Doppler Echocardiographic Measurements in Normal Chinese Adults (EMINCA): a prospective, nationwide, and multicentre study

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Aims Currently, available Doppler echocardiographic reference values are derived mainly from North American and European population studies, which may not applicable to the Chinese population. We aimed to establish normal reference values of Doppler echocardiographic parameters in a nationwide, population-based cohort of healthy Han Chinese adults.

Methods and results A total of 1394 qualified healthy subjects (mean age 47.3 ± 16.0 years, 678 men) were enrolled at 43 collaborating laboratories, 37 transvalvular flow and tissue Doppler parameters were obtained, and the impacts of gender and age on each parameter were analysed. Significant differences were found between men and women in 48.6% (18/37) of the parameters analysed, and among different age groups in 83.8% (31/37) of the parameters in men and in 86.5% (32/37) of the parameters in women.

Conclusions Normal reference values of Doppler echocardiographic parameters were established for the first time in a nationwide, population-based cohort of healthy Han Chinese adults. Since most of these parameters differed by gender and/or age, reference values specified for gender and age should be recommended in clinical practice.

Keywords Echocardiography • Doppler • Normal reference values • Chinese adults

Introduction Doppler echocardiography is a non-invasive technique that provides unique haemodynamic information and has become a standard method for assessing valvular heart diseases and ventricular diastolic function. Normal reference values of Doppler parameters are a prerequisite for distinguishing normality from abnormality, and recent studies have reported a significant variation of these values with age and gender in healthy populations. However, the normal reference values of Doppler flow velocities have never been systematically recommended by ASE guidelines, which have made it difficult to differentiate between a normal velocity and a mildly abnormal velocity in practice. The currently available Doppler reference values are mainly derived from North American and...
European population studies that may not be applicable to the Chinese population. Since Han Chinese is the predominant ethnic group in China and accounts for nearly 20% of the world’s popula-
tion, it is highly warranted to establish nationwide normal refer-
cence values of Doppler echocardiography for the Han Chinese
county to facilitate 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 and
multicentre study—Doppler Echocardiographic Measurements in
Normal Chinese Adults (EMINCA). Study with the purpose to es-
tablish the normal reference values of Doppler parameters in
a large population of healthy Han Chinese adults across a wide range
of ages.

Methods

Study population

We screened 1586 healthy volunteers at 43 collaborating echocardi-
ographic laboratories throughout China. The healthy volunteers were
mainly screened from hospital staff, health examination centres, and
adjacent communities. The inclusion criteria required that all volunteers
be aged from 18 to 79 years and have Han ethnicity, with a normal blood
pressure, a normal physical examination, a normal electrocardiogram,
and without a history of cardiovascular diseases. The exclusion criteria
included subjects with coronary artery disease, structural heart disease,
heart failure, hypertension, stroke, hyperlipidaemia, diabetes mellitus, or
any other endocrine diseases, acute or chronic respiratory diseases, an-
aemia, connective tissue disease, abnormal liver or renal function, obes-
ity, abnormal electrocardiogram, and valvular stenosis, more than mild
valvular regurgitation or wall motion abnormalities on echocardi-
ographic recordings. Professional athletes, pregnant or lactating women,
subjects addicted to alcohol, and subjects with inadequate echocardi-
ographic images were also excluded.

The study protocol was approved by the ethical committees of all col-
laborating hospitals and written informed consents were obtained from
all volunteers participating in this study. The EMINCA study was regis-
tered as ChiCTR-OCS-12002119 at the Chinese Clinical Trial Registry
(http://www.chictr.org), an authorized registry organization of the Inter-
national Clinical Trial Registry Platform of the World Health
Organization.

Doppler signal acquisition

Commercially available instruments of Philips iE33 (Philips Ultrasound,
Bothell, WA, USA) or GE Vivid E9 (GE Vingmed Ultrasound, Horten,
Norway) were used for this study. In accordance with the ASE guide-
lines, comprehensive echocardiography including conventional
pulsed-wave Doppler and tissue Doppler echocardiography was per-
formed to obtain transvalvular flow and tissue Doppler recordings. At
least five cardiac cycles were recorded from each recording on optical
disks in digital DICOM format.

