Original Article

Reference Values for Normal Pulmonary Artery and Ascending Thoracic Aorta by Magnetic Resonance among Thai Healthy Volunteers

Ing-orn Arunakul MD[1]

[1] Division of Cardiology, Department of Medicine, Thammasat University, Pathum Thani, Thailand

Objective: To measure the reference values of main pulmonary artery [MPA] and ascending aorta [ASC] dimensions for Thai healthy population by using non-contrast axial cardiac magnetic resonance imaging [CMR].

Materials and Methods: Transaxial set of fast spin echo images through the chest were obtained from 91 healthy subjects. The present study design was epidemiological observational study and the measurement of MPA and ASC dimensions was performed at the level of the bifurcation of the right and left pulmonary arteries.

Results: The mean age of the study subjects was 38 years and 60% were women. The sex-specific MPA, ASC dimensions, and ratio PA (ratio of MPA to ASC diameter) shown as mean ± SD in men and women were 23.6±2.6 mm, 23.8±2.5 mm for MPA; 27±3.2 mm, 26.9±2.8 mm for ASC; and 0.88±0.1, 0.89±0.1 for ratio PA. The sex-specific ninetieth percentile cut-point in men and women for MPA and ratio PA were 27 mm, and 1.0. There were positive correlations between age and ASC dimension (r = 0.398, $p<0.001$), age and MPA/BSA ratio (r = 0.361, $p<0.001$), and MPA and BSA (r = 0.235, $p = 0.025$), but negative correlation between age and ratio PA (r = -0.276, $p = 0.008$).

Conclusion: The findings of this study suggest that the MPA and ASC dimensions for Thai population are similar in both genders but slightly smaller than in Western population. Additionally, the ratio PA are slightly increased. There were correlations between increasing age and larger ASC, higher MPA/BSA ratio, and smaller ratio PA.

Keywords: Main pulmonary artery [MPA], Ascending thoracic aorta [ASC], Ratio PA, Reference values

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Cardiac magnetic resonance imaging [CMR] is an invaluable modality in this era of medicine, because of its safety and its appropriateness in various indications. Based on standard CMR protocols, main pulmonary artery [MPA] and ascending thoracic aorta [ASC] are derived and routinely demonstrated by transaxial images of thorax. Pulmonary hypertension is a common complication of chronic heart failure(1). In patients with left ventricular systolic dysfunction, elevated pulmonary artery pressure predicts higher risk for morbidity and mortality(2). In general, patients usually are asymptomatic in the early stages for months or even years, and then become worse when the disease progresses. Right heart catheterization [RHC] is the investigation of choice to confirm diagnosis of pulmonary artery hypertension [PAH](3). Multiple studies showed that the larger MPA size based on CT(4-9) or CMR(10-12) techniques correlates with the higher mean pulmonary pressure. Enlarged MPA diameter is a sign of pulmonary hypertension as the MPA adapts to increased pulmonary artery pressure most often due to increase in pulmonary vascular resistance(4,13). Therefore, measurement of MPA dimension could be a screening method for detection in the early stages of disease progression. According to Society for Cardiovascular Magnetic Resonance [SCMR](14), standard CMR protocol for MPA measurement is contrast-using technique with post processing images, but there is no clear-cut recommendation on how to do the measurement of non-contrast images of MPA, which has advantages in terms of safety and generalizability. From previously published data(15-18), there are reference values for the Caucasian population, but there is no data for Asian population. The author aimed to study the reference values of normal MPA and ASC dimensions for Thai population and to use

Correspondence to:
Arunakul I. Cardiac Imaging Specialist, Division of Cardiology, Department of Medicine, Faculty of Medicine, Thammasat University (Rangsit Campus), Klong Nueng, Klong Luang, Pathum Thani 12120, Thailand.
Phone: +66-2-9269793 ext. 4, **Fax**: +66-2-9269793
Email: iarn4@yahoo.com

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these values as a screening tool for further assessment of enlarged MPA etiologies such as pulmonary hypertension.

Materials and Methods

Subjects

Participants were recruited from the medical personnel of the Thammasat University Hospital. Study design was an epidemiological observational, prospective, cross-sectional study and was conducted between January and April 2018. The Institutional Review Board approval and the informed consent were obtained from all participants involved in the present study. Inclusion criteria were healthy medical personnel, age between 18 to 60 years old. Participants who had standard contraindications to MRI scanners such as history of hypertension (defined as BP greater than 140/90 mmHg), diabetes mellitus, chronic airway diseases (asthma or COPD), obesity (defined as BMI greater than 29 kg/m^2), cardiovascular diseases, renal diseases, or smoking, or inadequate quality images (due to artifact) to interpret were excluded from the present study as shown in the flowchart in Figure 1.

