RIGHT AND LEFT VENTRICULAR DIMENSIONS WITH 3 TESLA CARDIAC MAGNETIC RESONANCE IMAGING IN HEALTHY VOLUNTEERS: AN EXPLORATORY PILOT STUDY

By:

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Introduction: Cardiac magnetic resonance imaging (CMR) is a rapidly evolving field in medicine and it has a very promising future. Cardiac diseases are known to alter the cardiac dimensions such as chamber size, ventricular wall thickness, mass, contractility as well as ejection fraction. Studies on the cardiac dimensions are very important since they provide reference values for clinicians which facilitate the management of their patients. Among the current imaging modalities, MRI appears to be the best option for cardiac dimension assessment. Many international studies have been able to produce database on cardiac dimensions in relation to age, gender and risk factors using 1.5-Tesla (1.5 T) CMR. However, no studies have presented normal data at 3 Tesla scanner.

Objective: To evaluate the right and left cardiac ventricular dimensions in healthy volunteers with 3-Tesla magnetic resonance imaging.

Patients and Methods: A total of 50 volunteers (25 males, 25 females) without cardiovascular diseases were evaluated with 3T magnetic resonance scanner, using a steady-state free precession sequence (balanced turbo field-echo).

Results: Mean age was 28.04 for male and 30.12 for female. Right and left ventricular volumes and mass were larger in males than females. RV EDV 153.83 ± 22.67 ml vs 144.46 ± 14.92ml, RV ESV 67.58 ± 14.44 ml vs 47.58 ± 9.49 ml, RV SV 86.24 ± 11.74ml vs 66.97± 8.57 ml, RV mass 35.88 ± 8.18 g vs 26.29 ± 5.26 g. LV EDV 129.05 ± 18.3 ml vs 105.44 ± 13.91 ml, LV ESV 46.65 ± 9.56 ml vs 37.92 ± 8.39 ml, LV SV 82.42 ± 12.02 ml vs 67.52 ± 8.33ml, LV mass 107.04 ± 16.55 g vs 65.92 ± 8.49 g; ($p < 0.05$ for all). There was no difference in ejection fraction of right and left ventricles between the genders. Males showed significant decrease in volume indices for both ventricles with age, while female values demonstrated no significant correlation.

Conclusion: We have produced the local database for right and left ventricular dimensions in accordance with gender and age using 3T magnetic resonance imaging.

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Prof Madya Dr Mohd Shafie Abdullah: Co- Supervisor
Dr Wan Yus Haniff: Co- Supervisor

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LIST OF ABBREVIATIONS , SYMBOLS AND ACRONYMS

BMI	Body mass index
BSA	Body surface area
CMR	Cardiac magnetic resonance imaging
DM	Diabetes mellitus
EDV	End diastolic volume
ESV	End systolic volume
EF	Ejection fraction
ECG	Electrocardiogram
LV	Left ventricle
MESA	Multiethnic study of atherosclerosis
RV	Right ventricle
SV	Stroke volume

ABSTRACT

Background: Cardiac magnetic resonance imaging (CMR) has been widely used recently. The database on normal cardiac dimensions has been established in Europe using 1.5T magnetic resonance scanner. However, there is no similar database using 3T cardiac magnetic resonance scanner and for Asian population.

Objective: To evaluate the right and left cardiac ventricular dimensions in healthy volunteers with 3-Tesla magnetic resonance imaging.

Methodology: Fifty subjects (25 males, 25 females) without cardiovascular diseases were evaluated with 3T magnetic resonance scanner, using a steady-state free precession sequence (balanced turbo field-echo).