Analysis of conventional Doppler echocardiography

Doppler echocardiographic recordings were analysed at two core la-
boratories by two experienced echocardiographers (G.-H. Yao and
Y. Deng). From the mitral inflow spectra, the peak velocities of early
diastolic (E) and late diastolic (A) waves, E/A ratio, deceleration time
(DT) of E wave and time duration of A wave (A-d). Similarly, the
peak velocities of early diastolic (E-tv) and late diastolic (A-tv) waves,
and E/A-tv ratio were measured from the tricuspid inflow spectra. The
time duration of the right upper pulmonary venous reverse flow (Ar-d)
was measured at atrial systole, and the time interval (Ar-A) between
Ar-d and A-d was calculated. The peak systolic flow velocities at levels
of LV outflow tract (LVOT-v), aortic valve (AV-v), right ventricular
outflow tract (RVOT-v), and pulmonary valve (PV-v) were also mea-

Analysis of tissue Doppler echocardiography

The annular velocities at systole (s′), early diastole (e′), and late diastole
(a′) at both septal and lateral sites of the mitral annulus were measured
(Figure 1A). The average values of both sites were then calculated. Ratios
of septal e′/a′ and E/e′, lateral e′/a′ and E/e′, average e′/a′ and E/e′ were
also derived. Time intervals of LV isovolumetric relaxation time, isov-
olumetric contraction time and LV ejection time were also measured
from the tissue Doppler recordings (Figure 1B). Similarly, measurements
of the systolic, early and late diastolic velocities (s′-tv, e′-tv, and a′-tv)
were made at the level of lateral corner of the tricuspid annulus, and
e′/a′-tv and E/e′-tv ratios were calculated.

Interobserver and intraobserver variability

To test the reproducibility of measurements, 4 key Doppler para-
eters, including E, A, septal e′ and septal a′, were remeasured in
50 randomly selected subjects from the two core laboratories. Inter-
observer variability was performed by G.-H.Y. and M.-J.X., and intra-
observer variability was performed by G.-H.Y. The method of Bland–Altman plots was used to analyse the interobserver and in-
traobserver variability, and the interclass correlation coefficients
were calculated.

Statistical analysis

SPSS version 16.0 (SPSS, Inc., Chicago, IL, USA) was used for data ana-
lysis. Data were stratified by gender and age, and expressed as mean ±
SD and the 95% confidence interval for the mean values. Independent
samples t-test was used to compare the mean values between men
and women, and between subjects aged 18–29 years and other age
groups. The analysis of variance was applied to compare values among
age groups stratified by gender. Online MedCalc software was used to
perform Bland–Altman plots. Two-tailed P-values <0.05 were consid-
ered statistically significant.

Results

Study population

A total of 1394 healthy volunteers who met the inclusion and exclu-
sion criteria were finally enrolled from 43 collaborating laboratories.
There were 678 men (47.1 ± 16.2 years) and 716 women (47.5 ±
15.8 years). A total of 37 Doppler echocardiographic parameters
were obtained. The demographic features of the study population
were described in details previously. In brief, the mean values of
height, weight, body mass index, body surface area, and systolic
and diastolic blood pressures were significantly higher in males
than in females, whereas no significant differences were found be-
tween genders in age and heart rate in the whole study population
(Table 1).
Measurements of conventional pulsed-wave Doppler echocardiography

As summarized in Table 2, the values of the mitral inflow E (0.81 ± 0.19) and A (0.67 ± 0.20) in men were significantly lower than in women (E, 0.89 ± 0.21 and A, 0.72 ± 0.23, P < 0.01) in the whole study population, but there was no gender difference for E/A ratio (1.32 ± 0.46 vs. 1.36 ± 0.51, P > 0.05) and DT (171.1 ± 47.2 vs. 167.5 ± 43.9, P > 0.05). The age-stratified measurements of the mitral inflow E and E/A were decreased, whereas A and DT increased significantly with age groups in both genders (P < 0.005–0.001). Even though no differences between genders were found for the mean values of A-d, Ar-d, and Ar-A, the values of Ar-d and Ar-A increased with age groups in women (P < 0.05–0.001) but not in men.

Measurements of peak systolic velocities across the aortic valve and the pulmonary valve were higher in women than in men (P < 0.05–0.01), whereas no gender differences were found for peak systolic velocities at LV outflow tract and right ventricular outflow tract (Table 3). Velocities across the aortic valve, LV outflow tract, and right ventricular outflow tract in both genders and velocity across the pulmonary valve in men differed with age groups (P < 0.05–0.01), but these differences were not consistent across different age groups.

