Original Research

Normal Human Left and Right Ventricular Dimensions for MRI as Assessed by Turbo Gradient Echo and Steady-State Free Precession Imaging Sequences

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Purpose: To establish normal ranges of left ventricular (LV) and right ventricular (RV) dimensions as determined by the current pulse sequences in cardiac magnetic resonance imaging (MRI).

Materials and Methods: Sixty normal subjects (30 male and 30 female; age range, 20–65) were examined; both turbo gradient echo (TGE) and steady-state free precession (SSFP) pulse sequences were used to obtain contiguous short-axis cine data sets from the ventricular apex to the base of the heart. The LV and RV volumes and LV mass were calculated by modified Simpson's rule.

Results: Normal ranges were established and indexed to both body surface area (BSA) and height. There were statistically significant differences in the measurements between the genders and between TGE and SSFP pulse sequences. For TGE the LV end-diastolic volume (EDV)/BSA (mL/m^2) in males was 74.4 ± 14.6 and in females was 70.9 ± 11.7, while in SSFP in males it was 82.3 ± 14.7 and in females it was 77.7 ± 10.8. For the TGE the LV mass/BSA (g/m^2) in males was 77.8 ± 9.1 and in females it was 61.5 ± 7.5, while in SSFP in males it was 64.7 ± 9.3 and in females it was 52.0 ± 7.4. For TGE the RV EDV/BSA (mL/m^2) in males was 78.4 ± 14.0 and in females it was 67.5 ± 12.7, while in SSFP in males it was 86.2 ± 14.1 and in females it was 75.2 ± 13.8.

Conclusion: We have provided normal ranges that are gender specific as well as data that can be used for age-specific normal ranges for both SSFP and TGE pulse sequences.

Key Words: magnetic resonance imaging; steady-state imaging; gradient echo imaging; left ventricular volumes; right ventricular volumes; observer variability
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CARDIAC MAGNETIC RESONANCE IMAGING (MRI) has been shown to be an accurate and reproducible tool for the estimation of both left ventricular (LV) and right ventricular (RV) measurements (1–8). Currently, the two pulse sequences, which are in common clinical and research use for acquisition of volumes data sets, are segmented k-space turbo gradient echo (TGE) and the more recent steady-state free precession (SSFP) technique. The latter sequence has been validated in animal studies (9). TGE acquisition has been compared to previously validated sequences with excellent correlation (7).

Lorenz et al published the first normal range for cardiac MRI LV mass (g) and volumes, utilizing a conventional cine gradient echo sequence performed with free breathing (10). Another normal range for TGE with breath holding was developed by Marcus et al (11). There is a difference between the values obtained by the two groups. Lorenz et al report a mean LV mass of 178 ± 31 for men (N = 47) and of 125 ± 26 for women (N = 28), while Marcus et al report a mean LV mass of 142 ± 20 for men (N = 32) and 102 ± 15.9 for women (N = 29). These differences remained after indexation to body surface area (BSA). Therefore, there is a need for further work to establish a normal range for the TGE pulse sequence, which remains in common use. Furthermore, because of improved delineation of the endocardial borders and faster acquisition time, it is anticipated that SSFP pulse sequences will be the most frequently used technique in the future. Comparative values for ventricular volumes based on the acquisition with TGE and SSFP pulse sequences have been compared in several studies (12,13). These comparisons showed a systematic difference between the two techniques, with SSFP yielding larger end-diastolic volumes

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(EDVs) and end-systolic volumes (ESVs) and smaller LV mass measurements than TGE. Therefore, for clinical as well as research use of cardiac MRI, normal ranges for the SSFP pulse sequence need to be established.

In this study, we sought to establish normal ranges for LV volumes and mass as well as RV volumes for both SSFP and TGE pulse sequences. We grouped data from men and women separately, as previous studies have reported a gender difference (10,11,14). We also aimed to provide normal ranges for older and younger age groups, as it has been suggested that there may be a difference in their LV volumes (14).

MATERIALS AND METHODS

Study Population

We studied 60 normal subjects (30 males; mean age, 43 ± 12.0 years; range, 20–65 years; and 30 females; mean age, 42 ± 9.8 years; range, 20–60 years) with no history of cardiovascular disease or diabetes, a normal blood pressure, normal cardiovascular examination, and a normal resting electrocardiogram (ECG). Exclusion criteria were contraindications to MRI scanning, arrhythmia, age under 18 or over 65, elite athletes, and pregnancy. Informed consent was obtained from all subjects, and the local ethics committee approved the study.