Result: Mean age was 28.04 for male and 30.12 for female. Right and left ventricular volumes and mass were larger in males than females. RV EDV 153.83 ± 22.67 ml vs 144.46 ± 14.92ml, RV ESV 67.58 ± 14.44 ml vs 47.58 ± 9.49 ml, RV SV 86.24 ± 11.74ml vs 66.97± 8.57 ml, RV mass 35.88 ± 8.18 g vs 26.29 ± 5.26 g. LV EDV 129.05 ± 18.3 ml vs 105.44 ± 13.91 ml, LV ESV 46.65 ± 9.56 ml vs 37.92 ± 8.39 ml, LV SV 82.42 ± 12.02 ml vs 67.52 ± 8.33ml, LV mass 107.04 ± 16.55 g vs 65.92 ± 8.49 g; ($p < 0.05$ for all). There was no difference in ejection fraction of right and left ventricles between the genders. Males showed significant decrease in volume indices for both ventricles with age, while female values demonstrated no significant correlation.

Conclusion: We have produced the local database for right and left ventricular dimensions in accordance with gender and age using 3T magnetic resonance imaging.

Keyword: *Cardiac magnetic resonance imaging; 3 Tesla*

ABSTRAK

Pendahuluan: Pengimejan jantung dengan menggunakan mesin magnetik resonan telah meluas digunakan sejak kebelakangan ini. Banyak data normal untuk dimensi jantung telah dihasilkan di Eropah menggunakan mesin pengimejan magnetik dengan kekuatan 1.5 Tesla. Namun, masih belum ada data yang normal untuk dimensi jantung menggunakan mesin pengimejan magnetik dengan kekuatan 3 Tesla untuk populasi Asia.

Tujuan: Untuk menilai dimensi ventrikel jantung kanan dan kiri dalam sukarela yang sihat meggunakan mesin pengimejan magnetik resonan 3 Tesla.

Tatacara: Lima puluh sukarela yang sihat (25 lelaki, 25 perempuan) telah dinilai menggunakan mesin magnetik resonan 3 Tesla.

Keputusan: Purata umur untuk lelaki adalah 28.04 dan perempuan adalah 30.12. Isipadu dan berat ventrikel jantung kanan dan kiri adalah lebih besar untuk golongan lelaki berbanding perempuan. Isipadu akhir diastolik ventrikel kanan 153.83 ± 22.67 ml vs 144.46 ± 14.92 ml, isipadu akhir sistolik ventrikel kanan 67.58 ± 14.44 ml vs 47.58 ± 9.49 ml, isipadu strok ventrikel kanan 86.24 ± 11.74 ml vs 66.97± 8.57 ml, jisim ventrikel kanan 35.88 ± 8.18 g vs 26.29 ± 5.26 g. Isipadu akhir diastolik ventrikel kiri 129.05 ± 18.3 ml vs 105.44 ± 13.91 ml, isipadu akhir sistolik ventrikel kiri 46.65 ± 9.56 ml vs 37.92 ± 8.39 ml, isipadu strok ventrikel kiri 82.42 ± 12.02 ml vs 67.52 ± 8.33 ml, jisim ventrikel kiri 107.04 ± 16.55 g vs 65.92 ± 8.49 g; ($p < 0.05$). Tiada perbezaan antara ejeksi fraksi ventrikel jantung kanan dan kiri antara lelaki dan perempuan. Kedua -dua ventrikel jantung lelaki berkurang indeks isipadu dengan meningkatnya umur manakala tiada perbezaan dilihat untuk golongan perempuan.

Kesimpulan: Kajian kami menghasilkan data yang normal untuk dimensi ventrikel jantung kanan dan kiri untuk golongan lelaki dan perempuan menggunakan mesin pengimejan magnetik resonan 3 Tesla.

