

# Echocardiographic Measurements in Normal Chinese Adults Focusing on Cardiac Chambers and Great Arteries: A Prospective, Nationwide, and Multicenter Study

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**Background:** Currently available echocardiographic reference values are derived mainly from North American and European population studies, and no echocardiographic reference values are available for the Chinese population. The aim of this study was to establish normal values of echocardiographic measurements of the cardiac chambers and great arteries in a nationwide, population-based cohort of healthy Han Chinese adults.

**Methods:** A total of 1,586 healthy Han Chinese volunteers aged 18 to 79 years were screened at 43 collaborating laboratories throughout China. Standard M-mode and two-dimensional echocardiography was performed to obtain measurements of the cardiac chambers and great arteries. The impacts of gender and age on all echocardiographic measurements were analyzed.

**Results:** A total of 1,394 qualified healthy subjects (mean age,  $47.3 \pm 16.0$  years; 678 men) were ultimately enrolled. Except for left ventricular ejection fraction, values of cardiac chamber and great arterial dimensions were significantly higher in men than in women. Most measurements of the atrial and great arterial dimensions, left ventricular wall thickness, and left ventricular mass increased with age in both men and women.

**Conclusions:** Normal reference values of cardiac dimensional parameters were established for the first time in a nationwide, population-based cohort of healthy Han Chinese adults. Because most of these parameters were found to vary with gender and age, reference values stratified for gender and age should be used in clinical practice. (*J Am Soc Echocardiogr* 2015;28:570-9.)

**Keywords:** Echocardiography, Cardiac chamber, Great arteries, Normal reference values, Chinese adults

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This work was supported by research grants from the National 973 Basic Research Program (grants 2011CB503906, 2012CB518603, and 2013CB530703), the National High-Tech Research and Development Program of China (grant

2012AA02A510), the Program of Introducing Talents of Discipline to Universities (grant B07035), the State Program of National Natural Science Foundation of China for Innovative Research Group (grant 81321061), the State Key Program of National Natural Science of China (grant 61331001), the International Collaboration and Exchange Program of China (grant 81320108004), and the National Natural Science Foundation of China (grants 81425004, 91339109, 81173251, 81270350, 81300234, 81300217, 81100147, 81170136, 81170275, and 81270403).

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0894-7317/\$36.00

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<http://dx.doi.org/10.1016/j.echo.2015.01.022>

Abbreviations
<b>ASE</b> = American Society of Echocardiography
<b>BSA</b> = Body surface area
<b>DBP</b> = Diastolic blood pressure
<b>EMINCA</b> = Echocardiographic Measurements in Normal Chinese Adults
<b>IVSd</b> = Interventricular septal end-diastolic thickness
<b>IVSs</b> = Interventricular septal end-systolic thickness
<b>LA</b> = Left atrial
<b>LA-ap</b> = Left atrial anteroposterior dimension
<b>LAV</b> = Left atrial volume
<b>LV</b> = Left ventricular
<b>LVEDD</b> = Left ventricular end-diastolic diameter
<b>LVEDV</b> = Left ventricular end-diastolic volume
<b>LVEF</b> = Left ventricular ejection fraction
<b>LVM</b> = Left ventricular mass
<b>LVPWd</b> = Left ventricular posterior wall end-diastolic thickness
<b>LVPWs</b> = Left ventricular posterior wall end-systolic thickness
<b>RA</b> = Right atrial
<b>RA-l</b> = Right atrial long-axis dimension
<b>RA-t</b> = Right atrial transverse dimension
<b>RV</b> = Right ventricular
<b>SBP</b> = Systolic blood pressure

Quantitative measurements of cardiac chamber dimensions and function are crucial to disease severity estimation and therapeutic effect assessment, and a widely accepted set of normal reference values of echocardiographic measurements is indispensable for distinguishing normality from abnormality.<sup>1</sup> Recent studies have demonstrated that ethnicity-related differences exist in cardiac dimensions.<sup>2,3</sup> However, currently available echocardiographic reference values are derived mainly from North American and European population studies with wide heterogeneity of inclusion and exclusion criteria,<sup>4,6</sup> and no nationwide echocardiographic reference values are available for the healthy Chinese population. Therefore, it is highly warranted to establish race-specific echocardiographic reference values for the Chinese population to facilitate a quick and proper judgment in daily clinical practice. From January 2012 to December 2012, the Echocardiography Working Group of the Chinese Society of Ultrasound in Medicine designed, organized, and conducted a prospective, nationwide, multicenter study, Echocardiographic Measurements in Normal Chinese Adults (EMINCA), with the purpose of establishing normal reference values of cardiac chamber and great arterial dimensions (Part 1) as well as Doppler parameters (Part 2) and to identify the impacts of gender and age on these echocardiographic parameters in a large population of healthy Han Chinese adults over a wide