Both the men and women were subdivided into older (≥40 years) and younger (≤39 years) subgroups. In the male subjects, 17 were in the older subgroup (mean age, 52 ± 7.2 years; range, 41–65 years) and 13 in the younger subgroup (mean age, 31 ± 4.7 years; range, 20–37 years). In the female subjects, 17 were in the older subgroup (mean age, 48 ± 5.5 years; range, 41–60 years) and 13 in the younger subgroup (mean age, 32 ± 5.6 years; range, 20–39 years).

Acquisition Protocol

MRI studies were performed on a 1.5-Tesla Philips Intera CV MRI system (Philips Medical Systems, Best, The Netherlands) equipped with Master gradients (maximum gradient amplitude, 30 mT/m; maximum slew rate, 150 mT/m/msec). Imaging was performed with patients in the supine position, using a five-element cardiac phased-array coil and a vectorcardiographic method for ECG gating (15). All acquisitions were obtained during breath holding in expiration. Localizing scans were followed by breath-hold cine acquisitions in the ventricular long-axis, short-axis, and horizontal long-axis planes to ensure accurate planning of the LV short-axis orientation. Multiple-slice data sets, parallel to the mitral valve, covering the heart in 10–14 short-axis slices, were acquired using two methods:

1. A TGE pulse sequence (TR = 8.8 msec, TE = 5.2 msec, flip angle = 35°, bandwidth = 253 Hz/pixel, acquisition matrix = 256 × 119, field of view (FOV) = 340 × 204 mm, 6-mm slice thickness, 4-mm interslice gap, 10–15 phases/cardiac cycle, with one slice acquired per 10- to 12-second breath hold).
2. An SSFP pulse sequence (TR = 3.34 msec, TE = 1.67 msec, flip angle = 55°, bandwidth = 1042 Hz/pixel, acquisition matrix = 192 × 163, FOV = 360 × 288 mm, half Fourier acquisition, 6-mm slice thickness, 4-mm interslice gap, 18 phases/cardiac cycle, with two slices acquired per 10- to 12-second breath hold).

Image Analysis

Image analysis was performed off-line using commercially available analysis software (MASS version 4.0, Medis, Leiden, The Netherlands). To minimize subjectivity in contour tracing, we used previously described criteria for the delineation of cardiac borders (10). The contour tracing was aided by reviewing the multiple phase scans in the movie mode.

For both the LV and RV volume analysis, the first phase was defined as end-diastole. End-systole was defined visually as the two phases with the smallest LV and RV volumes. In all LV data sets, one experienced observer manually traced the endocardial and epicardial contours at end-diastole. Epicardial fat was excluded from the epicardial contour. On both end-systolic frames the endocardial border was manually traced, and the workstation selected the phase with the smallest total LV volume as end-systole. Two papillary muscles were outlined separately, excluded from the ventricular volume and included in the myocardial mass. At the base of the heart, slices were considered to be within the left ventricle if the blood volume was surrounded by 50% or more of ventricular myocardium. If the basal slice contained both ventricular and atrial myocardium, the contours were drawn up to the junction of the atrium and the ventricle and joined by a straight line through the blood pool. Similarly, if the aortic valve appeared in the basal slice, blood volume up to the aortic valve was included in the LV volume (Fig. 1).

In all RV data sets, one experienced observer manually traced the endocardial contours at end-diastole and at both end-systolic frames. The workstation selected the smaller of the two end-systolic frames as end-systole. In the basal slice, both in end-diastole and end-systole, if the pulmonary valve was evident, only the portion of the volume below the level of the pulmonary valve was included. For the inflow part of the right ventricle, the blood volume was excluded from the RV volume if the surrounding wall was thin and not trabeculated, as it was considered to be in the right atrium.

The LV and RV EDVs and ESVs were computed using a modified Simpson's rule. The LV and RV stroke volume (SV) and ejection fraction (EF) were calculated as SV = EDV – ESV, and EF = SV/EDV × 100%. LV mass was calculated as LV mass = 1.05 × (epicardial volume – endocardial volume). The RV mass was not measured in this study, as in both pulse sequences the pixel size was in the order of 2 mm, with the wall thickness of the right ventricle being in the order of 4 mm (16).