Kata kunci: *Pengimejan magnetik resona jantung; 3 Tesla*

INTRODUCTION

Cardiac magnetic resonance imaging (CMR) is a rapidly evolving field in medicine and it has a very promising future. Cardiac diseases are known to alter the cardiac dimensions such as chamber size, ventricular wall thickness, mass, contractility as well as ejection fraction. These parameters are often required by the clinicians as the guide in treating cardiac patients. Many international studies have been able to produce database on cardiac dimensions in relation to age, gender and risk factors using 1.5-tesla (1.5 T) CMR. Maceira *et al*, 2006 have produced a database on the right and left ventricular dimensions in relation to age and gender of normal healthy adults using steady-state free precession technique. Hudsmith *et al*, 2005 have added the normal left atrial dimensions to their study. Buechel *et al*, 2009 managed to obtain right and left ventricular parameters in normal children. Natori *et al*, 2006 discovered significant differences in left ventricular volume and mass between Asians (Chinese) and other ethnic groups (white Americans, African-Americans and Hispanics). Many multi-ethnics CMR studies were on specific cardiac diseases rather than on normal values . Other CMR studies concentrated on the effect of cardiovascular risk factors on the cardiac chambers especially the left ventricle. Friberg P *et al*, 2004 studied the correlation between the left ventricular mass and body mass index and systolic blood pressure among adolescents. They discovered that obese and hypertensive subjects had higher left ventricular mass than lean subjects. Eguchi K *et al*, 2008 have researched into the effect of type II diabetes mellitus in a multiethnic population, which has shown an increased risk of left ventricular hypertrophy by about 1.5-fold. Payne JR *et al*, 2006 did a study in 309 Caucasian army recruits and discovered positive association between cigarette smoking and left ventricular mass. A study which concentrated on right ventricle using CMRI showed positive association between its mass and systolic blood pressure (Chahal H *et al*, 2009).

Studies on the cardiac dimensions are very important since they provide reference values for clinicians which facilitate the management of their patients. Among the current imaging modalities, MRI appears to be the best option for cardiac dimension assessment.

STUDY PROTOCOL

Title:

Right and Left Ventricular Dimensions with 3 Tesla Cardiac Magnetic Resonance Imaging in Healthy Volunteers : an exploratory pilot study.

General objective:

To evaluate the right and left ventricular dimensions in healthy volunteers with 3-Tesla cardiac magnetic resonance imaging.

Specific objectives:

1. To determine the mass, volume and ejection fraction of right and left ventricles in healthy volunteers.

2. To determine the correlation between right ventricular dimensions with age based on gender in healthy volunteers.

3. To determine the correlation between left ventricular dimensions with age based on gender in healthy volunteers.

Literature review:

Cardiac magnetic resonance imaging (CMRI) is a rapidly evolving field in medicine and it has a very promising future. It is non-invasive, free of ionizing radiation, has excellent soft tissue contrast and gives highly reproducible result (Grothues et al, 2002 and 2004). After extensive research over the last few decades, this modalityhas been regarded as the “gold standard” inmany aspects of cardiac imaginginvestigation (Grothues et al, 2002 and Bellenger et al, 2000). Indications for CMRI include acquired and congenital heart diseases. Among these, ischaemic heart disease has been the commonest indication since CMRI was shown to have high sensitivity (92%) and specificity (99%) in discriminating infarcted tissues from the normal ones (Gotte et al, 2003).