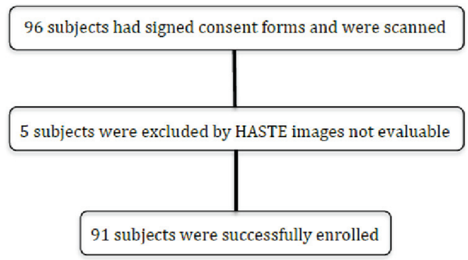
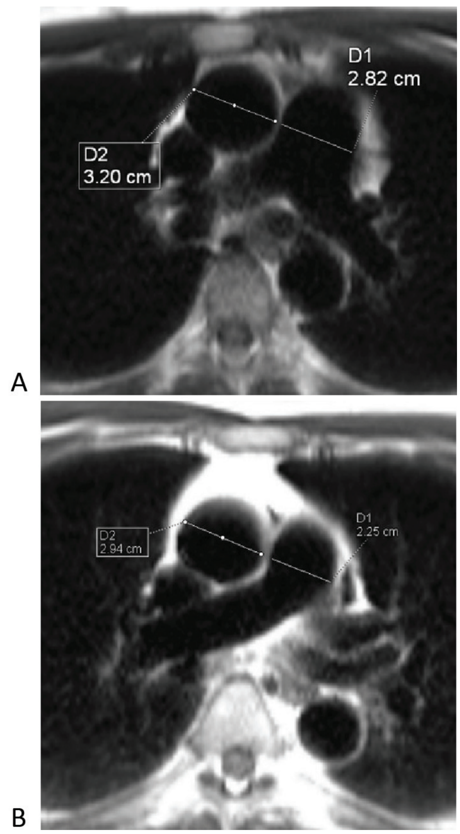


Figure 1. The flow chart demonstrated recruitment process of the study.

CMR data acquisition

All subjects were scanned with Siemens Magnetom Aera 1.5T system. Transaxial half-Fourier acquisition single-shot turbo spin echo [HASTE] or fast spin echo was acquired with pulse trigger (prospective) in diastolic phase during held expiration. HASTE or black blood sequence used the parameters: echo time [TE] 44 ms, matrix size 140×256, reconstruction voxel size 1.3×1.3×8.0 mm, slice thickness 8.0 mm, slice gap 0 mm, and field of view [FOV] 340 mm.



D1 = MPA diameter, D2 = ASC diameter

Figure 2. The axial CMR images to perform the MPA and ASC measurements. A) MPA was measured along the line that originates from the center of the ASC and passes perpendicular to the long axis of the MPA, at the level of the MPA bifurcation of right and left pulmonary arteries on axial section (preferable measurement method). B) MPA was measured at the level of the MPA bifurcation of right pulmonary arteries on axial section.

CMR-based measurement of pulmonary artery and aortic diameter

The CMR scans were read by one experienced CMR imaging specialist by using a dedicated offline cardiac workstation (syngo.via, version VB10B) with post processing. Specifically, the transverse axial diameter of the MPA and the ascending aorta [ASC] were measured as shown in Figure 2A or B. The preferred method of measurement was performed at the level of bifurcation of right and left pulmonary arteries (in Figure 2A). The ratio PA was calculated by the ratio of the MPA to ASC. MPA/BSA ratio was derived by body surface area [BSA] from Mosteller formula. Measurement reproducibility determined by two independent readings from two observers in a random sample of 90 subjects were excellent for intra- and inter-observer variability (intra- and inter-observer intraclass correlation coefficient: MPA 0.99, ASC 0.99, all p-value <0.001).

Statistical analysis

Descriptive statistics were expressed as mean ± SD for continuous variables and as frequency and percentages for nominal variables. To assess the relationship between MPA, ASC, and ratio PA with age, the present study used sex-specific Pearson correlation. The author determined the distributions (the 25th, 50th, 75th, and 90th percentiles within age- and sex-specific strata) of MPA, ASC, MPA/BSA ratio, and ratio PA measurements. To estimate the sample size, the author used the reference value of MPA diameter (23.4±2.9 mm) from Chuang et al 2013[16], and choose 1 mm difference for the present study to give 90% power, and 5% two-sided type-I error. The sample size of 91 was calculated by using one-sample mean test from Stata version 14.0.