To establish if the reproducibility of our analysis was similar to that of previously published data, the same observer remeasured six randomly selected data sets after an interval of 12 weeks to establish the intraob-

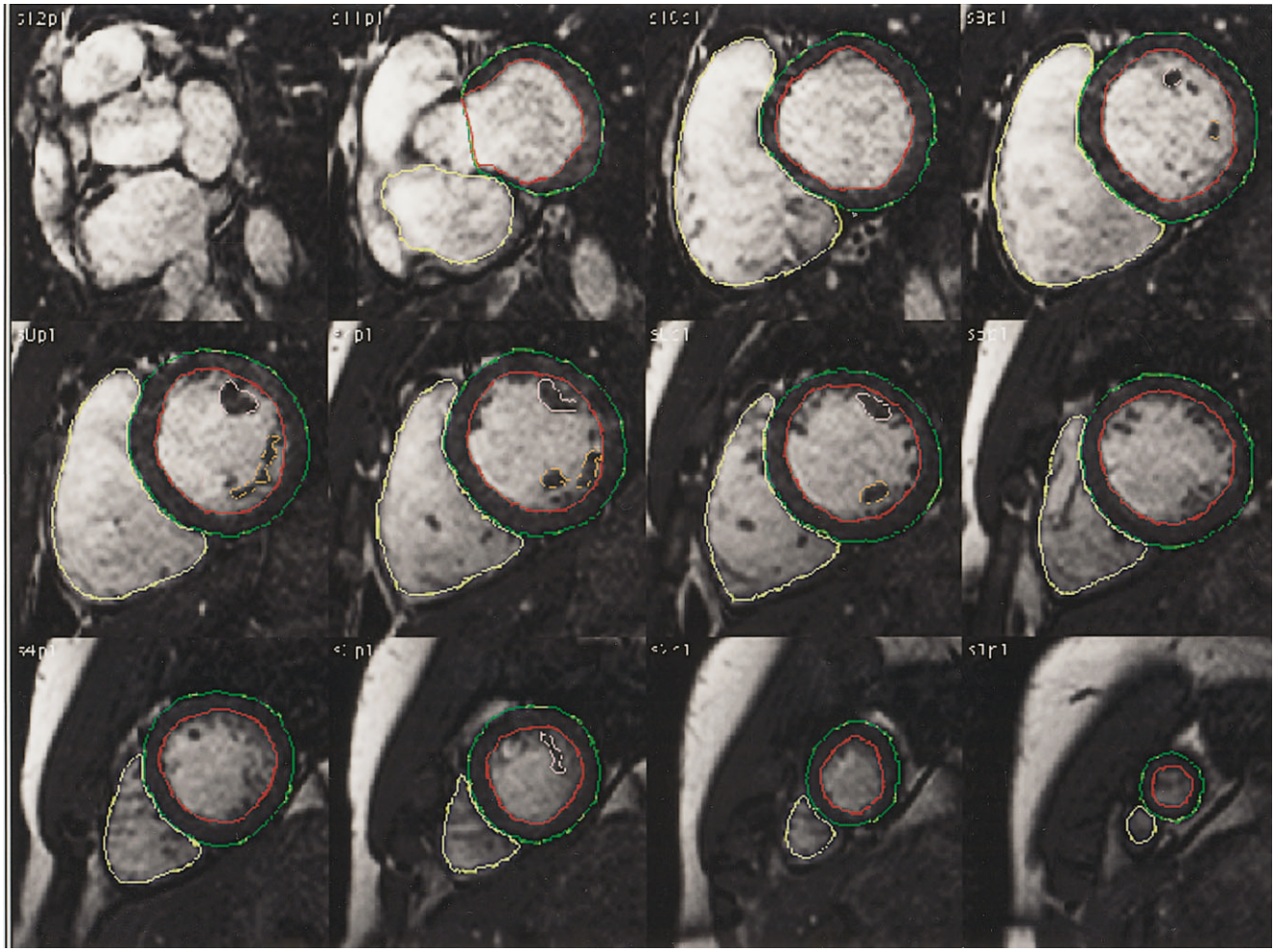

Figure 1. End-diastolic short-axis images acquired with the SSFP pulse sequence, with epicardial and endocardial contours defined for the left ventricle and endocardial contours defined for the right ventricle. In the basal slice, both the aortic valve and the pulmonary valve rings are excluded from the volumes.

server variability, and a second observer remeasured the same six data sets to assess the interobserver variability.