Cardiac diseases are known to alter the cardiac dimensions such as chamber size, ventricular wall thickness, mass, contractility as well as ejection fraction. These parameters are often required by the clinicians as the guide in treating cardiac patients. Many international studies have been able to produce database on cardiac dimensions in relation to age, gender and risk factors using 1.5-tesla (1.5 T) CMRI. Maceira et al, 2006 have produced a database on the right and left ventricular dimensions in relation to age and gender of normal healthy adults using steady-state free precession technique. From their study, males were shown to have significantly larger right and left ventricular mass and volumes than females. There was also a significant decrease in right ventricular mass and volume with increasing age in both genders. Similarly, the left ventricle showed a significant decrease in volume with age in males and females. However, there was no significant change seen between the left ventricular mass and age. Hudsmith et al, 2005 have added the normal left atrial dimensions to their study.Buechel et al, 2009 managed to obtain right and left ventricular parameters in normal children. The results showed significantly larger ventricular volume in males than females and the ejection fractions remain constant throughout the growing age in both genders. Natori et al, 2006 discovered significant differences in left ventricular volume and mass between Asians (Chinese) and other ethnic groups (white Americans, African-Americans and Hispanics). Many multi-ethnics CMR studies were on specific cardiac diseases rather than on normal values .Other CMR studies concentrated on the effect of cardiovascular risk factors on the cardiac chambers especially the left ventricle. Friberg P et al, 2004 studied the correlation between the left ventricular mass and body mass index and systolic blood pressure among adolescents. They discovered that obese and hypertensive subjects had higher left ventricular mass than lean subjects. Eguchi K et al, 2008 have researched into the effect of type II diabetes mellitus in a multiethnic population, which has shown an increased risk of left ventricular hypertrophy by about 1.5-fold. Payne JR et al, 2006 did a study in 309 Caucasian army recruits and discovered positive association between cigarette smoking and left ventricular mass. A study which concentrated on right ventricle using CMRI showed positive association between its mass and systolic blood pressure (Chahal H et al, 2009). In short, studies on the cardiac dimensions are very important since they provide reference values for clinicians which facilitate the management of their patients. Among the current imaging modalities, MRI appears to be the best option for cardiac dimension assessment.

Most of the previous studies were based on the 1.5 T MR scanners, largely due to the availability of the machines compared with the 3 T scanners. As a result of higher magnetic field strength, the earlier generations of 3 T MR scanner were not able to produce equally good quality cardiac images. Several problems which occurred with high magnetic strength were increased susceptibility artefacts at tissue borders (Noeske et al, 2000),increased T1 and radiofrequency field distortions (Dougherty et al, 2001). Following some modifications, the later generations of 3 T scanner using two-dimensional cine steady-state free precession technique have been able to provide high signal-to-noise and contrast-to-noise ratios, thus better image quality compared with the 1.5 T machines (Gutberlet et al, 2005). More studies are needed to compare 3 T with 1.5 T scanners.

Study hypothesis:

1.The mass ,volume and ejection fraction of right and left ventricles decrease with age in healthy volunteers.

2. The mass,volume and ejection fraction of right and left ventricles are higher in healthy male than female volunteers.

Methodology:

This is a cross sectional study which will be conducted at Hospital UniversitiSains Malaysia, KubangKerian, Kelantan under the inter-departmental collaboration (Department of Radiology and Internal Medicine: Cardiology).

Ethical consideration:

The researcher will select the volunteered subjects who fulfil the study criteria.The researcher are not taking their own students as volunteers in this study. The researcher will explain to the subjects the purpose of the study, confidentiality of information, the nature of examination and the contraindications to MRI. Blood investigation and ECG will be performed. There is no risk of ionizing radiation or side effect/complication from contrast media in this study. Informed consent will be obtained before subjects are enrolled into the study. The approval from Research Ethics Committee (Human) will be obtained.

Population and sample:

All volunteered subjects who undergo cardiac MR at HUSM.

Sampling technique:

No sampling method applied. All subjects who fulfil the study criteria recruited in the study.

Inclusion criteria:

1. Subjects above the age of 20 years and above.
2. Subjects with no clinical evidences of cardiovascular diseases (cardiac history, hypertension,hyperlipidaemia,diabetesmellitus,smoking, > obese class I; baseline ECG).
3. Blood profiles (fasting glucose and lipids) obtained within 1 month before cardiac MRI.

Exclusion criteria:

1. Subjects with contraindication to MR.
2. Images of non-diagnostic quality.
3. Images with incidental findings of congenital heart defect and cardiac/pericardial mass.