range of ages. Here we report the results of EMINCA Part 1. from the tertiary hospitals of all provinces and municipalities throughout China except Taiwan and should be accredited by the Chinese Society of Ultrasound in Medicine. The healthy volunteers were recruited mainly from hospital staff members, health examination centers, and adjacent communities. The inclusion criteria required that all volunteers be aged 18 to 79 years, have Han nationality, have normal blood pressure (systolic blood pressure [SBP] < 140 mm Hg, diastolic blood pressure [DBP] < 90 mm Hg), have normal results on physical examination and electrocardiography, and have no history of cardiovascular diseases. The exclusion criteria were coronary artery disease, structural heart disease, heart failure, hypertension, stroke, hyperlipidemia (serum total cholesterol  $\geq$  5.72 mmol/L or triglyceride  $\geq$  1.70 mmol/L), diabetes mellitus (fasting blood glucose > 7.0 mmol/L), and any other endocrine diseases, acute or chronic respiratory diseases, anemia, connective tissue disease, abnormal liver function (serum alanine aminotransferase or aspartate aminotransferase > 2.0 times the upper limit of normal), abnormal renal function (serum creatinine > 2 mg/dL), obesity (body mass index  $\geq$  28.0 kg/m<sup>2</sup>), abnormal results on electrocardiography, valvular stenosis, more than mild valvular regurgitation, or wall motion abnormalities on echocardiographic recordings. Professional athletes, pregnant or lactating women, subjects addicted to alcohol, and subjects with inadequate echocardiographic images were also excluded.<sup>7</sup> Body surface area (BSA) was calculated using the formula of Du Bois and Du Bois.<sup>8</sup>

The study protocol was approved by the ethical committees of all collaborating hospitals, and written informed consent was obtained from all volunteers participating in this study. The EMINCA study was registered as ChiCTR-OCS-12002119 at the Chinese Clinical Trial Registry (<http://www.chictr.org>), an authorized registry organization of the International Clinical Trial Registry Platform of the World Health Organization.

### Echocardiographic Image Acquisition

In an attempt to standardize echocardiographic image acquisitions and measurements, one or two experienced sonographers from each of the participating laboratories received intensive training at one of the two core laboratories (Shandong University Qilu Hospital and Sichuan Provincial People's Hospital) to get acquainted with the study protocol and to derive standard images and measurements.

Commercially available ultrasound equipment, the Philips iE33 (Philips Ultrasound, Bothell, WA) or the GE Vivid E9 (GE Vingmed Ultrasound AS, Horten, Norway), was used for this study. Standard M-mode and two-dimensional echocardiography were performed in all subjects according to American Society of Echocardiography (ASE) guidelines.<sup>1</sup> After the technical parameters were adjusted to obtain optimal images, all subjects were connected to an electrocardiograph and examined in the left lateral decubitus position to obtain the parasternal and apical cross-sectional views or in the supine position to obtain the subcostal and suprasternal cross-sectional views. To minimize the impact of respiratory motion on echocardiographic parameters, images were acquired during breath holding at the end of expiration. To avoid left atrial (LA) and right atrial (RA) or left ventricular (LV) or right ventricular (RV) foreshortening in the apical views, great care was taken to angulate the transducer to separately image the maximal LA and RA or LV and RV chambers. The frame rate was set at  $\geq$  50 sec<sup>-1</sup> for two-dimensional echocardiographic recordings. At least five cardiac cycles were recorded from each view on optical disks in digital Digital Imaging and Communications in Medicine format for online and offline analyses.

## METHODS

### Study Population

The EMINCA study was initially designed to enroll a total of 1,320 healthy Han Chinese volunteers aged 18 to 79 years, who were divided into six age groups: 18 to 29, 30 to 39, 40 to 49, 50 to 59, 60 to 69, and 70 to 79 years ( $n = 220$  in each group, 50% men). All participating echocardiographic laboratories were to be

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