Figure 1  Tissue Doppler spectra recorded at the lateral site of the mitral annulus showing (A) the annular velocities at systole (s’), early diastole (e’), and late diastole (a’) and (B) the time intervals of LV isovolumetric relaxation time (IVRT), isovolumetric contraction time (IVCT), and LV ejection time (LVET).
As listed in Table 4, the values of the tricuspid inflow E-tv (0.56 ± 0.13) and E/A-tv (1.4 ± 0.4) were significantly lower in men than in women (E-tv, 0.59 ± 0.14 and E/A-tv, 1.5 ± 0.5, P < 0.01), whereas no difference was found in A-tv between genders (0.42 ± 0.11 vs. 0.43 ± 0.12, P > 0.05). Similar to the mitral inflow parameters, values of E-tv and E/A-tv were decreased, whereas A-tv increased progressively with age groups in both genders (P < 0.001).

**Measurements of pulsed-wave tissue Doppler echocardiography**

Table 5 listed tissue Doppler measurements of the mitral annulus. The septal, lateral, and average s’ values were all higher in men than in women in the whole study population (P < 0.01), and these values decreased significantly with age groups in both men and women (P < 0.05−0.001). Measurements of septal, lateral, and average e’ also decreased with age groups in both genders (P < 0.001), but these values did not differ between men (9.9 ± 3.0, 13.0 ± 3.9, and 11.5 ± 3.2) and women (10.1 ± 3.2, 13.2 ± 4.1, and 11.6 ± 3.5). In contrast, measurements of septal, lateral, and average a’ all increased significantly with age groups in both genders (P < 0.001). The mean values of septal a’ and average a’ were higher in men than in women (P < 0.01), but lateral a’ did not differ between genders in the whole study population. The age-stratified values of septal, lateral, and average e’/a’ all decreased with age groups in both men and women (P < 0.001). The mean values of septal e’/a’ and average e’/a’ were higher in women than in men (P < 0.01), whereas there was no gender difference for lateral e’/a’. The mean values of septal E/e’ (8.7 ± 2.8), lateral E/e’ (6.7 ± 2.3), and average E/e’ (7.5 ± 2.3) in men were consistently lower than in women (9.5 ± 3.2, 7.4 ± 2.6, and 8.2 ± 2.7, all P < 0.01), and their age-stratified values all increased significantly in both genders (P < 0.001; Figure 2).

No differences between genders were found for the mean values of isovolumetric relaxation time and isovolumetric contraction time, while LV ejection time was longer in women than in men (P < 0.01), but it did not differ with age groups in both genders.

The tissue Doppler measurements derived at the lateral tricuspid annulus were presented in Table 4. Compared with that in subjects aged 18–29 years, the values of s’-tv were lower in those aged 40–49 years in men and aged 50–59 to 60–69 years in women (P < 0.05), but did not differ among age groups in both genders or between genders. The values of e’-tv and e’/a’-tv decreased with age in both genders (P < 0.001), with both values being lower in men than in women in the whole study population (P < 0.01). Similarly, the value of a’-tv increased with age in both genders (P < 0.001).

Although the value of E/e’-tv increased significantly with age in both genders, the highest value was found in subjects aged 70–79 years in men and 60–69 years in women. Unlike E/e’ in the mitral valve, no significant difference was found in the value of E/e’-tv between men and women (5.0 ± 1.6 vs. 5.0 ± 1.6, P > 0.05).

**Reproducibility measurements**

As shown in Figure 3, there was a high intraobserver and interobserver reproducibility of Doppler measurements. The intraclass correlation coefficient between intraobservers for E, A, septal e’, and septal a’ was 0.94, 0.97, 0.97, and 0.96, respectively (all P < 0.001). The intraclass correlation coefficient between interobservers for E, A, septal e’, and septal a’ was 0.93, 0.94, 0.94, and 0.91, respectively (all P < 0.001).

**Discussion**

To the best of our knowledge, this is the first prospective, nationwide, and multicentre study to define the normal reference values of 37 Doppler parameters in a large population with a wide range of ages, which laid a foundation for distinguishing normal from abnormal haemodynamics in clinical practice for Han Chinese adults.