Sample size:

Based on study by Payne et al,2006:

t tests - Correlation: Point biserial model

Analysis: A priori: Compute required sample size

Input:	Tail(s)	=	Two
	Effect size |r|	=	0.4000000
	α err prob	=	0.05
	Power (1-β err prob)	=	0.8
Output:	Noncentrality parameter δ	=	2.894987
	Critical t	=	2.018082
	Df	=	42
	Total sample size	=	44
	Actual power	=	0.807373

If expected 10% drop out rate, total sample size = 50 subjects

Research tools:

1. 3-Tesla Achieva MRI scanner (Philips, Best, The Netherlands)

2. Clinical workstation with Cardiac Explorer software application (View Forum cardiac
package version R5.1V1L1, Philips, Best, TheNetherlands)

Data collection:

Data will be collected from July 2014 to Jun 2015 and recorded in the data collection sheet. Relevant information will be obtained from subject's history, physical examination, ECG, blood profiles and medical record within 1 month before MRI study.

- Clinical history:

  Subjects will be screened for symptoms of cardiac disease and risk factor of cardiovascular disease (based on study proforma). Specific cardiovascular risk factors defined in this study are:

  1. Hypertension
  2. Diabetes mellitus
  3. Hyperlipidaemia
  4. Current smoker and ex-smoker of ≤ 1 year duration
  5. Obesity

- Physical examination:

  Subjects will be physically examined. Weight and height measured.

Hypertension is defined as persistent resting blood pressure of ≥ 140/90 after 2 measurements of 30 minutes apart.

BMI formula: Weight in kilograms /(Height in meters)^2

BMI is categorized according to World Health Organization;

Category	BMI range kg/m^2
Severely underweight	< 16.0
Underweight	16.0 – 18.4
Normal	18.5 – 24.9
Overweight	25.0 – 29.9
Obese Class I	30.0 – 34.9
Obese Class II	35.0 – 39.9
Obese Class III	> 40.0

- Baseline electrocardiogram (ECG)

  Subjects' ECG will be performed by the cardiology staff nurse and interpreted by the cardiology team. Examples of abnormal ECG are evidence of:

  - Ischaemia or infarction
  - Atrioventricular conduction defect
  - Ventricular hypertrophy
  - Axis deviation

- Blood glucose and lipid profiles

  Subjects will have blood glucose and lipid profiles done.

  Diabetes mellitus is defined as 2x fasting venous plasma glucose of ≥7.0mmol/L.

Hyperlipidaemia is defined as elevation of one or more of total cholesterol (>5.2mmol/L), low-density lipoprotein (>3.0mmol/L), triglycerides (>2.2mmol/L).

Selection of subjects for MRI is based on:

1. Absence of cardiac symptoms and physical findings of cardiovascular disease.
2. Absence of cardiovascular risk factors (hypertension, hyperlipidaemia, diabetes mellitus, current smoker, ex-smoker within the last 1 year and obese class I and beyond.
3. Normal baseline ECG

Cardiac MRI scan protocol:

This will be performed using 3 Tesla Achieva MRI scanner (Philips, Best, The Netherlands) using the surface coils and retrospective ECG triggering. All scans were performed by the same operator. End-expiratory breath-hold cines will be obtained in the vertical and horizontal long axis planes followed by contiguous short-axis cines from atrioventricular ring to apex. Flip angle 60^0, slice thickness 7mm and no gap.

Image analysis:

Images which fulfil the study criteria will be analysed using clinical workstation with Cardiac Explorer software application (View Forum cardiac package version R5.1V1L1, Philips, Best, TheNetherlands). The right and left ventricles will be measured using Simpson's rule (see Figure 1).

- Epicardial and endocardial borders will be delineated manually in all planes in all cardiac cycles in the short axis slices at end-diastole and end-systole.
- The contour tracing will be confirmed by reviewing the movie with contour attached.
- For left ventricle, basal slice is selected when at least 50% of blood volume is surrounded by myocardium in end-diastole and end systole. Apical slice is determined as last slice showing intracavity blood pool.
- For right ventricle, volumes below pulmonary valve are included. Right ventricular volumes will not be included if the surrounding muscle is thin and non-trabeculated.
- Papillary muscles are included in the mass and excluded from volume calculations.
- Interventricular septum will be included as part of left ventricular mass.
- From the data, the mass, volumes and ejection fraction of right and left ventricles will be auto-calculated using the Cardiac Explorer software, Philips.