Table 1. Clinical characteristics of the study population

	Healthy cohort (n = 91) mean ± SD
Age (year)	38.4±9.9
Male sex, n (%)	36 (39.6)
Height (cm)	163.9±9.5
Weight (kg)	62.8±11.2
BSA (m2)	1.69±0.19
BMI (kg/m2)	23.3±2.8
Systolic BP (mmHg)	116.1±9.3
Diastolic BP (mmHg)	73.4±8.2
Fasting plasma glucose (mg/dL)	91.5±8.5
Serum creatinine (mg/dL)	0.79±0.19

BSA = body surface area; BMI = body mass index; BP = blood pressure

Table 2. Mean and 90th percentile values of sex-specific MPA, ASC, ratio PA, and MPA/BSA ratio

	Men	p90 (men)	Women	p90 (women)
MPA (mm)	23.6±2.6	27.1	23.8±2.5	27.0
ASC (mm)	27.0±3.2	32.0	26.9±2.8	31.1
Ratio PA	0.88±0.1	1.02	0.89±0.1	1.01
MPA/BSA (mm/m^2)	12.85±1.55	15.17	15.06±1.40	16.95

MPA = main pulmonary artery diameter; ASC = ascending aortic diameter; ratio PA = ratio of diameter of MPA to ascending aorta; MPA/BSA = ratio of diameter of MPA to body surface area

Results

Ninety-one participants were recruited. The mean age was 38 years (22 to 59 years), and 60% were women. More than half of participants were younger than forty years old (56%), mean age of 33 and 42 years for men and women. All subjects had detailed data of body weight, height, BSA, baseline blood pressure [BP], fasting plasma glucose, and serum creatinine level as shown in Table 1.

The sex-specific MPA dimension is shown in Table 2, which demonstrate the mean MPA ± SD in men and women is 23.6±2.6 mm and 23.8±2.5 mm, respectively. Sex-specific mean ratio PA in men and women were 0.88±0.1 and 0.89±0.1, respectively. Sex-specific mean ASC dimension were 27±3.2 mm and 26.9±2.8 mm in men and women.

Table 3 shows the distribution of MPA dimension and ratio PA within age and sex-specific strata. The MPA diameter showed small differences within age strata and were smaller in women than in men (90th percentile cut-point for men ranged from 25.0 to 27.1 mm and for women ranged from 26.3 to 27.3 mm). The sex-specific ninetieth percentile was similar 27.1 mm in men and 27 mm in women. For simplicity, the author proposed 27 mm as the cut-point for MPA. From the ninetieth percentile values, there were a decrease in the ratio PA with increasing age with small differences for men and women. The ratio PA ranged from 0.87 to 1.02 in men and 0.99 to 1.05 in women. The sex-specific ninetieth percentile cut-point for ratio PA were 1.02 and 1.01 in men and women. For simplicity, we proposed 1.0 as the cut-point for ratio PA.

The distributions of ASC dimension and MPA/BSA ratio within age and sex-specific strata are shown

Table 3. MPA dimension and ratio PA stratified by age and sex

	MPA (mm)				Ratio PA			
	Men		Women		Men		Women	
Age (year)	<40	≥40	<40	≥40	<40	≥40	<40	≥40
No.	32	4	19	36	32	4	19	36
Mean ± SD	23.7±2.7	22.5±2.0	23.3±2.4	24.1±2.5	0.89±0.1	0.8±0.06	0.94±0.08	0.87±0.1
25th	22.1	21.0	21.4	22.5	0.81	0.75	0.88	0.79
50th	23.4	22.4	23.0	23.7	0.89	0.80	0.93	0.87
75th	25.1	24.1	25.0	25.7	0.95	0.85	1.01	0.95
90th	27.1	25.0	26.3	27.3	1.02	0.87	1.05	0.99

MPA = main pulmonary artery diameter; ratio PA = ratio of diameter of MPA to ascending aorta

Table 4. ASC dimension and MPA/BSA ratio stratified by age and sex

	ASC (mm)				MPA/BSA (mm/m^2)			
	Men		Women		Men		Women	
Age (year)	<40	≥40	<40	≥40	<40	≥40	<40	≥40
No.	32	4	19	36	32	4	19	36
Mean	26.9±3.1	28.3±3.7	24.9±1.7	28.0±2.6	12.93±1.56	12.24±1.56	14.86±1.45	15.17±1.38
25th	24.8	25.7	23.5	26.5	11.62	11.28	13.98	13.93
50th	26.8	28.7	24.8	28.0	13.09	12.34	14.66	15.15
75th	28.7	31.0	26.0	29.5	14.16	13.20	15.58	16.32
90th	31.0	32.3	27.2	31.5	15.17	14.05	17.37	16.95

ASC = ascending aorta; MPA/BSA = ratio of diameter of MPA to body surface area

in Table 4. The ASC diameter showed an increase with increasing age and was smaller in women than in men (ninetieth percentile cut-point for men ranged from 31.0 to 32.3 mm, and for women ranged from 27.2 to 31.5 mm). The sex-specific ninetieth percentile was 32 mm in men and 31.1 mm in women. From the ninetieth percentile values, there were a small difference in the MPA/BSA ratio within age strata and smaller in men than women. The MPA/BSA ratio ranged from 14.05 to 15.17 mm/m^2 in men and 16.95 to 17.37 mm/m^2 in women. The sex-specific ninetieth percentile cut-point for MPA/BSA ratio was 15.17 and 16.95 mm/m^2 in men and women.