Statistical Analysis

For all parameters the means ± standard deviation were calculated. The normal range was calculated as 2 standard deviations below the mean to 2 standard deviations above the mean. Interobserver and intraobserver variability were calculated using Bland and Altman's method (17). For the difference in measurements between males and females, as well as old and young subgroups, independent sample *t*-tests were performed. For the difference between TGE and SSFP mea-

Table 1
Mean Values ± SD of LV Dimensions Based on Acquisition With TGE and SSFP*

	TGE		SSFP	
	Males	Females	Males	Females
EDV (ml)	152.6 ± 34.3	123.0 ± 19.7	168.5 ± 33.4	134.9 ± 19.3
ESV (ml)	52.7 ± 13.8	40.6 ± 9.2	60.8 ± 16.0	48.9 ± 10.7
SV (ml)	99.9 ± 23.0	82.5 ± 13.5	107.7 ± 20.7	86.0 ± 12.3
EF %	65.5 ± 4.1	67.1 ± 4.6	64.2 ± 4.6	64.0 ± 4.9
Mass (g)	159.7 ± 25.7	106.7 ± 12.6	133.2 ± 23.9	90.2 ± 12.0
LV EDV/BSA (ml/m^2)	74.4 ± 14.6	70.9 ± 11.7	82.3 ± 14.7	77.7 ± 10.8
LV Mass/BSA (g/m^2)	77.8 ± 9.1	61.5 ± 7.5	64.7 ± 9.3	52.0 ± 7.4
LV EDV/HT (ml/m)	86.0 ± 17.9	75.3 ± 10.9	95.0 ± 17.3	82.6 ± 10.9
LV Mass/HT (g/m)	90.0 ± 12.7	65.4 ± 7.5	75.1 ± 12.3	55.3 ± 7.0

*LV EDV and LV mass have been indexed to BSA and Height.
EDV = end diastolic volume, ESV = end systolic volume, SV = stroke volume, EF = ejection fraction, BSA = body surface area, HT = height.

Table 2
Mean Values ± SD of RV Dimensions Based on Acquisition With TGE and SSFP*

	TGE		SSFP	
	Males	Females	Males	Females
EDV (ml)	160.4 ± 32.6	117.4 ± 23.2	176.5 ± 33.0	130.6 ± 23.7
ESV (ml)	67.8 ± 14.8	44.5 ± 9.3	79.3 ± 16.2	52.3 ± 9.9
SV (ml)	92.7 ± 22.1	72.9 ± 16.9	97.8 ± 18.7	78.3 ± 16.9
EF %	57.6 ± 5.4	61.8 ± 5.3	55.1 ± 3.7	59.8 ± 5.0
RV EDV/BSA (ml/m^2)	78.4 ± 14.0	67.5 ± 12.7	86.2 ± 14.1	75.2 ± 13.8
RV EDV/HT (ml/m)	90.4 ± 17.0	71.9 ± 13.7	99.5 ± 16.9	80.0 ± 14.2

*RV EDV has been indexed to BSA and Height.
EDV = end diastolic volume, ESV = end systolic volume, SV = stroke volume, EF = ejection fraction, BSA = body surface area, HT = height.

surements paired sample *t*-tests were performed. The level of significance was taken as $P < 0.05\%$. The statistics software used was Analyse-it Software (Analyse-it Software, Ltd., Leeds, UK).

RESULTS

Diagnostic quality data sets were obtained in all subjects. Figure 1 shows an example of end-diastolic short-axis images acquired with the SSFP pulse sequence, with epicardial and endocardial contours defined for the left ventricle and endocardial contours defined for the right ventricle.

Tables 1 and 2 show the means ± 1 standard deviation for all LV and RV volumes for both TGE and SSFP acquisitions for both men and women. They also show LV and RV EDV as well as LV mass indexed to BSA and height. Table 3 tabulates the normal ranges for the most important clinical parameters, such as LV and RV EDVs, LV and RV EFs, and LV mass, and the indexed parameters.

Measurements for LV and RV EDVs based on SSFP acquisition were larger ($P < 0.0001$), those for LV and RV EF were smaller ($P = 0.0001$ and 0.0005), and the LV mass was smaller ($P < 0.0001$) than the equivalent parameters acquired by the TGE technique (Tables 1 and 2). The significant difference remained after indexation of LV and RV EDVs and LV mass to height and BSA ($P < 0.0001$) (Tables 1 and 2).