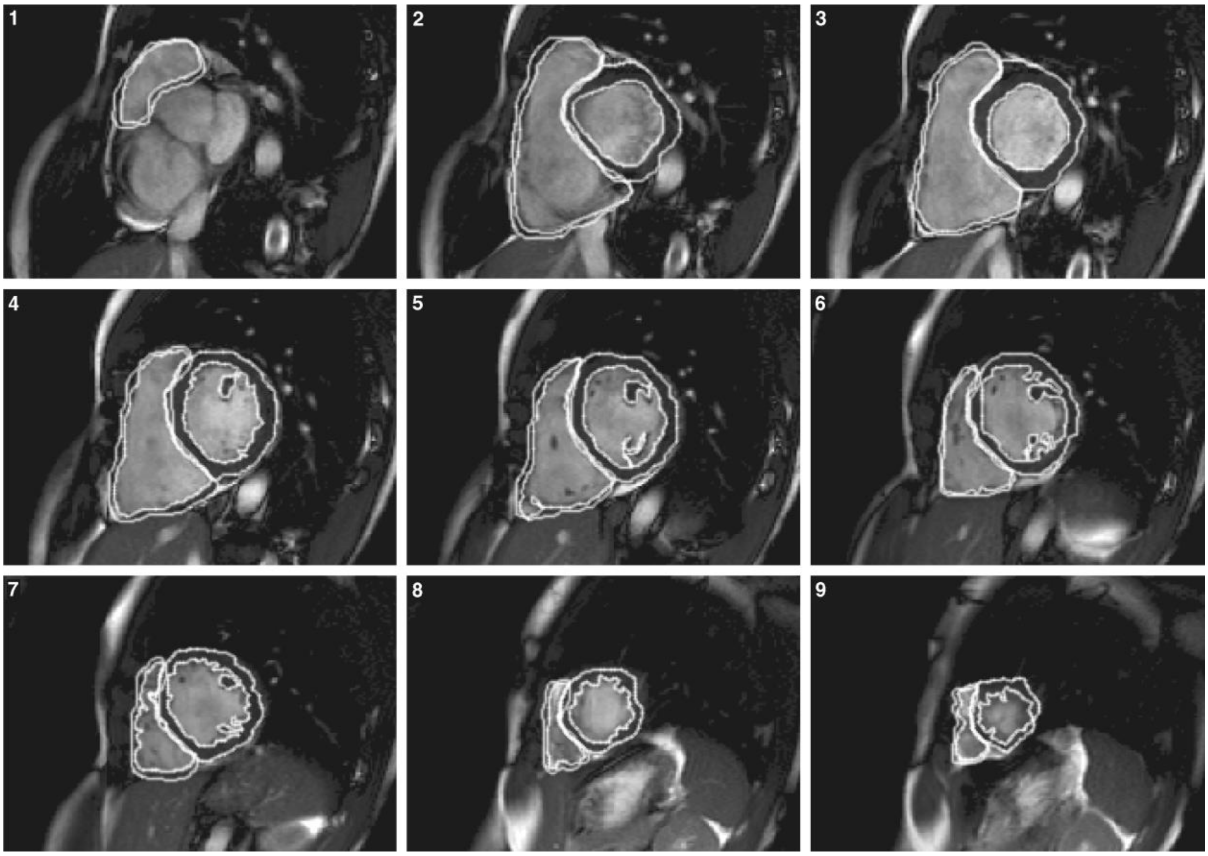

Figure 1: Marking of the epicardial and endocardial contours of the right and left ventricles

Definitions:

Myocardial mass = multiplication of tissue volume by 1.05 g/cm^3

Stroke volume (SV) = end-diastolic volume (EDV) – end-systolic volume (ESV)

Ejection fraction (EF) = (SV / EDV) x 100

Data will be tabulated using Statistical Package for Social Sciences (SPSS) software for Windows version 20.0.Data will be presented as mean +/- standard deviation (SD). Analysis for correlation between ventricular dimensions and age, gender and ethnicity will be performed.