There were positive correlations between age and ASC diameter ($r = 0.398$, $p<0.001$), age and MPA/BSA ratio ($r = 0.361$, $p<0.001$), and MPA and BSA ($r = 0.235$, $p = 0.025$). In contrast, there was negative correlation between age and ratio PA ($r = -0.276$, $p = 0.008$).

Discussion

The MPA, ASC dimensions, and ratio PA derived from a non-contrast, transaxial CMR imaging, named as HASTE or Black blood or fast spin echo sequence through the chest, is an invaluable screening modality for early detection of cardiopulmonary disease. The reasons for the selection of this sequence to perform the measurement were first, this black blood sequence is routinely scanned in standard CMR protocols[14], second the dimension of MPA assessed by this sequence is quite close to the value derived from contrast angiographic findings, and lastly this measurement is easily reproducible. The author preferred to measure the axial MPA and ASC diameters at the level of right and left pulmonary arteries bifurcation with the same method as Mahammedi et al[9] because this method was proven to have good positive correlation with pulmonary arterial pressure. MPA was measured along the line that originated from the center of the ASC and passed perpendicular to the long axis of the MPA. Therefore, this landmark had high reproducibility in repeated measurements, and provided a calculation of ratio PA. The author had observed the positive correlations between age and ASC diameter, age and MPA/BSA ratio, and MPA and BSA respectively, but no correlation between age and MPA diameter itself. Therefore, the author proposed to use MPA/BSA ratio to provide additional information in standard MPA measurement.

The strength of the present study is the uniform population in this cohort, and the excellent internal validation of the measurement. The present study data showed similar reference values of sex-specific (but not age-) MPA dimension and ratio PA in both men and women. According to the present study data, the ninetieth percentile values in both genders were similar, cut-point were 27 mm and 1.0 for MPA and ratio PA respectively. For ASC dimension, there were small differences in men and women with larger size in men. The ninetieth percentile cut-point were 32 mm in men and 31 mm in women. The present data was also analyzed MPA/BSA ratio for both genders, and there was slightly higher in women. The ninetieth percentile cut-point for MPA/BSA ratio were 15 and 17 in men and in women. From the present study cohort, the mean age of participants was younger than previous studies, therefore it absolutely affected to ratio PA increment because of the smaller ASC dimension.

Based on data of Chuang et al 2013[16], there were small differences in reference values of mean MPA, ASC, and ratio PA compared to the present study. Despite the similar CMR sequence and measurement technique, there were smaller size of ASC diameter in both men and women, and larger size of MPA diameter & ratio PA in both genders in the present study. The distinction of vessel size might explain by smaller body habitus of Asian population, and more aging subjects (mean age of 65 years) in that study. From previous larger clinical trials, there were various sequences and methods to measure the MPA and ASC diameters, so the reference values were slightly different. In comparison with other modalities, CT cutoff value for MPA for men was 29 mm, and for women was 27 mm, and cutoff value for ratio PA was 0.9 for both genders[12], and non-contrast transaxial images were chosen to perform measurements.

Based on the present study population, we randomized healthy volunteers, age from 28 to 48 years old, 60% female, and BSA from 1.5 to 1.88, so the reference data can be mostly applied among non-elderly age group and non-obese population. In obese subjects, the author suggested to use MPA/BSA ratio as the reference data instead of MPA diameter per se. The physician can apply the ninetieth percentile cutoff values of MPA, ASC, ratio PA, and MPA/BSA ratio in both genders to detect patients at risk for developing pulmonary hypertension in the clinical practice.

Limitation

There were few limitations of the present study such as inadequate quality images to interpret due to artifact, and variation in alignment of MPA and bifurcation in some subjects. Therefore, the author could not perform uniform MPA measurement in all subjects.

Conclusion

The normal reference values of MPA and ASC dimensions for Thai population are similar in both genders but slightly smaller than Caucasian, and ratio PA are slightly increased. There were correlations between increasing age and larger ASC, higher MPA/BSA ratio, and smaller ratio PA.

What is already known on this topic?

From the previous data[15-18], there are only reference values of MPA and ASC among Caucasian population, but lacking data for Asian or Thai population.

What this study adds?

To date, this study data would be the first normal reference values of MPA and ratio PA for Thai healthy cohort, and the MPA/BSA ratio might be applied as reference values for other population as well.

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Potential conflicts of interest

The author declares no conflict of interest.

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