There was also a statistically significant difference in volumes and mass between men and women, which was similar for both pulse sequences. This was present in the LV and RV EDVs as well as LV mass ($P < 0.0001$) and for the RV EF ($P = 0.004$, TGE; $P = 0.001$, SSFP), but not in the LV EF (Tables 1 and 2). The difference between LV EDV remained significant after indexation to height ($P = 0.007$, TGE; $P = 0.002$, SSFP), but not to BSA. The difference between RV EDV remained significant after indexation to both height ($P < 0.0001$) and BSA ($P = 0.003$) in both sequences. Similarly, the difference between LV mass measurements remained significant after indexation to both height and BSA ($P < 0.0001$) in both sequences (Tables 1 and 2).

Table 4 shows the LV volumes as well as indexed LV volumes in both sequences in the older subgroup (of men and women), and Table 5 shows the LV volumes and indexed LV volumes for both sequences in the younger subgroup (of men and women). The younger subgroups had a larger LV EDV and a larger LV mass than the older subgroups within both pulse sequences. The difference remained after indexation. However, none of these differences was statistically significant.

Tables 6 and 7 show the inter- and intraobserver variability for both pulse sequences, the mean bias,

Table 3
Normal Ranges for TGE and SSFP Sequences for Important Parameters With Adjustment to BSA and Height*

	TGE		SSFP	
	Male	Female	Male	Female
LV EDV (ml)	84–221	84–162	102–235	96–174
LV EDV/BSA (ml/m^2)	45–104	48–94	53–112	56–99
LV EDV/HT (ml/m)	50–122	54–97	60–130	61–104
LV EF %	57–74	58–76	55–73	54–74
LV Mass (g)	108–211	82–132	85–181	66–114
LV Mass/BSA (g/m^2)	60–96	47–77	46–83	37–67
LV Mass/HT (g/m)	65–115	50–80	51–100	41–69
RV EDV (ml)	95–226	71–164	111–243	83–178
RV EDV/BSA (ml/m^2)	50–106	42–93	58–114	48–103
RV EDV/HT (ml/m)	56–124	45–99	66–133	52–108
RV EF %	47–68	51–72	48–63	50–70

*Two Standard Deviations Below to Two Standard Deviations Above the Mean.
LV = left ventricle, RV = right ventricle, EDV = end diastolic volume, ESV = end systolic volume, SV = stroke volume, EF = ejection fraction, BSA = body surface area, HT = height.

Table 4
Mean Values ± SD for LV Dimensions Based on Acquisition With TGE and SSFP for Older Men and Women, Age Range 40–65 Years

	TGE		SSFP	
	Male	Female	Male	Female
EDV (ml)	145.5 ± 37.8	120.6 ± 17.9	160.8 ± 34.6	133.3 ± 18.7
EDV/BSA (ml/m^2)	70.6 ± 14.6	66.9 ± 8.9	78.3 ± 13.2	73.9 ± 8.9
EDV/HT (ml/m)	82.9 ± 19.9	74.2 ± 10.5	91.6 ± 17.9	82.0 ± 10.7
ESV (ml)	49.3 ± 14.8	39.0 ± 8.5	57.9 ± 15.9	47.8 ± 10.5
SV (ml)	96.2 ± 25.6	81.8 ± 12.5	102.8 ± 22.8	85.5 ± 13.0
EF %	66.2 ± 4.4	67.8 ± 4.3	64.1 ± 5.0	64.3 ± 5.3
Mass (g)	154.2 ± 26.7	103.4 ± 13.5	128.8 ± 23.2	88.1 ± 11.7
Mass/BSA (g/m^2)	75.1 ± 8.8	57.3 ± 5.6	62.4 ± 7.6	48.8 ± 5.4
Mass/HT (g/m)	87.9 ± 13.4	63.6 ± 7.8	73.5 ± 11.9	54.2 ± 6.8

EDV = end diastolic volume, ESV = end systolic volume, SV = stroke volume, EF = ejection fraction, BSA = body surface area, HT = height.

limits of agreement, and standard deviation of the difference.