**Effects of gender and age on conventional Doppler parameters**

In the EMINCA study, >40 and 80% of the conventional Doppler parameters differed with gender and age groups, respectively. In accordance with previous findings, 10,11 values of the mitral inflow E and E/A ratio decreased while A and DT increased gradually with ageing in both men and women. The age-related changes in these diastolic function parameters may reflect a prolonged LV myocardial relaxation, which may partially explain why older individuals are more prone to develop heart failure with preserved ejection fraction. On the other hand, values of the mitral inflow E and A in men were significantly lower than in women, which suggests that it is more appropriate to use gender-specific reference values in clinical practice.

A recent study by Shojaeifard et al. 12 in young healthy adults demonstrated that transtricuspid inflow measurements of E, A, and E/A did not differ significantly between men and women. However, our results showed that E-tv and E/A-tv were significantly higher in women than in men, which may be due to a much wider range of age and older population in the EMINCA study. Our results also showed that values of E-tv and E/A-tv decreased, while A-tv increased with age in both genders.

**Effects of gender and age on tissue Doppler parameters**

The value of e’ recorded from the mitral annulus has been recognized as a reliable index of myocardial relaxation due to its relative...
### Table 2
Measurements of mitral valve and right upper pulmonary venous inflow Doppler parameters stratified by gender and age

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Men (n = 678)</th>
<th>Women (n = 716)</th>
<th>p-value</th>
</tr>
</thead>
</table>
| E (m/s)             | 0.81 ± 0.19   | 0.89 ± 0.19    | 0.87 ± 0.17 | 0.79 ± 0.19 | 0.78 ± 0.19 | 0.77 ± 0.18 | 0.75 ± 0.17 | <0.0001 | 0.89 ± 0.21 | 0.98 ± 0.18 | 0.94 ± 0.20 | 0.93 ± 0.19 | 0.86 ± 0.20 | <0.0001 | 0.81 ± 0.19 | 0.79 ± 0.23 | 0.0001 | 0.74 | 0.04
| A (m/s)             | 0.67 ± 0.20   | 0.55 ± 0.14    | 0.59 ± 0.13 | 0.62 ± 0.17 | 0.69 ± 0.19 | 0.79 ± 0.20 | 0.88 ± 0.19 | <0.0001 | 0.72 ± 0.23 | 0.57 ± 0.18 | 0.61 ± 0.17 | 0.68 ± 0.16 | 0.75 ± 0.21 | <0.0001 | 0.88 ± 0.23 | 0.94 ± 0.26 | <0.0001 | 0.78 | 0.05
| E/A                 | 1.32 ± 0.46   | 1.19 ± 0.45    | 1.54 ± 0.37 | 1.33 ± 0.38 | 1.19 ± 0.36 | 1.04 ± 0.36 | 0.90 ± 0.31 | <0.0001 | 1.36 ± 0.51 | 1.82 ± 0.48 | 1.60 ± 0.41 | 1.43 ± 0.42 | 1.22 ± 0.40 | <0.0001 | 0.97 ± 0.34 | 0.89 ± 0.33 | <0.0001 | 0.91 | 0.03
| DT (ms)             | 171.1 ± 47.2  | 163.8 ± 47.5   | 168.0 ± 47.7 | 175.3 ± 45.6 | 174.0 ± 41.7 | 181.3 ± 55.5 | 0.005 <0.0001 | 167.5 ± 43.9 | 159.7 ± 44.5 | 160.8 ± 40.2 | 163.3 ± 39.5 | 167.2 ± 43.2 | 174.0 ± 42.7 | <0.0001 | 184.2 ± 52.0 | <0.0001 | 0.005 0.03
| A-d (ms)            | 150.8 ± 45.6  | 145.0 ± 40.3   | 149.8 ± 45.6 | 155.3 ± 59.2 | 155.2 ± 42.1 | 151.7 ± 39.8 | 0.423 0.0001 | 155.7 ± 54.2 | 141.7 ± 39.3 | 161.6 ± 68.5 | 164.5 ± 61.7 | 159.4 ± 56.7 | 149.6 ± 39.3 | 0.005 0.051 | 152.2 ± 37.5 | 0.0001 | 0.01 | 0.05
| Ar-d (ms)           | 111.5 ± 26.3  | 107.6 ± 28.9   | 112.1 ± 32.4 | 109.2 ± 24.9 | 114.0 ± 20.2 | 113.1 ± 23.0 | 0.258 0.0001 | 112.0 ± 24.7 | 104.0 ± 28.0 | 110.0 ± 27.8 | 113.2 ± 23.8 | 113.5 ± 21.4 | 114.4 ± 19.8 | 0.005 0.005 | 116.6 ± 24.6 | 0.0001 | 0.01 | 0.05
| Ar-A (ms)           | −39.5 ± 46.6  | −39.0 ± 43.6   | −38.0 ± 48.2 | −46.7 ± 57.0 | −40.8 ± 41.0 | −37.1 ± 40.9 | −32.2 ± 41.9 | 0.343 0.0001 | −44.0 ± 54.5 | −36.4 ± 40.6 | −51.6 ± 67.1 | −53.2 ± 64.2 | −46.1 ± 50.4 | −36.0 ± 43.0 | 0.005 0.005 | −34.9 ± 42.2 | −0.05 0.05

