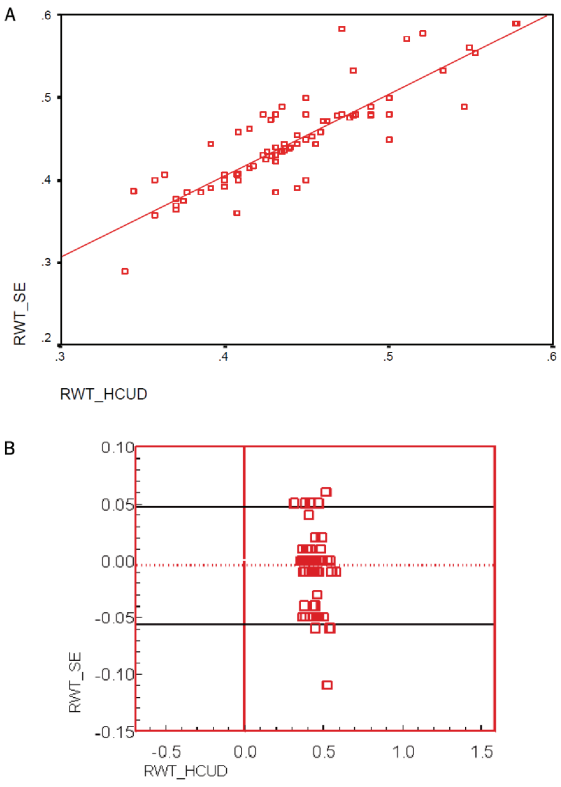

Figure 2. A. Relation between RWT HCU (x-axis) and RWT SE (y-axis). The regression model shows a good correlation in relative wall thickness obtained from two methods. (r=0.863, SEE=0.33, p<0.001). RWT–relative wall thickness, others as figure 1A. **B.** Bland-Altman plot of RWT obtained from HCU and SE shows a good agreement between two methods. 95% confidential interval of agreement between them ranges from -0.057 (5th percentile) and 0.047 (95% percentile) with a mean difference of 0.026.

rate detection of LV hypertrophy has been difficult. The electrocardiogram has been the traditional method to detect LV hypertrophy in epidemiologic studies. However, the specificity (94-100%) of electrocardiographic criteria for LV hypertrophy is better than their sensitivity (11-51%) [17-21]. Cardiac magnetic resonance imaging has emerged as a potential "gold standard" in the noninvasive detection of LV hypertrophy, but the high cost of immobile laboratories and certain patient specific conditions, i.e. patient aversion to claustrophobic imaging milieus, limit its widespread use [22]. Echocardiography has provided a safe noninvasive alternative method to evaluate cardiac anatomy and function. The development of necropsy-validated echocardiographic formulae has permitted accurate assessment of LV mass [7]. Echocardiographic LV mass has been shown to have excellent inter-study reproducibility and be a more sensitive tool for detection of LV hypertrophy than electrocardiography [12].

The introduction of the HCU may potentially increase detection of LV hypertrophy and thus, provide more rapid identification and treatment of high-risk hypertensive patients. In the first study to evaluate the feasibility of HCU in detecting LV hypertrophy in hypertensive patients, Vourvouri et al. evaluated 65 men and 35 women with hypertension and found excellent agreement to detect LV hypertrophy was 93% (k=0.77) using LV mass/BSA and 90% (k=0.76) using LV mass/height in an overwhelmingly Caucasian sample [23]. Senior et al. extended this finding to a community-based sample of 189 hypertensive patients in the United Kingdom (70% Caucasian, 27% South Asian and 3% Africo-Caribbean) and found agreement to detect LV hypertrophy was fair (83%, k=0.63) using LV mass/BSA criteria [24].

Our study extends the finding to a predominantly overweight or obese (81%) hypertensive minority (64% Hispanic and 32% African American) clinical cohort that the assessment of LV mass and relative wall thickness by HCU is feasible and correlates well with SE. Similar to the report by Vourvouri et al., we found excellent agreement to detect LV hypertrophy using LV mass/BSA (94 %, k=0.876). Since, majority (81%) of our patients were overweight or obese (mean BMI=31±8 vs. 27±4 kg/m^2 in the former sample), LV hypertrophy was also determined by adjusting LV mass to its allometric relation to height (height$^{2.7}$). Agreement to detect LV hypertrophy using prognostically-validated partition values of 49.2 g/m$^{2.7}$ in men and 46.7 g/m$^{2.7}$ in women was 92%, (k=0.774). It has been shown that height-based indexations of LV mass, which identify both blood pressure and obesity-associated increases in LV mass, maintain and enhance prediction of cardiac risk by LV mass determination [25-26]. Our study also indicates that assessment of LV geometry is feasible using HCU. Agreement to detect concentric geometry (relative wall thickness>0.420) using standard echocardiography as reference was 88% (k=0.756). Kizer et al. showed that the adjusted risk of having LV hypertrophy and concentric geometry, using conventional criteria, was greater for African-American than for white

hypertensives (odds ratio [OR]=1.8, 95% confidence interval [CI] 1.30-2.48), and OR=2.39, 95% CI 1.30-4.40, respectively) [27]. Our study shows that it is feasible to assess LV hypertrophy and concentric geometry by HCU in this higher risk group who are likely to benefit more from additional assessment to identify evidence of cardiac target organ damage.

The current guidelines do not recommend baseline echocardiography in the initiation of antihypertensive therapy for hypertensive patients [28]. However, recent evidence showing incremental benefit of echocardiographic LVH regression on cardiovascular outcomes in hypertensive patients should not be ignored [5-6, 29], as echocardiographic LV hypertrophy regression is an important indicator of adequacy of antihypertensive treatment thereby providing a therapeutic goal for which further BP reduction might be necessary [30]. The use of HCU may potentially encourage and increase point-of-care detection of LV hypertrophy because of lower cost (~1/10th of the price of the standard state-of-the-art echocardiography equipment), lighter weight and easy portability. In trained individuals, assessment of LV hypertrophy using HCU will provide immediate diagnostic information, risk stratification and prompt therapeutic intervention. Further studies are needed to determine the reliability of serial measurements of LV dimensions by HCU to monitor LV hypertrophy regression in hypertensive patients.

Study limitations

M-mode measurements of LV dimensions have traditionally been used to derive LV mass. The lack of M-mode capability in HCU requires that 2-D echocardiographic images be used to measure LV dimensions and mass that could potentially reduce diagnostic accuracy. However, as previously reported, there was a close correlation (r=0.967, mean difference=0.49 g, SD=10.25 g) between LV mass measurements by M-mode and 2-D echocardiography [11]. Our study employed a cardiology fellow-in-training to perform the HCU examination thus, the results may only be applicable when performed by similarly trained individuals. In our study, agreement for LV hypertrophy detection between cardiac sonographers and cardiology fellow-in-training was excellent (k=0.786, p<0.001) similar to previous reports [23-24]. Indeed, the guidelines recommends that individuals using HCU have appropriate user-specific training to ensure the most accurate acquisition and interpretation of data [31-32]. Further studies are needed to determine the reliability of serial measurements of LV dimensions by HCU.

Conclusion

Our study shows that screening for LV hypertrophy and concentric LV geometry by HCU is feasible and correlates very well with that of standard state-of-the-art echocardiography examination. HCU may allow for rapid point-of-care assessment and treatment of cardiac target organ damage in hypertensive patients.

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