DISCUSSION

This is the first study to define normal ranges for LV and RV volumes in a cohort of normal adults of a wide age range who were screened for cardiovascular disease. We report the normal ranges for two different pulse sequences, which are in current use. The previously reported differences between measurements based on TGE and SSFP pulse sequences were confirmed in this study (18). This difference remained statistically significant after indexation to height and BSA. This emphasizes the need for separate normal ranges and underlines that the normal ranges for the different pulse sequences are not interchangeable.

The differences between these two pulse sequences may be due to the difference in endocardial border definition. Slow flow of blood at the endocardial border results in a poor signal, reduced contrast between blood and myocardium, and therefore potential overestimation of wall thickness in the TGE pulse sequence. The improved border definition in the SSFP pulse sequence is the result of the contrast in SSFP imaging being dependent on the T2/T1 ratio of tissues and largely independent of blood flow through the imaging plane.

A recent study describing a normal range for cardiac MRI by Lorenz et al (10) reported different normal ranges to our results. The LV EDV in men was 136 ± 34 mL and in women was 96 ± 23 mL (EDV/BSA of 69 ± 11 mL/m^2 for men and 61 ± 10 mL/m^2 for women) compared with TGE sequence values of 152.6 ± 34.3 mL for men and 123.0 ± 19.7 mL for women (EDV/BSA of 74.4 ± 14.6 mL/m^2 for men and 70.9 ± 11.7 mL/m^2 for women) in our study. These differences were even larger when compared to the SSFP sequence values from our study. Similar differences were seen for LV mass.

The most likely reason for these differences is that Lorenz et al used a conventional cine gradient echo sequence with free breathing, while we used a TGE and an SSFP sequence with breath holding. While the conventional cine gradient echo sequence may have better temporal resolution, as only one signal for each cardiac phase is acquired per cardiac cycle, the free breathing may lead to respiratory motion artifacts. These differences in data acquisition may result in a difference in the cardiac dimensions and hence in the normal range values.

A second difference between the two studies is the age range of the two populations. The age range for the volunteers in the study by Lorenz et al was 8–55 years old. The inclusion of children in the normal range may have affected the normal range, although it would be

Table 5
Mean Values ± SD for LV Dimensions Based on Acquisition With TGE and SSFP for Younger Men and Women, Age Range 20–39 Years

	TGE		SSFP	
	Male	Female	Male	Female
EDV (ml)	161.8 ± 27.7	126.0 ± 22.2	178.6 ± 30.1	137.0 ± 20.7
EDV/BSA (ml/m^2)	79.3 ± 13.7	76.1 ± 13.2	87.6 ± 15.3	82.6 ± 11.5
EDV/HT (ml/m)	90.0 ± 14.8	76.7 ± 11.7	99.3 ± 16.1	83.5 ± 11.5
ESV (ml)	57.2 ± 11.2	42.7 ± 10.0	64.5 ± 16.0	50.2 ± 11.2
SV (ml)	104.6 ± 18.8	83.4 ± 15.1	114.2 ± 16.4	86.7 ± 11.7
EF %	64.7 ± 3.6	66.2 ± 4.9	64.3 ± 4.2	63.6 ± 4.5
Mass (g)	166.9 ± 23.4	110.9 ± 10.3	138.9 ± 24.5	92.9 ± 12.2
Mass/BSA (g/m^2)	81.4 ± 8.5	67.0 ± 5.9	67.8 ± 10.7	56.2 ± 7.7
Mass/HT (g/m)	92.7 ± 11.6	67.7 ± 6.6	77.2 ± 13.0	56.7 ± 7.3

EDV = end diastolic volume, ESV = end systolic volume, SV = stroke volume, EF = ejection fraction, BSA = body surface area, HT = height.

Table 6
Interobserver Variability for LV and RV Measurements for Both TGE and SSFP for a Sample of Men and Women

	TGE			SSFP		
	Bias	Limits of agreement	SDD	Bias	Limits of agreement	SDD
LV EDV (ml)	4.4	−13.6 to 22.5	9.0	−5.9	−23.4 to 11.6	8.8
LV EF %	−2.2	−9.7 to 5.4	3.8	−2.5	−7.6 to 2.5	2.5
LV Mass (g)	4.7	−15.1 to 24.6	9.9	−1.4	−17.2 to 14.4	7.9
RV EDV (ml)	3.7	−20.0 to 27.4	11.9	−5.8	−22.0 to 10.4	8.1
RV EF %	1.1	−8.7 to 10.8	4.9	2.9	−8.6 to 14.4	5.8

LV = left ventricle, RV = right ventricle, EDV = end diastolic volume, EF = ejection fraction, SDD = standard deviation of the difference.

expected to lower the mean LV volumes and mass for the cohort. We believe the difference in the LV volumes and mass between our two cohorts would have been even larger if we compared data for adults only. It is unlikely that the differences in results are due to subjective differences in contour drawing, as we followed the same set of criteria described by Lorenz et al.