Data were expressed as mean ± SD (95% CI).

*P < 0.05 and †P < 0.01 vs. subjects aged 18–29 years.

‡P < 0.01 vs. men in the whole population.

### Table 3
Measurements of peak systolic velocities of great arteries stratified by gender and age

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Men (n = 678)</th>
<th>Women (n = 716)</th>
<th>p-value</th>
</tr>
</thead>
</table>
| LVOTv (m/s)         | 0.99 ± 0.32   | 0.96 ± 0.19    | 0.98 ± 0.20 | 0.96 ± 0.21 | 0.95 ± 0.23 | 1.05 ± 0.24 | 1.06 ± 0.25 | <0.0001 | 1.00 ± 0.22 | 0.94 ± 0.20 | 0.98 ± 0.21 | 0.96 ± 0.21 | 1.02 ± 0.22 | <0.0001 | 1.03 ± 0.25 | 1.07 ± 0.24 | <0.0001 | 0.0001 0.03
| AV-v (m/s)          | 1.22 ± 0.22   | 1.21 ± 0.20    | 1.19 ± 0.20 | 1.19 ± 0.21 | 1.20 ± 0.24 | 1.32 ± 0.25 | 1.28 ± 0.23 | <0.0001 | 1.29 ± 0.23 | 1.32 ± 0.21 | 1.27 ± 0.21 | 1.27 ± 0.21 | 1.27 ± 0.22 | 1.37 ± 0.24 | 1.35 ± 0.28 | <0.0001 | 0.0001 0.001
| RVOTv (m/s)         | 0.74 ± 0.17   | 0.77 ± 0.16    | 0.76 ± 0.17 | 0.73 ± 0.18 | 0.70 ± 0.17 | 0.77 ± 0.21 | 0.70 ± 0.16 | <0.001 | 0.74 ± 0.16 | 0.77 ± 0.16 | 0.74 ± 0.16 | 0.71 ± 0.13 | 0.74 ± 0.16 | 0.76 ± 0.18 | 0.71 ± 0.16 | <0.05 0.005
| PVv (m/s)           | 0.100 ± 0.19  | 0.102 ± 0.18   | 0.100 ± 0.18 | 0.097 ± 0.10 | 0.096 ± 0.20 | 0.104 ± 0.21 | 0.099 ± 0.18 | <0.005 | 0.097 ± 0.18 | 0.097 ± 0.17 | 0.097 ± 0.16 | 0.092 ± 0.16 | 0.096 ± 0.18 | 0.099 ± 0.18 | 0.329 0.03

Data were expressed as mean ± SD (95% CI).

*P < 0.05 and †P < 0.01 vs. subjects aged 18–29 years.