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MANUSCRIPT

1. INTRODUCTION

Cardiac magnetic resonance imaging (CMR) is a rapidly evolving field in medicine and it has a very promising future. It is non-invasive, free of ionizing radiation, has excellent soft tissue contrast and gives highly reproducible result (Grothues *et al*, 2002). After extensive research over the last few decades, this modality has been regarded as the "gold standard" in many aspects of cardiac imaging investigation (Bellenger *et al*, 2000). Indications for CMR include acquired and congenital heart diseases. Among these, ischaemic heart disease has been the commonest indication since CMR was shown to have high sensitivity (92%) and specificity (99%) in discriminating infarcted tissues from the normal ones.

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Maceira *et al*, 2006 have produced a database on the right and left ventricular dimensions in relation to age and gender of normal healthy adults using steady-state free precession technique. From their study, males were shown to have significantly larger right and left ventricular mass and volumes than females. There was also a significant decrease in right ventricular mass and volume with increasing age in both genders. Similarly, the left ventricle showed a significant decrease in volume with age in males and females. However, there was no significant change seen between the left ventricular mass and age. Hudsmith *et al*, 2005 have added the normal left atrial dimensions to their study. Buechel *et al*, 2009 managed to obtain right and left ventricular parameters in normal children. The results showed significantly larger ventricular volume in males than females and the ejection fractions remain constant throughout the growing age in both genders. Natori *et al*, 2006 discovered significant differences in left ventricular volume and mass between Asians (Chinese) and other ethnic groups (white Americans, African-Americans and Hispanics). Many multi-ethnics CMR studies were on specific cardiac diseases rather than on normal values. Other CMR studies concentrated on the effect of cardiovascular risk factors on the cardiac chambers especially the left ventricle. Friberg *et al*, 2004 studied the correlation between the left ventricular mass and body mass index and systolic blood pressure among adolescents. They discovered that obese and hypertensive subjects had higher left ventricular mass than lean subjects. Eguchi *et al*, 2008 have researched into the effect of type II diabetes mellitus in a multiethnic population, which has shown an increased risk of left ventricular hypertrophy by about 1.5-fold. Payne *et al*, 2006 did a study in 309 Caucasian army recruits and discovered positive association between cigarette smoking and left ventricular mass. A study which concentrated on right ventricle using CMR showed positive association between its mass and systolic blood pressure (Chahal *et al*, 2009).

In short, studies on the cardiac dimensions are very important since they provide reference values for clinicians which facilitate the management of their patients. Among the current imaging modalities, MRI appears to be the best option for cardiac dimension assessment.

Most of the previous studies were based on the 1.5 T MR scanners, largely due to the availability of the machines compared with the 3 T scanners. As a result of higher magnetic field strength, the earlier generations of 3 T MR scanner were not able to produce equally good quality cardiac images. Several problems which occurred with high magnetic strength were increased susceptibility artefacts at tissue borders (Noeske *et al*, 2000), increased T1 and radiofrequency field distortions (Dougherty *et al*, 2001). Following some modifications, the later generations of 3 T scanner using two-dimensional cine steady-state free precession technique have been able to provide high signal-to-noise and contrast-to-noise ratios, thus better image quality compared with the 1.5 T machines (Gutberlet *et al*, 2005). More studies are needed to compare 3 T with 1.5 T scanners.