A second study on normal ranges by Marcus et al (11) used a TGE pulse sequence with breath holding and reported a mean EDV of 146 ± 28 mL for men and 110 ± 21 mL for women (EDV/BSA of 73.1 ± 10.9 mL/m^2 for men and 62.2 ± 11.6 mL/m^2 for women). These values are much closer to our values for the TGE sequence, which is a reflection of using a similar pulse sequence. However, Marcus et al used both 1.0-T and 1.5-T Siemens MRI scanners with acquisition parameters different than the ones used in our study; the subjects were instructed to hold their breath in moderate inspiration as opposed to full expiration in our study, and there were different strategies for inclusion of the basal slices. These factors may explain the small differences between the two results.

The results also demonstrate a gender difference in the LV and RV volumes, as previously described (10,11,14). These differences were statistically significant apart from the LV EF. When indexed to height and BSA, the difference remained significant apart from LV EDV indexed to BSA in both the TGE and SSFP techniques. The results also demonstrate a difference between the older and younger age groups, which has also been previously observed (14). In our cohort, the difference between the older and younger age groups was seen in both men and women and in both pulse sequences. The older subgroup was found to have lower EDV and LV mass than the younger subgroup, and the difference remained after indexation. However, none of these differences was statistically significant. This may be a reflection of the relatively small numbers in the subgroups. Nevertheless, such differences can be important when developing normal ranges for LV mass; for example, older hypertensives with elevated LV mass can be underdiagnosed if the normal ranges are based on a younger cohort of normals.

M-mode echocardiography is the most widely used imaging tool to measure LV mass. The LV mass is calculated using the Penn formula (19). Normal ranges for LV mass using M-mode echocardiography have been reported for men as 176 ± 45 g and for women as 121 ± 40 g, and adjusted to BSA for men as 89 ± 21 g/m^2 and for women as 69 ± 19 g/m^2 (20). Both LV mass results in TGE and SSFP are lower than the echocardiography values, and our indexed LV masses to BSA for both sequences are still lower than the echocardiography values (Table 1).

The standard deviations in the echocardiography study were higher than those of the cardiac MRI. This is a result of the cubing of the linear wall thickness values in the Penn formula (21). The larger standard deviation of LV mass by M-mode echocardiography results in a wider normal range and hence lower detection rate of milder degrees of LV hypertrophy. Other limitations of M-mode echocardiography LV mass are dependency on acoustic access, the angle of the transducer beam as well as the reliance on mathematical formulae, and geometric assumptions with the consequence of poor reproducibility. These have been extensively discussed in the literature (22–24).

In conclusion, this study provides normal ranges for LV and RV measurements that are gender specific for two of the most widely used acquisition sequences in cardiac MRI. We also provide data that can be used to establish age-specific normal ranges. Age-specific normal ranges would further enhance the clinical use of such measurements. To our knowledge, this is the first such normal range for SSFP pulse sequence, which is rapidly becoming the preferred cardiac MRI pulse se-

Table 7
Intraobserver Variability for LV and RV Measurements for Both TGE and SSFP for a Sample of Men and Women

	TGE			SSFP		
	Bias	Limits of agreement	SDD	Bias	Limits of agreement	SDD
LV EDV (ml)	2.4	−10.7 to 15.5	6.6	−2.7	−10.4 to 5.0	3.9
LV EF%	−0.2	−4.0 to 3.6	1.9	0.8	−3.3 to 5.0	2.1
LV Mass (g)	4.6	−14.4 to 23.6	9.5	2.1	−12.2 to 16.3	7.1
RV EDV (ml)	1.5	−18.2 to 21.2	9.9	−1.3	−12.9 to 10.4	5.8
RV EF%	0.6	−6.2 to 7.3	3.4	1.5	−4.4 to 7.4	3.0

LV = left ventricle, RV = right ventricle, EDV = end diastolic volume, EF = ejection fraction, SDD = standard deviation of the difference.

quence for acquisition of volumetric data sets of the left and right ventricles.

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