‡P < 0.05 and †P < 0.01 vs. men in the whole population.
### Table 4  Measurements of tricuspid valve inflow and tricuspid annulus tissue Doppler parameters stratified by gender and age

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Men (n = 678)</th>
<th>Women (n = 716)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-tv (m/s)</td>
<td>0.56 ± 0.13</td>
<td>0.59 ± 0.14†</td>
</tr>
<tr>
<td></td>
<td>(0.55–0.57)</td>
<td>(0.58–0.60)</td>
</tr>
<tr>
<td>A-tv (m/s)</td>
<td>0.42 ± 0.11</td>
<td>0.43 ± 0.12†</td>
</tr>
<tr>
<td></td>
<td>(0.41–0.43)</td>
<td>(0.41–0.44)</td>
</tr>
<tr>
<td>E/A-tv</td>
<td>1.4 ± 0.4</td>
<td>1.5 ± 0.5†</td>
</tr>
<tr>
<td></td>
<td>(1.3–1.4)</td>
<td>(1.4–1.5)</td>
</tr>
<tr>
<td>s-tv (cm/s)</td>
<td>13.0 ± 2.5</td>
<td>12.8 ± 2.4</td>
</tr>
<tr>
<td></td>
<td>(12.8–13.2)</td>
<td>(12.6–13.4)</td>
</tr>
<tr>
<td>e'-tv (cm/s)</td>
<td>11.9 ± 3.3</td>
<td>12.7 ± 3.7†</td>
</tr>
<tr>
<td></td>
<td>(11.7–12.2)</td>
<td>(12.4–13.0)</td>
</tr>
<tr>
<td>d'-tv (cm/s)</td>
<td>12.9 ± 3.9</td>
<td>13.0 ± 3.7</td>
</tr>
<tr>
<td></td>
<td>(12.6–13.2)</td>
<td>(12.7–13.3)</td>
</tr>
<tr>
<td>e'/a'-tv</td>
<td>1.0 ± 0.5</td>
<td>1.1 ± 0.5†</td>
</tr>
<tr>
<td></td>
<td>(0.9–1.1)</td>
<td>(1.0–1.1)</td>
</tr>
<tr>
<td>E/e'-tv</td>
<td>5.0 ± 1.6</td>
<td>5.0 ± 1.4</td>
</tr>
<tr>
<td></td>
<td>(4.9–5.1)</td>
<td>(4.9–5.1)</td>
</tr>
</tbody>
</table>

Data were expressed as mean ± SD (95% CI).

*P < 0.05 and †P < 0.01 vs. subjects aged 18–29 years.