Therefore, the purpose of this study was to evaluate the right and left ventricular dimensions (mass, volume and ejection fraction) in healthy volunteers with 3 Tesla cardiac magnetic resonance imaging.

2. METHODOLOGY

Study population

This cross sectional study was conducted at Hospital Universiti Sains Malaysia, Kubang Kerian, Kelantan under the interdepartmental collaboration (Department of Radiology and Internal medicine: cardiology) in 1 year period (January – December 2015). All subjects who fulfill the study criteria were recruited in the study. No sampling method applied. The inclusion criteria were age 20 years and above with no clinical evidence of cardiovascular diseases (cardiac history, hypertension, hyperlipidaemia, diabetes mellitus, smoking, obese class I) and normal blood profiles (fasting glucose and lipids). Subjects with contraindication to CMR, images of non diagnostic quality and images with incidental findings of congenital heart defect and cardiac/pericardial mass were excluded from study. Volunteers with contraindications to CMR were not enrolled. The study was approved by the institutional ethics committee, and all subjects gave written informed consent.

Cardiovascular magnetic resonance imaging protocol

All CMR examinations were performed on a 3 Tesla MR scanner (Philips, Best, The Netherlands) with the dedicated cardiac coils placed on thorax and retrospective ECG triggering for capture of the entire cardiac cycle including diastole. All scans were performed by the same operator. Patient was put in supine position. The protocol time of the study was approximately 30 minutes. Localizing images in orthogonal planes, vertical and horizontal long axes (Figure 1 -5), and short axis of the heart have been carried out at flip angle 60 degree, slice thickness 7mm and no gap. By using image localization, the cine images in the four chamber plane (4ch) of the heart have been acquired. This was followed by cine image acquisition in the short axis of the right and left ventricles from the base (passing the atrioventricular ring) to the apex, using the balanced turbo field echo technique.

Image analysis

CMR image analysis was performed with clinical workstation using Cardiac Explorer software application (View Forum cardiac package version R5.1V1L1, Philips, Best, The Netherlands). One radiologist trained in CMR have analyzed all of the images. Manual tracing of the endocardial and epicardial borders of successive short axis slice at end diastole and end systole was performed. The contour tracing was confirmed by reviewing the cine images.

For left ventricle, basal slice was selected when at least 50% of blood volume was surrounded by myocardium in end diastole and end systole. Apical slice was determined as the last slice showing intracavity blood pool (Figure 6).

For right ventricle, volumes below the pulmonary valve were included. Right ventricular volumes were excluded if the surrounding muscle was thin and not trabeculated. Papillary muscles were included in the mass and excluded from volume calculations. The interventricular septum was included as part of the left ventricular mass. From the data, the mass, volumes and ejection fraction of right and left ventricles were auto calculated using the Cardiac Explorer software, Philips. Left ventricular mass was determined by the sum of myocardial area (the difference between endocardial and epicardial contour) times slice thickness plus image gap in the end diastolic phase multiplied by specific gravity of myocardium (1.05g/ml). Stroke volume was calculated as the difference between end diastolic volume and end systolic volume. Ejection fraction was calculated as stroke volume divided by end diastolic volume multiplied by 100.

Statistical analysis

All data are presented as mean ± standard deviation (SD). Data was tabulated using Statistical Package for Social Sciences (SPSS) software for Windows version 20.0. Mean values of two independent variables were compared using independent t-test. Normality of the variables and equal variance assumption were checked prior to analysis. Analysis for correlation between ventricular dimensions and age and gender was performed. The correlation coefficient, r, reflects the strength of the linear relationship between two variables .To get a feeling for strong or weak correlations, correlations from 0 to 0.25 (or -0.25) indicate little or no relationship, those from 0.25 to 0.50 (or -0.25 to -0.50) reflects a fair degree of relationship; and those from 0.50 to 0.75 (or -0.50 to -0.75) a moderate degree of relationship, while correlations over 0.75 (or -0.75) reflect a strong relationship.