‡P < 0.05 and †P < 0.01 vs. men in the whole population.
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Men (n = 678)</th>
<th>Women (n = 716)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>(n = 678)</td>
<td>(n = 716)</td>
</tr>
<tr>
<td>n</td>
<td>(n = 678)</td>
<td>(n = 716)</td>
</tr>
<tr>
<td>P-value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septal s (cm/s)</td>
<td>8.1 ± 1.7</td>
<td>9.1 ± 1.8</td>
</tr>
<tr>
<td>(8.7–9.0)</td>
<td>(8.9–9.1)</td>
<td></td>
</tr>
<tr>
<td>Septal d (cm/s)</td>
<td>9.9 ± 1.0</td>
<td>12.6 ± 2.2</td>
</tr>
<tr>
<td>(7.0–13.3)</td>
<td>(12.0–13.3)</td>
<td></td>
</tr>
<tr>
<td>Septal l (cm/s)</td>
<td>9.4 ± 2.1</td>
<td>8.2 ± 1.7</td>
</tr>
<tr>
<td>(9.3–9.6)</td>
<td>(7.9–8.3)</td>
<td></td>
</tr>
<tr>
<td>Septal E/I</td>
<td>1.1 ± 0.5</td>
<td>1.3 ± 0.4</td>
</tr>
<tr>
<td>(1.1–1.2)</td>
<td>(1.5–1.7)</td>
<td></td>
</tr>
<tr>
<td>Septal E/e</td>
<td>8.7 ± 2.8</td>
<td>7.2 ± 1.7</td>
</tr>
<tr>
<td>(8.5–9.0)</td>
<td>(7.7–8.4)</td>
<td></td>
</tr>
<tr>
<td>Lateral s (cm/s)</td>
<td>10.8 ± 2.6</td>
<td>11.8 ± 2.6</td>
</tr>
<tr>
<td>(10.6–11.0)</td>
<td>(11.4–12.3)</td>
<td></td>
</tr>
<tr>
<td>Lateral d (cm/s)</td>
<td>13.0 ± 3.9</td>
<td>16.6 ± 3.2</td>
</tr>
<tr>
<td>(12.7–13.3)</td>
<td>(16.1–17.2)</td>
<td></td>
</tr>
<tr>
<td>Lateral l (cm/s)</td>
<td>9.9 ± 2.6</td>
<td>8.4 ± 2.0</td>
</tr>
<tr>
<td>(9.7–10.1)</td>
<td>(8.0–8.7)</td>
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</tr>
<tr>
<td>Lateral E (cm/s)</td>
<td>1.4 ± 0.6</td>
<td>2.1 ± 0.6</td>
</tr>
<tr>
<td>(1.1–1.5)</td>
<td>(2.0–2.2)</td>
<td></td>
</tr>
<tr>
<td>Lateral E/e</td>
<td>6.7 ± 3.3</td>
<td>5.5 ± 2.1</td>
</tr>
<tr>
<td>(6.5–6.9)</td>
<td>(5.3–5.8)</td>
<td></td>
</tr>
<tr>
<td>Average s (cm/s)</td>
<td>9.8 ± 1.8</td>
<td>10.5 ± 1.6</td>
</tr>
<tr>
<td>(9.7–10.0)</td>
<td>(10.2–10.8)</td>
<td></td>
</tr>
<tr>
<td>Average d (cm/s)</td>
<td>11.5 ± 3.2</td>
<td>14.6 ± 2.2</td>
</tr>
<tr>
<td>(11.2–15.0)</td>
<td>(14.2–15.0)</td>
<td></td>
</tr>
<tr>
<td>Average l (cm/s)</td>
<td>9.6 ± 2.1</td>
<td>8.3 ± 1.5</td>
</tr>
<tr>
<td>(9.5–9.8)</td>
<td>(8.0–8.6)</td>
<td></td>
</tr>
<tr>
<td>Average E (cm/s)</td>
<td>1.3 ± 0.5</td>
<td>1.8 ± 0.4</td>
</tr>
<tr>
<td>(1.2–1.3)</td>
<td>(1.8–1.9)</td>
<td></td>
</tr>
<tr>
<td>Average E/e</td>
<td>7.5 ± 2.3</td>
<td>6.2 ± 1.4</td>
</tr>
<tr>
<td>(7.3–7.7)</td>
<td>(6.0–6.4)</td>
<td></td>
</tr>
<tr>
<td>IRVT (ms)</td>
<td>75.2 ± 19.8</td>
<td>70.5 ± 20.8</td>
</tr>
<tr>
<td>(73.7–76.7)</td>
<td>(69.7–74.2)</td>
<td></td>
</tr>
<tr>
<td>IVCT (ms)</td>
<td>68.9 ± 18.3</td>
<td>66.5 ± 17.2</td>
</tr>
<tr>
<td>(67.5–70.3)</td>
<td>(63.6–69.5)</td>
<td></td>
</tr>
<tr>
<td>LVET (ms)</td>
<td>288.9 ± 30.3</td>
<td>288.2 ± 32.8</td>
</tr>
<tr>
<td>(284.6–2912)</td>
<td>(282.5–2940)</td>
<td></td>
</tr>
</tbody>
</table>

Data were expressed as mean ± SD (95% CI). *P < 0.05 and **P < 0.01 vs. subjects aged 18–29 years. †P < 0.01 vs. in the men population.
in elderly women. Similarly, the measurements of $\alpha$-tv and $E/e'$-tv increased with age in both genders. The value of $s$-tv did not differ with age in both genders. Similar to the study by Dalen et al., $e'$-tv value was higher in women than in men, and there was no gender difference for $\alpha$-tv. But unlike to their results, we found no gender difference in $s$-tv and $E/e'$-tv measurements.
Figure 3 The Bland–Altman plots of the intraobserver and interobserver variability of the peak velocities of early diastolic wave (E) (A and B) and late diastolic wave (A) (C and D) of the mitral inflow, and the septal annular velocities at early diastole (e′-s) (E and F) and late diastole (a′-s) (G and H).
A limitation of the present study was that only Han Chinese adults were included, and thus the results may not be applicable to non-Han Chinese or other racial subjects. Further studies comparing Doppler echocardiographic measurements between Chinese Han population and Chinese minorities or other racial groups are warranted.

Conclusions
The EMINCA study is the largest, prospective, nationwide, and multicentre study which established the normal reference values of 37 Doppler echocardiographic parameters in healthy Han Chinese adults. Most of the Doppler measurements were found to differ with gender and age, and thus reference values specified for gender and age should be recommended in daily clinical practice.

Conflict of interest: None declared.

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Appendix
The following hospitals (investigators) participated in this study: The First Hospital of China Medical University (Jin Yang); The Memorial Hospital of Sun Yat-Sen University (Yulin Wei); The Second Xiangya Hospital of Central South University (Qichang Zhou); Shenzhen People’s Hospital (Ying Wu); The Second Affiliated Hospital of Nanjing Medical University (Yanni Liu); The First Affiliated Hospital of Nanjing Medical University (Di Xu); China-Japan United Hospital of Jilin University (Donghai Gao); The Second Affiliated Hospital of Harbin Medical University (Jiawei Tian); The General Hospital of Tibet Armed Police, Lhasa, Tibet (Shuzhen Xu); Affiliated Hospital of China Medical University (Jiawei Tian); The General Hospital of Tibet People’s Hospital (Ying Wu); Xi Jing Hospital of the Fourth Military Medical University (Jun Zhang); The Fourth Hospital of He Bei Medical University (Ruoling Han), Second Hospital of He Bei Medical University (Hongnian Yin), and Beijing An Zhen Hospital of Capital Medical University (Ya Yang).

Hospital (Caiyi Zhu); Affiliated Yan hospital of Kunming Medical University (Yunchuan Ding); HolhHot First Hospital (Baifang Shi); Sir Run Run Shaw Hospital, Zhejiang University College of Medicine (Bowen Zhao); The First Affiliated Hospital of Medical School of Shijiazhu University (Kunxia Guo); The Second Affiliated Hospital, School of Medicine, Xi’an Jiaotong University (Qi Zhou); Xinhua Hospital Affiliated to School of Medicine, Shanghai Jiao Tong University (Kun Sun); The Second Affiliated Hospital of Chong Qing Medical University (Haitao Ran); General Hospital of Beijing Military Region (Juanhua Wang); Fuwai Hospital (Xiu Zhang Lv); Xi Jing Hospital of the Fourth Military Medical University (Jun Zhang); The Fourth Hospital of He Bei Medical University (Ruoling Han), Second Hospital of He Bei Medical University (Hongnian Yin), and Beijing An Zhen Hospital of Capital Medical University (Ya Yang).

References


Ischaemic stroke from a large mitral vegetation as clinical presentation of infective endocarditis

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Neurological complications appear in 20–40% of patients with left-side infective endocarditis; one-half of them correspond to ischaemic stroke, 20% to cerebral haemorrhage, and 30% to other complications (transient ischaemic attack, menigitis, infectious aneurysm, brain abscess). A 45-year-old woman presented with right-sided hemiparesis and dysarthria. She had a 5-day history of intermittent fever, malaise, and polyarthralgia. Patient denied drug abuse, recent dental procedure, or rheumatic disease history. On admission, her pulse rate was 100 per minute and body temperature 37.7°C. Physical examination revealed characteristic Janeway lesions and Osler nodules (Panel). No cardiac murmur was audible and lung sounds were clear. Laboratory tests revealed leukocytosis and elevation of inflammatory biomarkers. Evidence of acute infarct of the left anterior cerebral artery and multiple foci of cortical ischaemic events were noted in the brain magnetic resonance imaging (MRI). Transthoracic echocardiography showed a large vegetation of 15 mm localized in the anterior and posterior mitral valves (Supplementary data online) with no regurgitation. Emboli to the spleen and kidney were found in the abdomen computed tomography (Panel). Two blood cultures were positive for Staphylococcus aureus 12 h after admission, and directed therapy was instituted. Early mitral valve replacement was performed with a mechanical valve. While completing antibiotic treatment, she developed persistent headache, which prompted repeating the brain MRI, revealing an image consistent with a brain abscess in the left frontal area. The antibiotic regimen was modified with improvement in neurological symptoms and discharged to complete her antibiotic course at home.

Panel (A) Osler nodes and localized arthritis (*); (B) Janeway lesion; (C) right kidney embolism (CT); (D) large vegetation at mitral valve (TTE); (E) surgical resection specimens; (F) brain abscess (MRI).

Supplementary data are available at European Heart Journal—Cardiovascular Imaging online.